Agenzia nazionale per le nuove tecnologie, l'energia
e lo sviluppo economico sostenibile

Ministero dello Sviluppo Economico

RICERCA DI SISTEMA ELETTRICO

La presenza italiana in campo internazionale per il coordinamento strategico e programmatico nel settore delle Tecnologie di Cattura e Stoccaggio della CO_2 (CCS)

Giuseppe Girardi

Report RdS/2012/209

LA PRESENZA ITALIANA IN CAMPO INTERNAZIONALE PER IL COORDINAMENTO STRATEGICO E PROGRAMMATICO DELLE TECNOLOGIE DI CATTURA E STOCCAGGIO DLLA CO2 (CCS)

Giuseppe Girardi (ENEA)

Settembre 2012

Report Ricerca di Sistem a Elettrico
Accordo di Programma Ministero dello Sviluppo Economico - ENEA
Area: Produzione di energia elettrica e protezione dell'ambiente
Progetto: Studi sull'utilizzo pulito dei combstibili fossili e cattura e sequestro della CO_2
Responsabile el Pro getto: Ing. Stefano Giammartini, ENEA

Le attività sono state condotte in stretto raccordo con il Ministero dello Sviluppo Economico, insieme al Ministero dell'istruzione dell'Università e della Ricerca, al Ministero dell'Ambiente e della tutela del Territorio e del Mare, e al Dipartimento Politiche Europee della Presidenza del Consiglio dei Ministri. Hanno collaborato Istituzioni pubbliche e private, in particolare: OGS, RSE, CNR, INGV, svariate Università, ENEL, Sotacarbo, Carbosulcis, Assocarboni, Fuelmed, Osservatorio sulle CCS della Fondazione per lo Sviluppo Sostenibile.

Un grande apprezzamento per il lavoro svolto dai colleghi dell'ENEA impegnati nelle attività di R/S e di divulgazione, e a tecnici e ricercatori di Sotacarbo.

Un ringraziamento particolare al Dott. Andrea Corleto, contrattista presso l'Università di Roma la Sapienza, giornalista ed esperto in comunicazione, che ha operato ad altissimo livello per la diffusione delle informazioni e per la "public acceptance".

Indice

Sommario

Nel presente documento sono sinteticamente descritte le attività, ed i risultati più rilevanti, condotte nell'ambito di alcuni organismi internazionali. In particolare si fa riferimento a:

Partecipazione, quale delegato italiano, nel Technical Group del ***CSLF*** *(Carbon Sequestration Leadership Forum)*. Il CSLF è un consesso internazionale, nato su iniziativa governativa, che ha la missione di facilitare lo sviluppo e l'applicazione delle tecnologie CCS attraverso collaborazioni internazionali volte a superare i principali ostacoli di ordine tecnico, economico ed ambientale, promuovendo anche la consapevolezza del pubblico nonché sviluppi normativi e finanziari internazionali. Il nostro impegno in tale ambito ha consentito al nostro Paese, seppure in assenza di una chiara strategia nel settore e di una road-map nazionale, di mantenere uno stretto contatto con tutti i principali attori internazionali.

Partecipazione, quale delegato italiano, a organismi della ***IEA****: Working party on Fossil Fuels e Implementing Agreement Clean Coal Centre (CCC)*.

Partecipazione, quale rappresentante ENEA, al ***Global Carbon Capture and Storage Institute*** *(GCCSI).* Il GCCSI è un'organizzazione nata su iniziativa del Governo australiano il cui obiettivo è mobilitare risorse pubbliche e private per diffondere le tecniche CCS. L'impegno immediato è quello di accelerare l'avvio di oltre venti progetti pilota. E' in discussione il piano strategico.

Partecipazione, quale Membro italiano, alla Technology Task Force della piattaforma tecnologica europea ***ZEP****.* La piattaforma tecnologica ZEP (Zero Emission Fossil Fuels Power Plants) unisce e rappresenta gli operatori industriali europei impegnati nelle tecnologie CCS; partecipano rappresentanti del mondo della ricerca e vati operatori. E' organizzata in tre task force: quella che affronta gli aspetti tecnologici (a cui partecipa per l'Italia un rappresentante di ENEA, uno dell'ENEL, uno di Ansaldo Energia) ha sviluppato una road-map e sta completando uno studio sugli aspetti economici.

Partecipazione, quale delegato italiano, al ***CCS-EII Team****, team della Iniziativa Industriale Europea (EII) per la cattura, trasporto e stoccaggio della CO2 (CCS) del SET Plan (Strategic Energy technologies)*. Opera, in particolare, per l'individuazione di strategie europee e sui finanziamenti europei, specialmente quelli per attività dimostrative, come il NER 300

Partecipazione, quale rappresentante ENEA e coordinatore nazionale, a ***EERA*** *(European Energy research Alliance) per le tecnologie CCS*. E' un organismo analogo alla piattaforma ZEP ma riunisce gli operatori del mondo della ricerca. Sono stati lanciati Joint Programmes, fra cui quello sulle CCS di cui ENEA è uno dei partner principali

Partecipazione, quale rappresentante europeo di EERA, alla delegazione europea nella visita in Australia. Scopo degli incontri è stato la definizione di accordi di collaborazione fra Australia ed EU.

Iniziative progettuali internazionali. Sono stati presi contatti con gli operatori cinesi, nell'ambito di una collaborazione già avviata fra Cina ed ENEL, e si è partecipato alla costruzione di due grandi proposte progettuali europee: progetto ECCSEL (approvato) e progetto ECRI (rinviato ad un successivo bando)

Introduzione

Le attività sono inserite nel complesso contesto internazionale nel quale operano governi, istituzioni pubbliche e operatori privati, con l'obiettivo di accelerare lo sviluppo e l'ingegnerizzazione delle tecnologie CCS, le uniche in grado di consentire un impiego "sostenibile" dei combustibili fossili nel settore energetico, in particolare puntando alla drastica riduzione delle emissioni di CO2.

Per fronteggiare efficacemente le modificazioni climatiche è necessario un approccio mirato su efficienza e rinnovabili; tuttavia permarrà per i prossimi decenni un ricorso massiccio alle fonti fossili, tendenzialmente il gas nei Paesi sviluppati ed il carbone nei Paesi ad economie emergenti.

Le emissioni globali di CO2 relative al settore energetico hanno raggiunto 30.4 Gt nel 2010, il 5.3% in più rispetto al 2009, rappresentando una crescita annua quasi senza precedenti.

La domanda di energia nel mondo crescerà nei prossimi 20 anni ad un tasso medio dell'1.8%/anno, con il ricorso al carbone che, seppure in misura minore di quanto ipotizzabile qualche anno fa, condizionerà pesantemente il livello di emissioni di CO2 e di inquinanti. Inoltre, gran parte dell'incremento previsto delle emissioni da oggi al 2030 proviene dai Paesi non OECD, di cui i tre quarti da Cina, India e altre economie emergenti.

Pertanto, la necessità di accelerare la transizione verso un'economia non più basata sui combustibili fossili porta a considerare cruciale lo sviluppo e l'applicazione delle TECNOLOGIE CCS - cattura e stoccaggio dell'anidride carbonica - in grado di abbattere drasticamente le emissioni di CO_2 in atmosfera prodotte da:

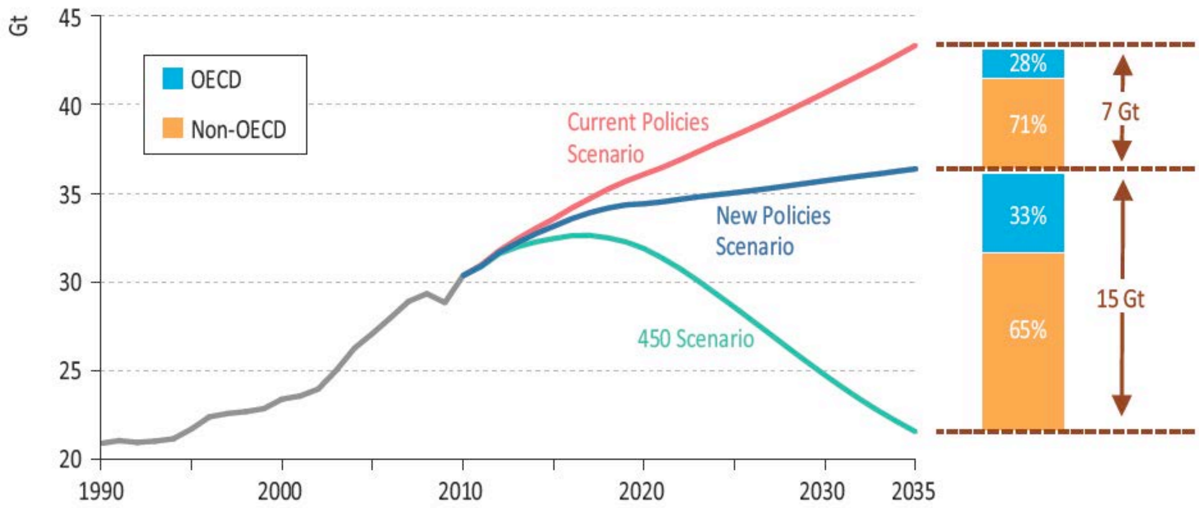
- impianti termoelettrici alimentati a gas o carbone;
- altri processi industriali massicci emettitori di CO_2 come il siderurgico, il petrolchimico, il cementiero;
- impianti di "poligenerazione" per la produzione di combustibili liquidi e gassosi a partire da fonti fossili o altri materiali;
- impianti per la produzione di biocombustibili, ed in generale impianti che utilizzano biomasse, con bilancio negativo di emissioni di gas serra.
- impianti di rigassificazione del gas naturale (LNG), per le opportunità offerte dall'integrazione di tali impianti in altri processi industriali che prevedono la cattura della CO_2.

La IEA ha definito il cosiddetto scenario 450, che prevede il raggiungimento di una concentrazione atmosferica di 450 ppm di CO2 equivalenti, con conseguente innalzamento medio della temperatura globale di 2 °C: ciò avrebbe in ogni caso effetti negativi come l'innalzamento del livello del mare, inondazioni più intense, tornadi e siccità; per questo motivo si pensa anche ad un target più restrittivo di 350 ppm. Lo scenario prevede una crescita delle emissioni con il raggiungimento del picco massimo prima del 2020 per poi decrescere a 21.6 Gt nel 2035.

Le analisi effettuate da IEA portano a dire che se non si metterà in campo una forte azione politica internazionale coordinata entro il 2017, probabilmente le emissioni globali di CO2 coerenti con lo scenario 450 saranno emesse dagli impianti esistenti a quella data e quindi tutte le future nuove infrastrutture dovrebbero essere ad emissioni zero.

Il settore degli impianti di potenza è cruciale per il conseguimento degli obiettivi dello scenario 450 al 2035, richiedendo investimenti anche per la chiusura o retrofitting di impianti vecchi, considerando che il non investire 1 $ al 2020 potrà comportare una spesa di 4.3 $ dopo il 2020 per compensare l'aumento delle emissioni.

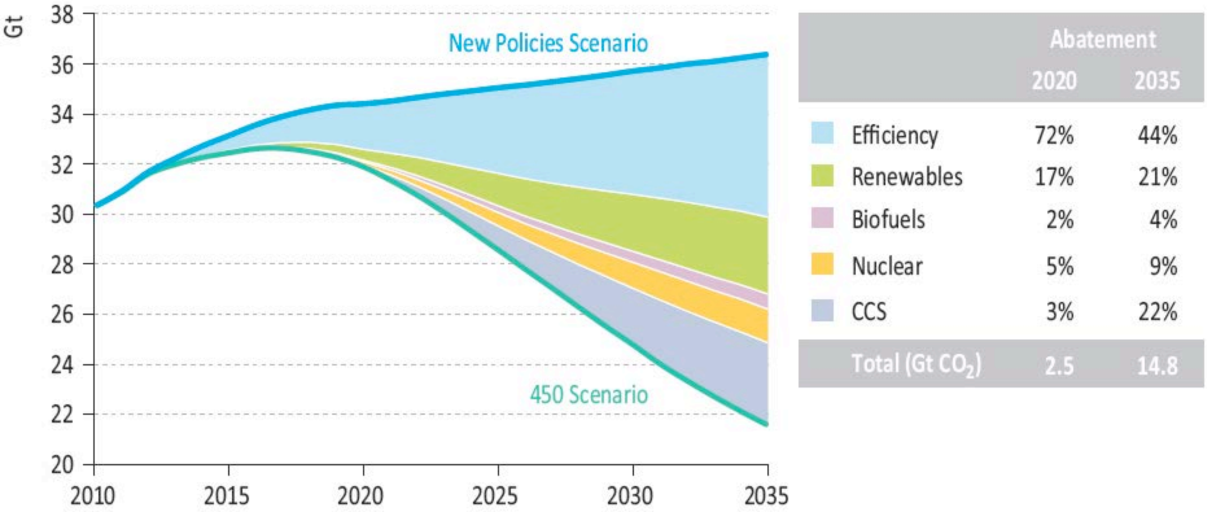
Ad oggi si prende in considerazione anche lo scenario cosiddetto "New Policies" che prevede una stabilizzazione della concentrazione ad un livello di 650 ppm con un incremento medio della temperatura di 3.5 °C, con conseguenze assai più severe: in questo scenario le emissioni continuano ad aumentare, raggiungendo 36.4 Gt nel 2035, con una traiettoria di emissioni che porta ad un incremento della temperatura globale di 3.5 °C. Il grafico seguente riporta gli andamenti delle emissioni neo tre scenari tipo.

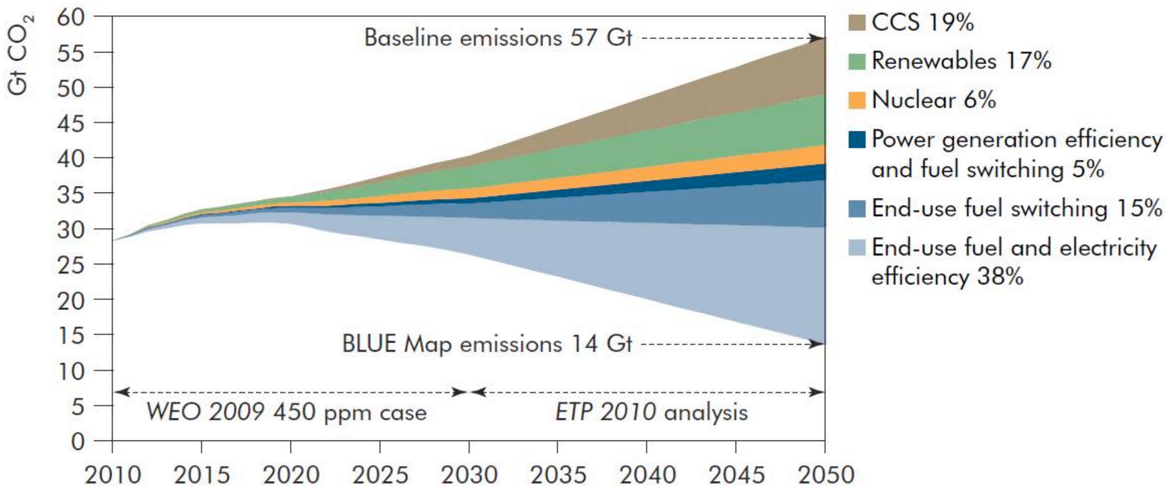


Le tecnologie CCS (cattura e stoccaggio, essenzialmente geologico, di CO_2) costituiscono la filiera che permette di separare il biossido di carbonio emesso dagli impianti alimentati a combustibili fossili e di neutralizzarlo in maniera definitiva sottraendolo così alla quota rilasciata in atmosfera. La soluzione già matura prevede lo stoccaggio nel sottosuolo in formazioni geologiche a profondità superiori gli 800 m, ma sono allo studio altri metodi di natura biologica e chimica.

In questo quadro, le tecnologie CCS rappresentano una opzione chiave, potendo contribuire per circa il 20% delle emissioni da ridurre nello scenario 450, anche se esistono incertezze sulla loro concreta applicazione per questioni tecniche e di costi, politiche e normative. Per queste ragioni è possibile che l'applicazione delle CCS slitti di dieci anni, e possa realizzarsi solo dopo il 2030 con un aumento del costo dello scenario 450 di circa 1.14 Miliardi $ (l'8%).

Anche con riferimento al 2050 le CCS possono contribuire per circa il 20% alla riduzione delle emissioni nell'ipotesi di scenario che prevede, al 2050, la riduzione del 50% delle emissioni rispetto ai livelli attuali. Le due figure seguenti sintetizzano quanto detto rispetto al contributo che differenti misure possono portare alla riduzione complessiva delle emissioni di CO_2.





Il livello dello sviluppo delle tecnologie CCS è tale che esse sono già oggi disponibili per applicazioni industriali dimostrative, promosse dalla UE e da altri grandi paesi (USA, Cina, Australia, ecc..). Contestualmente, per aumentare l'efficienza e per abbattere i costi ancora assai elevati sono indispensabili programmi di ricerca e messa a punto su installazioni pilota volti a sviluppare e qualificare soluzioni innovative e testare l'intera filiera con prove su scala significativa.

Molte delle tecnologie necessarie per la cattura e il sequestro della CO_2 sono già disponibili, seppure a costi non sostenibili, e possono essere applicate per iniziare la fase di dimostrazione industriale. Particolare attenzione è posta, in tutto il mondo come in Italia, a fornire ampia informazione per accrescere i livelli di accettabilità sociale, specialmente per lo stoccaggio geologico.

In tutto il mondo, e anche in Europa, sono in corso importanti programmi di ricerca sulle tecnologie CCS e dimostrazione su scala industriale. Particolarmente attivi risultano USA, Australia, Sud Africa, Cina e paesi orientali; l'Europa è all'avanguardia sia sul piano dello sviluppo tecnologico che su quello degli investimenti comunitari e nazionali e privati.
Sono unanimemente definiti i punti chiave da affrontare:

- abbassare il costo della CO_2 evitata a valori intorno a 40 €/t CO_2 entro 10 anni;
- ridurre i costi di investimento e di esercizio degli impianti CCS;
- ridurre l'energia aggiuntiva richiesta per l'applicazione delle tecnologie CCS;
- ottenere elevata disponibilità in termini di ore/anno di esercizio;
- favorire la public acceptance.

L'Europa intende affrontare le grandi sfide del clima e dell'energia attraverso un grande programma di innovazione, Il **SET Plan** "*Strategic Energy Technology Plan*".
Le CCS sono considerate fra le priorità, e l'esigenza più urgente è dimostrare la tecnologia su scala industriale e su iniziative "pilota" su scala più picccola.
Per conseguire questi obiettivi la UE ha lanciato due grandi programmi per il finanziamento della ricerca industriale e dimostrazione nei settori strategici:
L'EEPR (*European Energy Programme for Recovery, EEPR*), il Programma energetico europeo per la ripresa, finanzia l'avvio di progetti pilota e dimostrativi sulle CCS;
Il NER 300 - *300 million allowances (rights to emit one tonne of carbon dioxide) in the New Entrants' Reserve of the European Emissions Trading Scheme* - è il più grande strumento di finanziamento per un programma di dimostrazione di tecnologie a basse emissioni di carbonio, ed è finanziato dalla vendita di 300 milioni di permessi di emissione emessi per impianti nuovi entranti (NER) del sistema *Emissions Trading europeo* (ETS).

Vi sono, poi, gli indirizzi di **FP7** e **Horizon 2020**, che orientano sempre più nettamente verso pochi progetti fortemente connessi con le grandi iniziative pilota e dimostrative.
Infine, un ruolo crescente sta assumendo la **EERA** (European Energy Research Alliance) che ha recentemente lanciato un Joint Programme sulle CCS e sta consolidando il suo ruolo di riferimento, nell'ambito del SET Plan, per l'individuazione delle priorità di ricerca e sviluppo, affiancandosi alla piattaforma tecnologica **ZEP** (zero Emission Fossil Fuels Power Plants) che rappresenta essenzialmente il mondo industriale.

L'Italia è sostanzialmente in linea con la strategia internazionale ed europea, nonostante il superamento di alcune scelte operate nel passato, come quella di non puntare sul carbone. Rimane forte l'interesse ad attività di ricerca così come ad iniziative industriali quali:

a) ricerca sul sistema elettrico, finanziata dal MiSE;
b) partecipazione a svariati progetti europei (FP7)
c) progetto dimostrativo dell'ENEL (slittato relativamente al grande dimostrativo di Porto Tolle, ma completamente in atto sulle infrastrutture di Brindisi);
d) iniziative nel SULCIS: impianto da 400 MWe, ancora in fase di valutazione presso EC per l'ammissibilità del finanziamento pubblico, e progetto pilota di taglia inferiore;
e) attività di R/S/D già finanziate dalla Regione Sardegna, ed attività in fase di finanziamento
f) rimangono in vigore, infine vari accordi internazionali firmati dal nostro governo (USA, Cina, UK ecc.)
g) da ultimo, non per importanza, il MiSE – insieme al MATT - sta procedendo rapidamente all'approvazione dei regolamenti attuativi della direttiva europea sul confinamento della CO2 già adottata in Italia.

La direttiva 2009/31/CE del 23 aprile 2009 sullo stoccaggio geologico della CO2 ha l'obiettivo di sviluppare un quadro economico e normativo atto ad eliminare gli ostacoli giuridici ancora esistenti, per attuare una CCS ambientalmente sicura. In Italia è stata recepita la Direttiva Europea, con ciò ponendo il nostro Paese, che già dispone di una serie di impianti sperimentali per la CCS per iniziativa di ENEL, ENEA, Sotacarbo ed ENI, in grado di dare inizio ad una fase di sviluppo tecnologico.

La direttiva 2009/29/CE modifica la direttiva 2003/87/CE al fine di perfezionare ed estendere il sistema comunitario per lo scambio delle quote di emissione di gas serra: essa prevede sostanzialmente che dal 2013 dovrà essere superato il sistema delle quote assegnate di CO_2, e gli emettitori di CO_2 non dovranno pagare soltanto le quote eccedenti quelle assegnate ma l'intero quantitativo di CO_2 emessa.
Il recepimento in Italia, come negli altri Paesi, è assai complesso e presumibilmente la data del 2013 non potrà essere rispettata; il prezzo previsto della CO_2 è non bene identificabile in quanto dipende da svariati fattori; oggi è su livelli – intorno a 10 €/ton – assai più bassi delle ipotesi largamente adottate di 30 €/t CO_2.

* * * * * * * *

In questo quadro, il lavoro svolto a livello internazionale ed europeo è stato utile per rafforzare il ruolo e la presenza italiana in un settore nel quale si gioca una delle sfide più difficili dei prossimi anni, che è quella di accelerare il percorso verso una società "low carbon"; due sono le considerazioni a monte: a) nei prossimi decenni continuerà l'impiego massiccio di combustibili fossili; b) l'unico modo per limitare i danni è l'impiego delle CCS. E' una sfida che si gioca a livello globale, che richiede una sempre maggiore e più efficace cooperazione internazionale.

Di quanto detto vi è consapevolezza diffusa in Italia, e ciò ha sostenuto il ruolo svolto di coordinamento a livello nazionale che la presenza in Europa e su scala più ampia ha richiesto: per questo un grande ringraziamento va ai vari operatori industriali e della ricerca, ed ai rappresentanti dei Ministeri coinvolti.

Descrizione delle attività svolte e risultati

Vengono richiamati ruolo e finalità dei vari organismi a cui si è partecipato, indicando in estrema sintesi I principali obiettivi delle attività svolte, riportando copie dei documenti originali emessi.
Si riportano, infine, i documenti progettuali presentati in ambito FP7

Partecipazione al CSLF (Carbon Sequestration Leadership Forum)

*le attività si riferiscono alla partecipazione, quale delegato italiano, al Technical Group del **CSLF**.*

Il CSLF è un consesso internazionale, istituito a livello ministeriale, che attualmente coinvolge 24 nazioni più l'Unione Europea, che rappresentano oltre 3.5 miliardi di persone, pari a circa il 60% della intera popolazione mondiale. La missione del CSLF consiste nel facilitare lo sviluppo e l'applicazione delle tecnologie CCS attraverso collaborazioni internazionali volte a superare i principali ostacoli di ordine tecnico, economico ed ambientale, promuovendo anche la consapevolezza del pubblico nonché sviluppi normativi e finanziari internazionali.
Il CSLF ha ormai assunto un ruolo fondamentale nel panorama internazionale, ed ha operato in stretta sinergia con l'Agenzia Internazionale per l'Energia (IEA) nella stesura di documenti strategici per vari incontri, quali il G8-Energia di Roma dove, si ricorda, il nostro Paese ha sottoscritto importanti accordi di collaborazione anche con il governo USA.
La partecipazione assidua dell'Italia a tutte le riunioni del CSLF ha consentito al nostro Paese di mantenere uno stretto contatto con tutti i principali attori internazionali e di promuovere le iniziative italiane.
Nel meeting di Edmonton (Maggio 2011) era stato presentato il progetto Porto Tolle dell'ENEL, poi incluso nella lista dei grandi progetti supportati dal CSLF. Nel meeting ministeriale di Pechino (Settembre 2011) si è discusso su obiettivi e tempi di realizzazione del progetto Porto Tolle, analizzando anche le altre attività italiane sia di R/D che relative a nuovi pilota e/o dimostrativi da realizzare nell'area del Sulcis. Nel successivo meeting di Bergen (Maggio 2012) si è continuata l'analisi delle priorità internazionali per l'aggiornamento del piano strategico e della road-map del CSLF. A valle dei meeting sono ste visitate importanti installazioni sperimentali: un impianto coal to liquid cattura e stoccaggio della CO2 nella regione della Mongolia cinese, e un'area dedicata alla sperimentazione di tecniche di cattura a Mongstad. Entrambi i governi cinese e norvegese partecipano in maniera determinante alle citate iniziative, sia avendo definito un quadro strategico certo, sia attraverso il supporto economico.

Si riportano, in Allegato1, i seguenti documenti:

<u>Progetto ZEPT (Zero Emission Porto Tolle</u>

- scheda presentata al CSLF

<u>Meeting del CSL: Pechino</u>

- report della riunione del Policy Group
- report del meeting del technical Group
- report del meeting congiunto Policy e technical Group
- stakeholder statement
- comunicato ufficiale givernativo

<u>Meeting del CSLF: Bergen</u>

- report del meeting
- iter per presentazione di progetti al CSLF
- Norvegia: strumenti per la promozione delle tecnologie CCS
- Norvegia: sviluppo delle CCS; iol Centro do Mongstadt

Partecipazione a IEA (International Energy Agency)

Le attività si riferiscono alla partecipazione, quale delegato governativo italiano, al Working Party on Fossil Fuels e all'Implementing Agreement Clean Coal Centre (CCC) della IEA.

Si tratta di iniziative di estrema importanza relative all'intero settore dei combustibili fossili, in particolare il solo carbone per l'implementing Agreement CCC, nel quale ha assunto un ruolo primario la tematica delle CCS: ciò è dovuto alla consapevolezza – unanimemente condivisa – che nei prossimi decennia il ricorso ai fossili sarà ancora massiccio e determinante, e l'unica via per un loro impiego il più possibile sostenibile sta nell'applicazione delle tecnologie CCS. Ciò richiede la realizzazione di grandi impianti dimostrativi basati sulle tecnologie attuali (come noto poco efficienti e assai costose, e dunque non ancora competitive) per la sperimentazione su scala industrial dell'intera "filiera" cattura-trasporto-stoccaggio, e lo sviluppo si sistemi di seconda generazione per raggiungere la competitività economica). Essenziali sono le attività sullo stoccaggio, per la determinazione accurate delle otenzialità effettive, per la caratterizzazione dei siti, e per accrescere il livello di confidenza e accettabilità sociale. Quello di IEA è, dunque, un consesso cruciale al quale l'italia ha partecipato presentando le iniziative nazionali e confrontandole con quelle degli altri paesi. In particolare, è stato chiesto di tenere una presentazione ufficiale delle attività imn Italia nel corso della riunione del Working parti di parigi (Dicembre 2011).

Si riportano, in Allegato 2, i seguenti documenti:

- agenda della riunione del Working Party on Fossil Fuels
- presentazione attività in Italia
- nota sulla situazione del Progetto Porto Tolle
- statment della Piattaforma tecnologica europea ZEP al COP17

Partecipazione al Global CCS Institute (GCCSI)

Le attività si riferiscono alla partecipazione, quale rappresentante ENEA, al GCCSI.

Al G8 Ambiente, tenutosi nell'aprile 2008 a Siracusa, è stato sottoscritto, nell'ambito dell'Intesa italo-australiana per la cooperazione nello sviluppo delle tecnologie CCS, un "Memorandum of Understanding" tra ENEL e il ministro australiano dell'Agricoltura, della Pesca e delle Foreste, che prevede l'adesione di ENEL come socio fondatore al Global Carbon Capture and Storage Institute (GCCSI). Il GCCSI è un'organizzazione nata su iniziativa del Governo australiano il cui obiettivo è mobilitare risorse pubbliche e private per diffondere le tecniche CCS; l'impegno immediato è quello di accelerare l'avvio progetti pilota e dimostrativi. Hanno aderito al GCCSI tutti i Paesi dell'Europa maggiormente impegnati nello sviluppo delle tecnologie CCS, oltre a Stati Uniti, Canada, Messico, Sud-Africa ed altri Paesi dell'Oceania e dell'Asia. L'adesione al GCCSI ci ha consentito di entrare in un circuito internazionale che sta assumento un ruolo di leadership assoluta quale stakeholder "indipendente", di acquisire informazioni anche su progetti extra-europei; sono state acquisite le condizioni per partecipare a pieno titolo alla rete di alleanze tecnologiche e industriali che nasceranno nell'ambito dell'organizzazione, di essere costantemente aggiornata sugli sviluppi normativi e regolamentari del CCS nel mondo e, infine, di valutare i risultati delle varie iniziative di comunicazione attivate dagli altri membri.

Si riporta, in Allegato 3, il seguente documento:

- accelerating CCS: 2013 — 2017 five-year strategic plan

Partecipazione alla Task Force Technology (TFT) della Piattaforma Zero Emission Fossil Fuels Power Plants (ZEP)

Le attività si riferiscono alla partecipazione, quale Membro italiano, alla Technology Task Force di ZEP

La piattaforma tecnologica ZEP (fondata nel 2005, unisce e rappresenta gli operatori industriali europei impegnati nelle tecnologie CCS; partecipano rappresentanti dei Governi nazionali, del mondo della ricerca e di organizzazioni terze. Svolge un ruolo essenziale per la definizione delle strategie europee. I membri della Task Force Tecnology (TFT), oltre a incontrarsi periodicamente per la messa a punto degli indirizzi da suggerire alla Commissione – in funzione delle attività di finanziamento di progetti di ricerca e dimostrazione - hanno operato, usando ampiamente lo strumento delle riunioni via Skype, per la stesura di documenti quali la **road-map** e uno studio assai importante sui costi delle CCS: tale ultimo documento è diventato un riferimento internazionale essenziale per le valutazioni economiche sulle varie tecnologie, ed evidenzia la fattibilità del raggiungimento di condizioni idonee per la applicazione commerciale delle CCS a partire dal 2020.

Si riportano, in Allegato 4, i seguenti documenti:

- documento sui costi delle CCS
- nota di ZEP sul documento sui costi delle CCS

Partecipazione al CCS EII Team (European Industrial Initiatives) del SET Plan (Strategic Energy Technologies)

Le attività si riferiscono alla *partecipazione, quale delegato governativo italiano, al **CCS-EII Team** (Iniziativa Industriale Europea sulle CCS) del **SET Plan** Strategic Energy Technologies)*:

E' un gruppo costituito da un rappresentante per ciascuno Stato membro, da alcuni rappresentanti della piattaforma ZEP e di EERA, e da alcuni stakeholder. Svolge un ruolo cruciale per la definizione degli indirizzi attuativi delle varie iniziative previste in ambito SET Plan, cercando di armonizzare le attività di ricerca, pilota e dimostrative, e allo stesso tempo allargando occasioni di cooperazione fra gli Stati. In particolare sono state concordate e trasmesse alla Commissione le linee guida per i bandi FP7 e NER300, dopo aver definito un piano strategico ed un insieme di Key Performance Indicators (KPIs). L'Italia ha presentato il proprio programma (costruito dalla integrazione delle varie iniziative, pubbliche e private) attraverso un documento complessivo, e si è confrontata con gli altri Paesi in particolare in merito al progetto dimostrativo di Porto Tolle dell'ENEL: si è anche avuto modo di approfondire le conoscenze di tale progetto nel corso di 2 audit, ai quali è stato chiamato anche il rappresentante italiano nel CCS-EII Team, che la Commissione ha tenuto con ENEL per valutare lo stato di avanzamento delle attività finanziate con 10 M€ del "Recovery Plan". E' stato presentato anche il progetto dimostrativo SULCIS, ancora in fase di fattibilità, peraltro molto apprezzato.

Si riportano, in Allegato 5, i seguenti documenti:

- agenda riunione di Otobre 2011
- conferenza del SET Plan, Varsavia Novembre 2011
- decisione sui Key Performance Indicators (KPI) per i progetti sulle CCS
- presentazione delle attività in Italia

Partecipazione a EERA

Le attività si riferiscono alla partecipazione, quale rappresentante ENEA e coordinatore nazionale, al Joint Programme sulle CCS di EERA (European Energy research Alliance).

EERA E' un organismo per molti aspetti analogo alla piattaforma ZEP ma riunisce gli operatori del mondo della ricerca sulle tematiche ritenute cruciali, e fra esse le CCS. Il lavoro svolto si è concentrato sulla definizione del Joint Programme (JP), un ampio programma di ricerca con obiettivi nel medio-lungo periodo costruito con il concorso di un numero rilevante di organismi dei vari Paesi che hanno concordato di armonizzare programmi in corso e già finanziati. L'ENEA, insieme ai suoi associati (varie Università) ha proposto il pacchetto delle attività svolte nell'ambito dell'ADP MISE-ENEA, con ciò valorizzando tali attività e creando opportunità per future collaborazioni. E' da rilevare che il ruolo di EERA sarà cruciale nei prossimi anni in quanto si prevede che, in ambito Horizon 2020, i finanziamenti comunitari verranno assegnati non più a singoli progetti ma a programmi complessivi, come appunto i JPs: è stato, dunque, essenziale essere fra i promotori dell'iniziativa, caratterizzando l'ENEA come uno fra i principali partner del JP. Nell'assemblea generale di Giugno 2012 si è concordato di aggiornare il JP entro l'anno, anche a seguito della adesione di altri membri.

Si riportano, in Allegato 6, i seguenti documenti:

<u>Accordi generali in ambito EERA</u>

- EERA: declaration of intents
- EERA: Intellectual Property Rights
- EERA: Letter of intents di ENEA
- EERA: relazione sulla partecipazione di ENEA

<u>Meeting EERA, Dicembre 2011</u>

- agenda della riunione
- memo Topics identified for co-operation EUAustralia within CCS
- visit to Australia short report

<u>Assemblea generale EERA, Giugno 2012</u>

- sintesi impegno ENEA e associati nel Joint Programme
- proposta ENEA di un nuovo topic su instabilità di combustione
- proposta ENEA di un nuovo topic su uso della CO2
- Joint Program, versione integrale in discussione per aggiornamenti
- Joint Programme, versione pubblica

Partecipazione alla Delegazione europea nella visita in Australia

Le attività si riferiscono alla partecipazione, quale rappresentante europeo di EERA, alla Delegazione europea nella visita in Australia.

Si è trattato di una importante missione, della durata di 5 giorni lavorativi, volta a discutere possibili collaborazioni fra la UE e l'Australia. Sono stati visitati importanti laboratori di ricerca, analizzando le rispettive priorità/iniziative, e incontrati rappresenti del Governo della regione Vittoria (a Melbourne) e dello Stato (a Camberra). Il risultato più tangibile è stato la possibilità per organismi australiani di partecipare all'ultimo bando FP7 (scadenza Novembre 2012). La missione è stata preceduta da un lavoro iniziale di impostazione e da un meeting conclusivo con i dirigenti della CE.

Si riportano, in Allegato 7, i seguenti documenti:

- report finale sulla vista
- elenco esperti che costituiscono la delegazione, oltre ai funzionari EC
- programma degli incontri
- presentazione agli australiani delle attività di EERA

Iniziative progettuali internazionali

Sono stati presi contatti con gli operatori cinesi, nell'ambito di una collaborazione già avviata fra Cina ed ENEL, e si è partecipato alla costruzione di due grandi proposte progettuali europee promosse da SINTEF e NTNU: progetto ECCSEL (approvato) e progetto ECRI (rinviato ad un successivo bando)

Si riportano, in Allegato 8, i seguenti documenti:

- presentazione delle attività in Italia per una collaborazione con Cina ed ENEL
- presentazione delle attività in Italia per una collaborazione con SINTEF
- progetto ECCSEL
- progetto ECRI

Conclusioni

La Commissione valuta che, senza la CCS, i costi del conseguimento di una riduzione in Europa del 30% dei gas serra nel 2030 senza la CCS potrebbero essere del 40% superiori. Il mancato avvio della CCS avrebbe notevoli impatti negativi sulla capacità dell'Europa di soddisfare il limite dei 2 °C, sulla competitività, ma anche sull'occupazione e avrebbe un impatto leggermente negativo anche sulla sicurezza dell'approvvigionamento.
Per l'applicazione delle tecnologie CCS occorre affrontare e risolvere un insieme di problematiche legate a:

- sviluppo e qualificazione delle tecnologie
- economicità del processo di CCS che allo stato attuale è caratterizzato ancora da costi elevati;
- aspetti legali e autorizzativi, dovuti al fatto che l'attuale regolamentazione ambientale e mineraria non contempla, di fatto, l'opzione delle CCS;
- la percezione da parte dell'opinione pubblica del rischio associato ad una attività poco nota e non sempre di facile comprensione a livello di rischi e benefici, soprattutto in termini di possibili perdite di CO_2 dai serbatoi di confinamento.

Per quanto riguarda lo ***sviluppo delle tecnologie***, sono abbastanza chiare le esigenze e svariati attori hanno prodotto road-map che sostanzialmente concordano nella impostazione generale pur differendo rispetto a specifici obiettivi delle differenti aree geografiche.

Il ***fattore economico*** è, ovviamente, determinante e rappresenta uno dei principali ostacoli verso la diffusione di queste tecnologie: proprio per queste ragioni la UE sta finanziando i grandi progetti dimostrativi con fondi utili a coprire gli extra costi imputabili alle CCS.
I programmi dimostrativi dovranno fornire le prime indicazioni utili alla riduzione dei costi, mentre il successivo programma dovrà consentire il passaggio definitivo alla competitività per il 2030. È necessario, poi, affrontare gli ostacoli commerciali per la diffusione delle tecnologie CCS, in quanto lasciarla al libero gioco degli investimenti sul mercato può essere insufficiente, anche se le CCS sono state recentemente inserite nei meccanismi flessibili.

In conclusione, gli obiettivi delle attività nei prossimi anni si possono così sintetizzare:

- abbassare il costo della CO_2 evitata a valori intorno a 40 €/tCO_2;
- ridurre i costi di investimento degli impianti CCS;
- ridurre i costi di esercizio degli impianti CCS;
- ridurre l'energia aggiuntiva richiesta per l'applicazione delle tecnologie CCS;
- ottenere elevata disponibilità in termini di ore/anno di esercizio.

Gli ***aspetti legali e autorizzativi*** hanno assunto una rilevanza particolare, e sono determinanti per lo sviluppo dei progetti dimostrativi, soprattutto nelle fasi di trasporto e stoccaggio geologico della CO_2 e anche rispetto alle problematiche di accettabilità sociale dell'intero processo di CCS.
La UE ha definito un quadro chiaro con la citata direttiva, e l'Italia sta concludendo la fase di recepimento: rimangono aperti tutti gli aspetti applicativi che incontrano sempre grandi difficoltà nel nostro Paese.

Il problema dell'***accettabilità pubblica*** è il secondo grande ostacolo - insieme a quello economico – per la diffusione delle CCS. L'adozione di nuovi sistemi di produzione e gestione dell'energia comporta l'acuirsi di conflitti nel territorio; da un lato si rendono necessari adeguamenti e innovazioni nell'ambito amministrativo-legislativo, dall'altro è indispensabile far conoscere e accettare le nuove tecnologie e i vantaggi che esse procurano, per assicurarsi la collaborazione dei cittadini e delle istituzioni territoriali: occorre dunque attivare una strategia di preventiva e corretta comunicazione che coinvolga fin dall'inizio ogni stakeholder. Ciò vale in modo particolare per le CCS.

In Italia esistono le condizioni per proseguire e ampliare il programma di ricerca e sviluppo e costruire rapidamente un piano industriale centrato su impianti pilota per la fase dimostrativa; possiamo, infatti, contare su alcuni importanti punti di forza:

- la capacità degli enti di ricerca e di molti istituti universitari di mettere a sistema specifiche competenze e partecipare a progetti nazionali, europei e internazionali; e, in questo quadro, le grandi potenzialità offerte dalle infrastrutture sperimentali su scala pilota realizzate presso ENEA e Sotacarbo;
- il credito che a livello europeo tali centri hanno saputo guadagnarsi, e la presenza – assicurata in particolare da ENEA – nei più importanti contesti internazionali (quali CSLF, ZEP, EERA, IEA, SET Plan, Global Institute) e la stipula di accordi bilaterali con USA, UK, Cina, e accordi tecnologici con organismi di altri Paesi;
- la presenza sul territorio italiano e nei mari circostanti di numerosi "laboratori naturali", cioè di siti in cui la CO_2 fuoriesce naturalmente, e di siti potenzialmente idonei allo stoccaggio, offrendo opportunità uniche per valutare gli impatti sui sistemi vegetali e animali, e la possibilità di studiare le varie opzioni tecnologiche di stoccaggio affinando anche le tecniche di monitoraggio della CO_2;
- le iniziative avviate di recente dai due maggiori stakeholders italiani, ENEL ed ENI, e da altre realtà industriali quale Carbosulcis, Techint ecc…

Non v'è dubbio che il ricorso alle tecnologie CCS rappresenti una strada essenziale da percorrere nella impostazione di una moderna strategia energetica; per l'Italia, in particolare, costituisce una grande opportunità che si presenta all'industria nazionale - la grande industria e tutto l'indotto – ed al "sistema Paese" di competizione nel mercato globale delle grandi infrastrutture energetiche.

Abbreviazioni ed acronimi

CCS	Carbon Capture and Storage
CSLF	Carbon Sequestration Leadership Forum
ECCSEL	European Carbon Dioxide Capture and Storage Laboratory Infrastructure
ECRI	European CCS Research Infrastructures
EERA	European Energy Research Alleance
EII	European Industrial Initiative
GCCSI	Global CCS Institute
IEA	International Energy Agency
KPI	Key Performance Indicator
SET Plan	Strategic Energy Technology Plan
TFT	Task Force Tecnology (di ZEP)
ZEP	Zero Emission fossil fuels power Plants
ZEPT	Zero Emission Porto Tolle

Allegati

Allegato1. Partecipazione al CSLF (Carbon Sequestration Leadership Forum)

Progetto ZEPT (Zero Emission Porto Tolle

- scheda presentata al CSLF

Meeting del CSLF: Pechino

- report della riunione del Policy Group
- report del meeting del technical Group
- report del meeting congiunto Policy e technical Group
- stakeholder statement
- comunicato ufficiale givernativo

Meeting del CSLF: Bergen

- report del meeting
- iter per presentazione di progetti al CSLF
- Norvegia: strumenti per la promozione delle tecnologie CCS
- Norvegia: sviluppo delle CCS; il Centro do Mongstadt

Allegato 2. Partecipazione alla IEA (International Energy Agency)

- agenda della riunione del Working Party on Fossil Fuels
- presentazione attività in Italia
- nota sulla situazione del Progetto Porto Tolle
- statment della Piattaforma tecnologica europea ZEP al COP17

Allegato 3. Partecipazione al Global CCS Institute (GCCSI)

- accelerating CCS: 2013 — 2017 five-year strategic plan

Allegato 4. Partecipazione alla Task Force Technology (TFT) della Piattaforma Zero Emission Fossil Fuel Power Plants (ZEP)

- documento sui costi delle CCS
- nota di ZEP sul documento sui costi delle CCS

Allegato 5. Partecipazione a CCS EII Team (Iniziativa industriale Europea sulle CCS) del SET Plan (Strategic Energy Technologies)

- agenda riunione di Otobre 2011
- conferenza del SET Plan, Varsavia Novembre 2011
- decisione sui Key Performance Indicators (KPI) per i progetti sulle CCS
- presentazione delle attività in Italia

Allegato 6. Partecipazione a EERA (European Energy Research Alleance)

<u>Accordi generali in ambito EERA</u>

- EERA: declaration of intents
- EERA: Intellectual Property Rights
- EERA: Letter of intents di ENEA
- EERA: relazione sulla partecipazione di ENEA

<u>Meeting EERA, Dicembre 2011</u>

- agenda della riunione
- memo Topics identified for co-operation EUAustralia within CCS
- visit to Australia short report

<u>Assemblea generale EERA, Giugno 2012</u>

- sintesi impegno ENEA e associati nel Joint Programme
- proposta ENEA di un nuovo topic su instabilità di combustione
- proposta ENEA di un nuovo topic su uso della CO2
- Joint Program, versione integrale in discussione per aggiornamenti
- Joint Programme, versione pubblica

Allegato 7. Partecipazione alla delegazione europea nella visita in Australia per cooperazione sulle CCS

- report finale sulla vista
- elenco esperti che costituiscono la delegazione, oltre ai funzionari EC
- programma degli incontri
- presentazione agli australiani delle attività di EERA

Allegato 8. Iniziative progettuali internazionali:

- presentazione delle attività in Italia per una collaborazione con Cina ed ENEL
- presentazione delle attività in Italia per una collaborazione con SINTEF
- progetto ECCSEL
- progetto ECRI

 Pag. 19

Allegato 1.

Partecipazione al CSLF (Carbon Sequestration Leadership Forum)

Progetto ZEPT (Zero Emission Porto Tolle

scheda presentata al CSLF

Meeting del CSLF: Pechino

report della riunione del Policy Group

report del meeting del technical Group

report del meeting congiunto Policy e technical Group

stakeholder statement

comunicato ufficiale givernativo

Meeting del CSLF: Bergen

report del meeting

iter per presentazione di progetti al CSLF

Norvegia: strumenti per la promozione delle tecnologie CCS

Norvegia: sviluppo delle CCS; il Centro do Mongstadt

 Pag. 19

Pag. 20

CSLF PROJECT SUBMISSION FORM

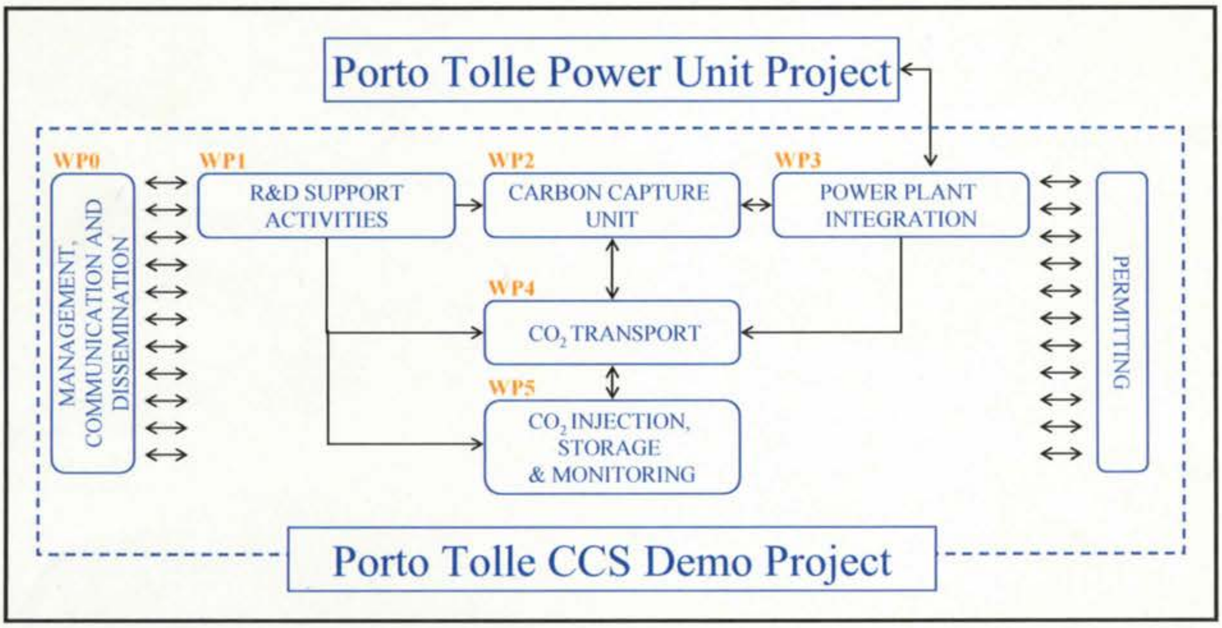
PROJECT TITLE: Zero Emission Porto Tolle (ZEPT)

PROJECT LOCATION:
Power plant owned by Enel Produzione and located in Porto Tolle, Province of Rovigo, Region of Veneto,160 km south from Venice, Italy
Please provide the city (or nearest town), the state/province/region, and the country.

PROJECT GOAL:
The goal of the Porto Tolle Zero Emission Project is to demonstrate the industrial application of the CO_2 capture and geological storage in the power sector at full scale. The demo plant will be operated for an extended period (10 years) in order to fully demonstrate the technology on an industrial scale, access clearly the real costs of CCS and provide a commercial solution for new installations after 2020. The project is intended to prove the retrofit option for high-efficiency coal fired units which will be built (or replaced) in the coming 10-15 years.

Please provide a simple and to-the-point explanation in one or two sentences that can be easily understood by someone with no prior knowledge of the project.

PROJECT OBJECTIVES AND ANTICIPATED OUTCOMES:
The "Porto Tolle CCS demo" project work plan consists of six technical work packages.
The logical interaction between the work packages is schematically shown in the figure below.



- WP0 Management, Communication and Dissemination: The basic tasks for this WP are to coordinate, manage, and support all other WPs towards the realisation of the project objectives. The communication strategy will aim to reach a very broad range of recipients at local, national and international level, including citizens, stakeholder, institutional and governmental audiences and selecting tools tailored for each audience both during the lifetime of the project and afterwards.

Pag. 20

- WP1 R&D Support Activities: At the beginning of 2010, Enel has completed the realization of a Carbon Capture pilot that is now under operation. The main goal of the experimental activities will be the evaluation of the merit of the different capture processes in terms of energy consumption and environmental impact.

- WP2 Carbon Capture Unit (CCU): Enel has identified a set of companies as the most referenced in the field of Carbon Capture projects worldwide. All the selected technologies are based on amine absorption of the CO_2 in packed column, with steam stripping to regenerate the solution and separate the CO_2. The main differences in the technologies are the solvent used, and detailed plant design solutions to reduce energy penalty and emissions.

- WP3 Power Plant Integration: includes all the necessary connections in order to supply the exhaust flue gas and all utilities from Porto Tolle power unit 3 to the CCU.

- WP4 CO_2 Transport: The captured CO_2 will be delivered to the storage site under dense phase condition via off-shore pipeline. During the detailed engineering phase, the pipeline route and the approaches to shore and off-shore structure will be finalised.

- WP5 CO_2 Injection, Storage and Monitoring: The injection and storage part of the project consists of the following four main activities: 1) Site selection and characterization; 2) Site preparation and well construction; 3) Operation and performance assessment; 4) Closure and post closure management. A cross-cutting issue is the design of the monitoring plan covering the lifetime of storage project.

Please provide a breakdown of the Project Goal into the constituent steps comprising the whole. Use bullet points to separate the steps and indicate key anticipated outcomes. Indicate what the project does to facilitate CCS deployment.

PROJECT DESCRIPTION AND RELEVANCE (non-technical):

The Porto Tolle project is part of a wider programme aimed at large-scale application of post-combustion. This technology applies chemical absorption to remove the CO_2 contained in flue gases from power plants. Enel is exploring all possible options to capture as much CO_2 as possible from its fossil-fuel facilities. Among such options, this technology appears as the most promising and advanced, and offers retrofitting solutions for existing facilities.
In this context, Enel has completed a pilot capture station at a coal-fuelled plant in Brindisi, in southern Italy, where the technology can be tested on a significant scale. The facility will help develop the Porto Tolle demonstration plant.
This project, besides fully demonstrating this technology on an industrial scale, so as to provide a commercial solution for new installations after 2020, is used to test the possibility of retrofitting highly efficient coal-fired groups.
This experience will benefit the entire area of Europe where geological storage is possible, mainly in deep saline aquifers.

Please provide a concise synopsis of the project (who, what, why, where and how) with easily understandable descriptions of the associated science, technology, and goals. This should include an indication of areas of industrial application and relevance. Target audience: policy makers, press, non-scientific community.

PROJECT DESCRIPTION (technical):

Full chain description

The Porto Tolle Power Plant, consisting of 4 Units Heavy Fuel Oil fired, 660MWe each, will be converted from oil to high efficiency coal firing. The new plant will have a capacity of about 2000 MW, consisting of 3 USC units of 660 MWe.
The demo Carbon Capture Unit (CCU) will be able to treat a flue gas flow rate of 0.81 MNm3/h, corresponding to 40% of the flue gas coming out from Unit 3 (660 MWe) and to a power capacity of

JW

 Pag. 22

250 MWe net. The design CO_2 capture efficiency (on mass basis) of the CCU is 90% of the treated flue gas, producing about 4500 t/day corresponding to approximately 1 Mt/y of CO_2.
The separated CO_2 will be transported by a carbon steel pipeline, from an onshore pipeline terminal at Porto Tolle to an offshore injection platform through a subsea pipeline of about 100 km length. The pipeline will be entirely developed within the Italian territory.
Regarding storage location, the pre-FEED studies have been based on the data of a saline aquifer reservoir, located at around 25 km from the Adriatic coast off Rimini and having a preferential NW-SE orientation covering an area of 4.5x2.7-3 km (about 12-13.5 km^2). The reservoir thickness ranges between 500 and 1200 m.; however additional nearby reservoirs are also under investigation.
The Porto Tolle power plant Unit 3 provides steam (both low and high pressure) needed for the operation of the CCU. Unit 3 will also provide the electric power needed for all the auxiliaries and the CO_2 compressors. Key factors of the new power units will be the high efficiency thermal cycle (44% net), and extremely low pollutant emissions.
The unit at the Porto Tolle power plant on which the demo CCS plant will be installed is designed to be powered by coal or cofired by coal and biomass (biomass co-firing up to 5% of the total heat input). The Porto Tolle power plant will be designed and built to assure an environmentally compatible use of coal for power production, satisfying the more stringent regulations on emissions, effluents and residues.
Following the preliminary assessment of potential post-combustion Carbon Capture technology suppliers, Enel has identified a set of companies as the most referenced in the field of Carbon Capture projects worldwide. Four licensors have been selected to develop the FEED for the CCU; at present, these studies are in progress. On the basis of the FEED results, a bid for the license agreement will be carried out and one technology will be selected. All the selected technologies are based on amine absorption of the CO_2 in packed column, with steam stripping to regenerate the solution and separate the CO_2. The main differences in the technologies are the solvent used, and detailed plant design solutions to reduce energy penalty and emissions.
The CCU will be fed with desulphurized gas taken before the Gas - Gas Heater of the Unit 3, after the existing wet-FGD.
The plant will consist of three main sections:

- a pre-treatment section, in which the cooling and SOx removal will be carried out, in order to minimize the degradation of the solvent to be used for the CO_2 absorption process and to reach the adequate temperature for the absorption process;
- the absorber column, in which the CO_2 chemical absorption will be carried out. The type of solvent to be used depends on the selected technology;
- the stripper column (solvent regeneration section), in which the CO_2 chemical absorption process is reversed.

The CO_2 compression will be performed by 2x50% compressors. The number of compression stages will be dependent on the selected technology. Depending on the final delivery pressure, it is possible that the last compression stage will be replaced by a pumping stage, as an option for energy saving.
Detailed design of the compression plant will be carried out during the FEED, in which several options concerning the process operation and types of equipment will be developed. The final compression pressure of the CO_2 will be defined later according to the final CO_2 reservoir storage study.
Similarly, the CO_2 transmission system pipeline diameter, wall thickness and material grade will be established during the FEED.
The wellheads, injection facilities and related utilities will be installed on a platform, whose design will be developed in the Compression and Transport System (CTS) FEED study. The study will include consideration of different structural concepts and a preferred concept will be selected for the design development stage of the CTS-FEED study.
A pipeline riser from the seabed to the platform deck will be realized and will pass up the height of the structure. The top of riser will be connected to the platform topside piping system. The passage through the riser will continue at fullbore through isolation valves, pass a branch connection (or connections) through further isolation valves and into a pig receiver barrel. A branch from the

AN

 Pag. 22

pipeline will lead to the well manifold. The manifold will distribute the CO2 from the pipeline to the injection wells. After distribution at the manifold, the CO2 will pass through an instrumented pipe run to determine the mass flow rate.
The number of injection wells required is to be determined through further studies.
The study for the identification of suitable CO2 storage structures in the North Adriatic sea was performed in two steps: a preliminary regional screening based on public data only and a detailed local one. In this second phase of the study existing 2D and 3D seismic data and borehole information were used to provide a new detailed 3D characterisation of the potential reservoir.
As already said, one of the promising sites is a saline aquifer structure, placed offshore northern Adriatic Sea and corresponding to the more external portion of the buried northern Apennine chain front. Detailed reservoir studies aimed at its characterization are in progress, (dynamic flow, geochemical and geomechanical models). The approach includes the improvement at different levels: regional, local and near wellbore.
Enel, at the same time, is evaluating some alternative storage sites in the closer area. The final selection will be performed on the basis of injectivity evaluation to ensure the safety and integrity of the storage system.
The total amount of CO_2 to be stored annually is about 1 Mt; in the first ten years of operation is foreseen to store 9,7 Mt.

R&D activities
Research activities related to each section of the full CCS chain are in progress.
At the beginning of 2010, Enel has completed, the realization of a capture pilot plant treating 10.000 Nm^3/h of flue gas at Enel Brindisi coal fired power plant; the solvent used for CO_2 chemical absorption is Monoethanolamine at different mass percentages. Testing on this pilot facility is in progress and will allow to assess the environmental impact of the process (solvent and additives handling, wastes management, composition of CO_2 stream and emissions).
Moreover, the solvent to be used at Porto Tolle CCU will be tested on this facility.
Regarding CO_2 transport, in the frame of the Eni-Enel agreement of October 2008, a pilot pipeline will be realized at Enel Brindisi power plant that will allow to reproduce large scale transport conditions, to perform material corrosion tests and to gain knowledge on CO_2 pipeline operating conditions (e.g. transient operation).
An independent research block in the sector of the CO_2 storage related to brine mitigation assessment and monitoring deployment will be started soon.

Public Funding
In December 2009 Enel signed an agreement for a grant of 100 M€ from the European Energy Programme for Recovery (EEPR) fund

Please provide a more detailed technical description of the project with all significant information. Target audience: engineers and scientists.

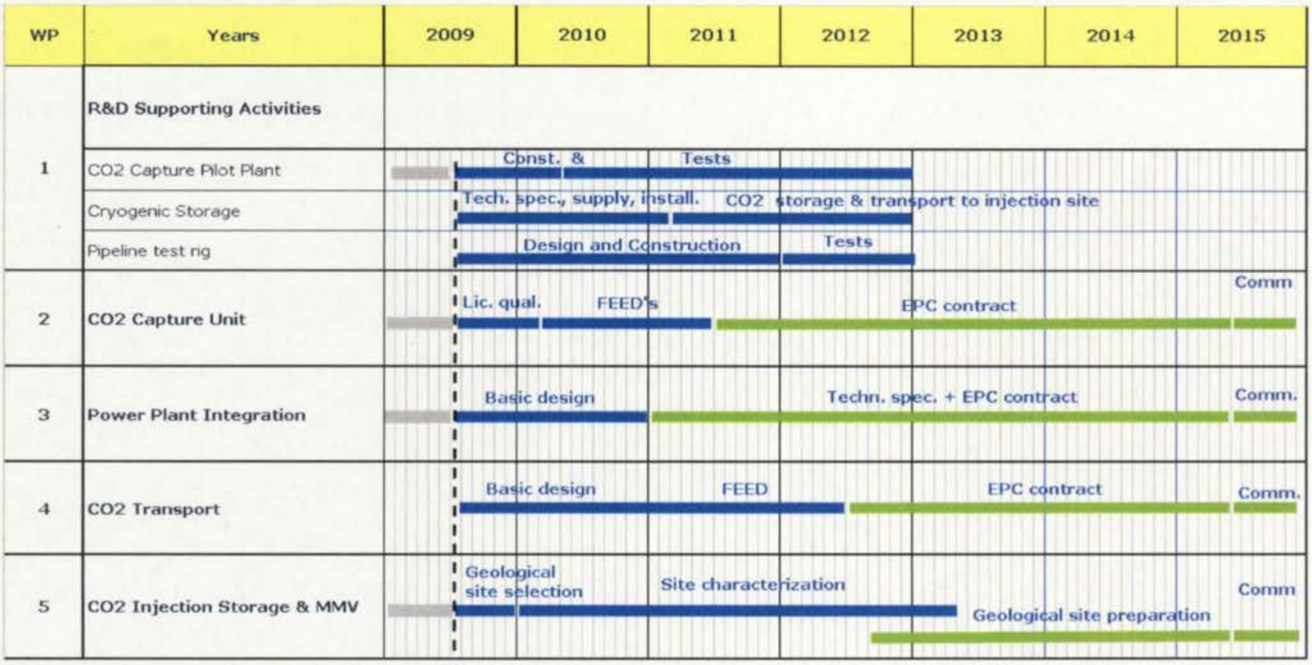
PROJECT ELEMENTS:
Please check all that apply.
Pre-combustion CO_2 Capture ____
Post-combustion CO_2 Capture __X__
Oxyfuel Combustion ____
CO_2 Capture by Other Means (please describe):
CO_2 Transport __X__
CO_2 Storage with Enhanced Oil Recovery ____
CO_2 Storage with Enhanced Coal Bed Methane Recovery ____
CO_2 Storage with Enhanced Natural Gas Recovery ____
CO_2 Storage with No Resource Recovery __X__
CO_2 Measurement, Monitoring, and Verification of Storage (MMV) __X__

AN

Pag. 24

Identification of Potential CO_2 Storage Sites _X___
Identification of Target CO_2 Sources ____
Economic Evaluation __X__
Environmental Evaluation __X__
Risk Assessment (HSE) __X__
Risk Assessment (Financial) __X__
Other (please describe):

PROJECT TIMELINE:



Activities carried out in the frame of the EEPR Grant Agreement signed in December 2009 with European Commission

Please provide the project start date, any milestone events (listed chronologically), and the end date. Use most realistic timeline available. Use official (contract signing, etc.) start date. End date should reflect contractual timeline if possible. Use bullet points.

Please also provide answers to the following questions:
Has the project already progressed through the early phases of planning, such as (but not exclusively) documenting the project scope, outputs and outcomes? ___YES____

Has the project management identified the magnitude of resource requirements sufficient to achieve the major milestones of the project? ___YES____

Has the project management identified funding sources for the project? __YES_____

INFORMATION AVAILABILITY:

For CCS to be rapidly developed and successfully installed in the time scales required by climate change concerns, a comprehensive and aggressive sharing of knowledge gained from CCS demonstration project is key to accelerate the technology to commercial availability by 2020. Relevant and useful knowledge about CCS must be quickly and effectively disseminated and applied in the right way, at the right times, and to the right stakeholders.

This is the goal of the Porto Tolle CCS Knowledge Management & Sharing (KM&S) effort. By collecting and making available to all stakeholders key knowledge obtained during the design, construction, and operation of the CCS demonstration project, this effort will help to promote the global adoption of CCS technology.

Pag. 24

The Porto Tolle Project is part of the European Knowledge Sharing Network (EKSN) that was developed by the European Commission as a mechanism to convey knowledge on CCS technology across geographical boundaries and optimise the use of project resources. Knowledge sharing refers to the process of exchanging good practices and lessons learned between projects and providing stakeholders with information on project progress, performance and reliability.
The drivers for knowledge sharing in the Network are summarised by the following four objectives:

1. De-risking of CCS with regard to scaling up to commercial size
2. Acceleration of the deployment of CCS to support the achievement of the EU ambition of commercialisation of CCS by 2020
3. Increasing the understanding of, and confidence in, CCS by the wider public
4. Maintenance of a competitive market for the post-demonstration deployment of CCS Technologies

Two sharing levels for knowledge were identified. The first sharing level for knowledge (Level 1) has been established to ensure that members are able to exchange experiences on a reciprocal basis wherever possible, or to ensure added value for sharing parties, in order to accelerate CCS development and identify good practices and lessons learned. Knowledge shared at this level is available within the Network (i.e. all members and the Network team).
The second level for sharing knowledge (Level 2) has been established to ensure that external stakeholders have access to sufficient information to meet their needs. In the case of the public, all information on health, safety and environment is made accessible. In the case of the wider CCS community, information that enables the identification of research needs and informs global project developers about CCS costs and risks is made accessible.
This KM&S strategy will contribute to CSLF goals since it facilitates the development and deployment of CCS technologies via collaborative efforts that address key technical, economic, and environmental obstacles

Please provide a description of the types of information that will made available from the project and the outcomes that would be achieved by the project. Please also provide information about the relevance of the project to the overall aims of the CSLF and to carbon capture and storage technology in general.

Please also provide answers to the following questions:
Is the project management willing to share non-proprietary project information with other CSLF Members? ___YES____

Will the expected information from the project be sufficient to allow others to make informed estimates of the technology's potential technical performance, costs, and benefits for any future applications? ____YES___

Will English-language project summaries be available for posting at the CSLF website? __YES_____
(Please also provide details on how, and how often, these summaries and other project information will be made available.)

RELEVANCE TO CSLF GAPS ANALYSIS:
Please check items that apply in the Attachment.

PROJECT CONTACTS:

Project manager: Stefano Malloggi
Via Andrea Pisano 120 – 56122 Pisa - Italy
Tel: +39 0506185648
email: stefano.malloggi@enel.com

Site visits: Cristiana La Marca
Via Andrea Pisano 120 – 56122 Pisa – Italy
Tel: +39 050 6185471
email: cristiana.lamarca@enel.com

AN

 Pag. 26

Please provide name and contact information (including telephone and e-mail) for the project manager or coordinator. If relevant, please also provide name and contact information (including telephone and e-mail) for the person who will handle any requests for site visits.

Please also provide an answer to the following question:
What restrictions, issues, or costs will be assumed by any visitors to the project site?
All the visitors will have to be previously approved by ENEL and any visit will have to be compatible with the activities at the site and obey to all the internal safety regulations.

OTHER PROJECT PARTICIPANTS:

- ENEL Ingegneria e Innovazione SpA
- ENEL Produzione SpA
- ENI SpA
- IFP
- Istituto Nazionale di Geofisica e Vulcanologia (INGV)
- Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)

Please provide a listing of all entities who are participating in this project. If available, please also include a management structure diagram or otherwise indicate the role of each participating entity.

PROJECT WEBSITES:
http://www.zeportotolle.com/
Please provide the web address of the main project website, if one exists. If available, please also provide the web addresses of other project-related websites such as workshops, project presentations, etc.

PROJECT NOMINATORS:
Livio Vido - President of ENEL Ingegneria e Innovazione SpA

In order to formalize and document the relationship with the CSLF, the project representative and at least two CSLF Members nominating the project must sign the Project Submission Form specifying that relationship before the project can be considered.

Project Representative
(ENEL Ingegneria e Innovazione SpA)
(Affiliation)

CSLF Delegate
(CSLF Member)

UNITÀ TECNICA
Tecnologie Avanzate per l'Energia e l'Industria
Coordinamento
Uso Sostenibile Combustibili Fossili
Il Responsabile
(Ing. Giuseppe Girardi)

CSLF Delegate
(CSLF Member)

AN

 Pag. 26

 Pag. 27

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

CAPTURE TECHNOLOGIES

Post-Combustion Capture	
Optimise capture systems	X
Improved solvent systems	X
Power plant concepts to integrate CO_2 capture	X
CO_2 capture pilot plant	X
Fully integrated demonstration plant	X
Develop better solvents	X
Optimise capture process systems to reduce power stations energy loss and environmental impact	X
Advance organic / inorganic non-precipitation absorption systems	-
Identify advantages and limitations of precipitating systems (e.g., carbonates)	-
Develop better understanding of the assessment of environmental impacts of capture technologies	X
Pre-Combustion Capture	
Hydrogen-rich turbines	-
Improved air separation processes	-
Improved water-gas shift	-
Improved H_2/CO_2 separation	-
Power plant concepts to integrate CO_2 capture	-
Polygeneration optimization	-
Advance integration and optimization of components for power station applications	-
Coal and liquid petroleum gasification, natural gas reformer, syngas cooler	-
Improve CO_2 separation and capture technologies	-
Develop high efficiency and low emission H2 gas turbines	-
Fully integrated demonstration plant	-
Oxyfuel Combustion	
Boiler design	-
Improved air separation processes	-
Oxy-fuel gas turbines	-
Combustion science	-
Power plant concepts to integrate CO_2 capture	-
CO_2 capture pilot plant	-
Fully integrated demonstration plant	-
High temperature turbines	-
CO_2/N_2 separation technology for industrial processes	-
Research into material selections	-
Cryogenic air separation	-

 Pag. 28

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

CAPTURE TECHNOLOGIES

Industrial Applications	
Capture from non-power industrial processes	-
Emerging and new concepts for CO_2 capture	
Research into Post-combustion carbonate looping cycles	-
Research into Gas separation membranes and adsorption processes for CO_2	-
Research into Ion-transport membranes for O_2 separation	-
Research into Chemical looping	-
Generation Efficiency	
Support initiatives to improve efficiency of electricity generation plant	-
Develop high efficiency gas turbines and support new cycle concepts	-
Develop alternative power generation processes that have the potential to produce improved economics when paired with absorption capture	-

 Pag. 28

 Pag. 29

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

STORAGE TECHNOLOGIES

Injection	
Optimum well spacings and patterns	X
Optimum injection parameters	X
Definition of variable rock facies or rock property types for injectivity.	X
Sustainability of high injection rates	X
Formation water compression / displacement in closed or open system	X
Reservoir engineering aspects	X
Address costs associated with storage, especially drilling and establishing wells	X
Storage Options	
Saline Aquifers – fluids/rock relationships and interactions	X
Coal – rock properties	-
EOR – lessons to be applied to other storage reservoirs	-
Depleted oil and gas fields – viability	-
Basalts – proof of concept	-
Ultra-low permeability rocks (e.g., organic rich shales, non-conventional reservoirs) – proof of concept	-
A world-wide digital CO_2 storage atlas	-
Deep Saline Formations	
Consistent methodology for storage capacity estimation	X
Record and define existing aquifer capacity data from world-wide projects	
Provides a robust storage capacity classification system and informs the legal end of storage licensing procedures	
Reservoir and cap rock characteristics – storage injectivity, capacity and integrity	X
Predicting spatial reservoir and cap rock characteristics with uncertainties	X
Depleted Oil and Gas Fields	
Depleted oil and gas fields – existing wells and remediation	-
Inventory of oil and gas fields with large storage capacity	-
Unmineable Coal Seams	
Worldwide storage capacity in unmineable coal seams	-
CO_2-coal interactions – methane displacement and permeability decreases	-
Mineral Carbonation	
Enhancing mineral trapping in specific types of settings (basalt, saline aquifers, etc.)	-
Impact on fluid flow, injectivity, and geomechanics	-
Thermodynamics and kinetics of chemical and microbiological reactions	-
Techno-economic viability of mineral storage of CO_2	-
Gaps in Uses of CO_2 (EOR and EGR)	
Validate enhanced recovery of gas (EGR) (including ECBM)	-

 Pag. 29

Pag. 30

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

STORAGE TECHNOLOGIES

Trapping	
Understanding physical or chemical trapping mechanisms	X
Migration rate	X
Hydrodynamics	
Petroleum field development impact on hydrodynamic regime	
Research the impact of the quality of CO_2 (purity of CO_2) on interactions with the formation, brine, and storage behaviour	
CO_2 Properties	
Behaviour of CO_2 under different regimes of pressure, temperature and fluid mixtures	X
Assessments	
Storage Capacity assessment methodologies or standards	X
Country wide or regional assessments of storage potential	-
Innovative methods for assessments of geological storage potential	-
Geological site characterisation, methodologies, techniques and standards	X
Protocols for evaluation of potential sterilisation of existing resources	-
Develop appropriate models to predict the fate and effects of the injected CO_2 (multi-phase fluid flow, thermo-mechanical-chemical effects and feedback), including leakage	X
Leakage	
Flux rates of modern and ancient systems	X
Quantification and modeling of potential subsurface leakage impacts	X
Existing facilities and materials	X
Economics	
Costs of storage	X
Software	
Parameters for modeling fluid and rock interactions	X
Improvements in software for basin wide geological, reservoir engineering and hydrodynamic model	-
Integration in single software system of geological, reservoir engineering and hydrodynamic aspects	-
Risk	
Risk assessment models	X
Public Outreach	
Procedures and approaches for communicating the impacts of geological storage to the general public	X

Pag. 30

Pag. 31

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

MONITORING

General	
Assess long-term site security post-injection including verified mathematical models of storage	X
Define methods for the production and disposal of brine from saline formations as a result of CO_2 injection	X
Wellbore Integrity	
Functionality and resolution of available logging tools	X
Improved interpretation of cased hole logs	
Improved wellbore monitoring techniques	
Physical or chemical changes to cement	X
Identification of Faults and Fractures	
Use of seismic techniques	X
Use of non-seismic geophysical techniques	
Improved recognition and interpretation of the nature of faults and fractures	
Subsurface Leaks	
Seismic, resolution	
Seismic, cost reduction	
Evaluation of permanent or semi-permanent sampling points in an observation well	
Surface and Near-Surface Leaks	
Detecting CO_2 seeps into subaqueous settings	
Remote sensing of CO_2 flux	
Use of vegetational changes by hyperspectral surveys changes to identify gas levels in the vadose zone	
Improved remote sensing to identify sources of CO_2	
Compile baseline surveys for measurement, monitoring and verification (MMV) activities including site-specific information on CO_2 background concentration and seismic activity	X
Develop instruments capable of measuring CO_2 levels close to background and to distinguish between CO_2 from natural processes and that from storage	
Monitor impacts (if any) on the environment	X
Guideline Development	
Determination of effective pre-injection surveys	
Improved integration of monitoring techniques	
Identify thresholds of leakage that can be measured	
Develop best practice guidelines selection, operation and closure, including risk assessment and response and remediation plans in case of leakage	

Pag. 31

Pag. 32

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

MONITORING

Gaps in Security of Geologic Storage	
Model the fate and effects of injected or leaked CO_2	
Develop best practice guidelines on how to characterize and monitor a site prior to, during, and after storage	
Build tools that can be used to characterise a potential storage site	
Develop low cost and sensitive CO_2 monitoring technologies	
Construct maximum impact procedures and guidelines for dealing with CO_2 leaks	
Create risk assessment tools to identify the likelihood and consequence of CO_2 leaks and inform effective decision making	

Pag. 32

Pag. 33

CSLF Gaps Analysis Checklist

(Please check all of the following technology areas that your project will address.)

TRANSPORT

General	
Cost benefit analysis and modeling of CO_2 pipeline and transport systems	
Tanker transport of liquid CO_2	X (pilot plant only)
Specifications for impurities from various processes	X
Dispersion modeling and safety analysis for incidental release of large quantities of CO_2	X
Safety and mitigation of pipelines through urban areas	-
Safety protocols to protect CO_2 pipelines, including response and remediation	X
Identify regulations and standards for CO2 transport	X
Integration	
Identify reliable sources of information and data related to the design, cost, and space requirements, operation, and integration of CCS with energy facilities	X
Conduct periodic technical reviews of all aspects of recognized large-scale CCS demonstration projects and report on the "lessons learned"	X
On a periodic basis, update the Technology Roadmap to include technology gaps identified during the technical assessment of demonstration projects	-
Integrate with existing infrastructure	-
Cross-Cutting Issues	
Energy price issues would encourage the take-up of CCS	

Pag. 33

CSLF-P-2011-09
Revised Draft: 25 November 2011
Prepared by CSLF Secretariat

POLICY GROUP

Revised Draft
Minutes of the CSLF Policy Group Meeting

Beijing, China
20-21 September 2011

Barbara N. McKee
Tel: 1 301 903 3820
Fax: 1 301 903 1591
CSLFSecretariat@hq.doe.gov

CSLF-P-2011-09
Revised Draft: 25 November 2011

CSLF IS GOING GREEN*

MINUTES OF THE CSLF POLICY GROUP MEETING
BEIJING, CHINA
20-21 SEPTEMBER 2011

Note by the Secretariat

Background

The Policy Group of the Carbon Sequestration Leadership Forum held a business meeting on 20-21 September 2011, in Beijing, China. Initial draft minutes of this meeting were compiled by the CSLF Secretariat and were circulated to the Policy Group delegates for comments. Comments received were incorporated into this revised draft. Presentations mentioned in these minutes are now online at the CSLF website.

Action Requested

Policy Group delegates are requested to approve these revised draft minutes.

* **Note:** This document is available only electronically. Please print it prior to the CSLF meeting if you need a hardcopy.

 Pag. 36

CSLF-P-2011-09
Revised Draft: 25 November 2011
Prepared by CSLF Secretariat

REVISED DRAFT

Minutes of the Policy Group Meeting

Beijing, China
Tuesday and Wednesday, 20 and 21 September 2011

LIST OF ATTENDEES

Policy Group Delegates

Chairman:	Charles McConnell (United States)
Australia:	Ann Boon, Margaret Sewell
Brazil:	Daniel Falcon Lins
Canada:	Marc D'Iorio, Milenka Mitrović
China:	Li Xin, Sizhen Peng
European Commission:	Wiktor Raldow
France:	Bernard Frois
Germany:	Hubert Höwener, Peer Hoth
Italy:	Liliana Panei
Japan:	Hirotada Bessho, Shigenori Hata
Korea:	Byong Ki Park, Wonchang Yang
Mexico:	José Miguel González Santaló
Netherlands:	Paul van Slobbe
Norway:	Tone Skogen, Kristoffer Stabrun
Poland:	Janusz Michalski
Saudi Arabia:	Abdulmuhsen Alsunaid, Abdullah AlSarhan
South Africa:	Muzi Mkhize, Faizel Mulla
United Arab Emirates:	Bader Al Lamki, Keristofer Seryani
United Kingdom:	Jeremy Martin, James Godber
United States:	James Wood

Technical Group Chairman

Trygve Riis

CSLF Secretariat

Barbara McKee, Jeffrey Price, Richard Lynch. Jeffrey Jarrett, Adam Wong, Kathryn Paulsgrove

Observer Participants

Brazil:	Marcelo Ketzer (Chairman of the CSLF Task Force on CCUS in the Academic Community)
United Kingdom:	Jeff Chapman (Co-chair of the CSLF Stakeholders Forum)
Clinton Foundation:	Tony Wood
Global CCS Institute:	Barry Jones
International Energy Agency:	Juho Lipponen
World Bank:	Natalia Kulichenko-Lotz

 Pag. 36

 Pag. 37

<u>Tuesday, 20 September</u>

1. Opening Remarks

Policy Group Chairman Charles McConnell welcomed participants. He thanked the participants for their commitment to the CSLF, the Chinese hosts for their hospitality, Barbara McKee and the Secretariat for the hard work organizing the conference, and the various task forces for their work that would be reported in the meeting. He said that CCS was at a turning point in the policies and practices that needed to be implemented and in the commercial scale projects that were about to be launched leading to commercial deployment. Chairman McConnell also introduced himself, providing background on the 34 years he spent in industry at Praxair and the Battelle Memorial Institute where he was developing a business related to the geologic storage of carbon dioxide (CO_2), particularly related to Enhanced Oil Recovery (EOR).

Chairman McConnell said that there was a need to embrace a new term – Carbon Capture Utilization and Storage (CCUS) – to address applications such as EOR that make productive use of CO_2 in order to provide a bridge into CCS. It is necessary to provide economic benefit and an incentive for industry to invest because CO_2 storage alone does not yet provide adequate incentive in the current global economic environment. It is also vitally important to reduce the cost of capture and to effectively communicate to the public about the need for CCUS. All this is necessary so that the coming decade of research, development and demonstration actually succeeds in enabling global deployment.

2. Introduction of Delegates

Chairman McConnell asked the Policy Group delegates seated at the table to very briefly introduce themselves, which they all did.

3. Adoption of Agenda

Barbara McKee, Director of the CSLF Secretariat, stated that the Agenda was prepared based on recommendations from the Policy Group and items that resulted from the last Policy Group Meeting and she asked that the Agenda be approved. The Agenda was approved without change.

4. Review and Approval of Minutes from Warsaw Meeting

The draft Minutes of the previous Policy Group meeting held in Warsaw, Poland in October 2010, had been circulated for comment to the Policy Group prior to the meeting. The final draft, which incorporated comments received, had been posted on the CSLF website. The Minutes were approved without further change.

5. Review of Warsaw Action Items

Barbara McKee, Director of the CSLF Secretariat, reviewed the status of the Action Items. She stated that most of the Action Items had been completed and that Bernard Frois, Chairman of the Task Force on Financing CCS, would inform us of the status of one of those Action Items, the study of trigger points for CCS investment.

Chairman Frois stated that the study was to address trigger points for mobilizing investment. Trigger points were understood as potential show stoppers for investment and the most significant of these is a lack of clear policy on CO_2. Other important issues

 Pag. 37

are regulatory frameworks, attractive returns for investors and performance based on commercial-scale systems. These conclusions are based on several workshops on financing, information sharing with financial experts with the Global CCS Institute and coordination with the World Bank.

Another Action Item that was outstanding was a communications roundtable. This would need to be implemented at a later meeting.

Policy Group Task Force Reports

6. Capacity Building Task Force Report

Task Force Chairman Abdulmuhsen Alsunaid of Saudi Arabia reported on the Capacity Building Task Force. He noted that an understanding was reached at the Warsaw meeting as to the responsibilities of the Capacity Building Task Force and the Capacity Building Governing Council and that work has been proceeding based on that understanding. A joint report by both the Task Force and the Governing Council is included in the notebook provided to delegates. In addition to the projects noted in that report, two additional projects, one for Mexico and one for China, were approved by the Task Force and recommended for funding to the Governing Council in the Task Force meeting in the morning prior to the Policy Group meeting. The Task Force is also requesting that developing country Members submit further requests for capacity building. In addition, some of the activities of the Task Force on CCS in the Academic Community may also have the potential to involve capacity building.

7. Report from the Capacity Building Governing Council

Capacity Building Governing Council Chairman Tone Skogen of Norway reported that CSLF donor countries have committed approximately US$3 million to the CSLF Capacity Building Fund, which is administered by the Secretariat. The governance of the Fund is performed by the Capacity Building Governing Council, which has developed a Terms of Reference for its operation.

To date, a total of 14 requests for assistance have been received from developing country CSLF Members, two of which were subsequently withdrawn. A total of eight capacity building projects in four countries have been approved to date and will be conducted by the CSLF. Four proposals are also in development and a couple of other projects are also in the pipeline, but have not yet been received. About US$1 million is still available for further projects. Projects approved so far include:

- Brazil – training program for CCS and monitoring in the offshore environment;
- China – CCUS website and information sharing workshops;
- Mexico – project to educate professors in CCS; and
- South Africa – workshops and conferences on CCS and a study on the impacts of CCS on national priorities.

Discussions are also underway for a project with India and another project with Brazil. Even though projects may be held in one country, they are open to CSLF participants from other Members.

Delegates made several comments on the capacity building activities. It was noted that the CSLF had been holding capacity building workshops for over five years and these provided the impetus for the current program, which is intended to be driven by the needs of the recipient country. The need to share information developed for CSLF capacity

Pag. 39

building activities among Members was also noted. Delegates from the countries receiving capacity building assistance also thanked the donor countries and the CSLF and stated that they believed the projects would benefit their countries. Asked what she would like to see changed, Tone Skogen stated that she would like to see more applications for capacity building projects.

The need for further funding to continue the Capacity Building Program was also discussed. The Secretariat and the Capacity Building Governing Council were directed to work to raise further money for the CSLF Capacity Building Fund. In response, Barbara McKee asked that Policy Group delegates provide the names and contacts of organizations that could potentially donate to the CSLF Capacity Building Fund.

8. Communications and Public Outreach Task Force Report

Task Force Chairman John Grasser of the United States stated that the Task Force was following a strategic plan and that the goal of the strategic plan was to address the barriers to public awareness and acceptance of CCS technology. The principal objectives of the strategic plan were to raise visibility of the CSLF, engage key audiences, meet CSLF Strategic Plan requirements and achieve the objectives at low or no cost. He noted that this Task Force had been very active over the past year. The Task Force had developed DVDs and a communications kit and talking points on CCS for use by CSLF Members. This includes a standard speech and a Power Point presentation. The Task Force provides news clips to CSLF Members and stakeholders on a daily basis and has developed an event recognition agreement that conference and meeting sponsors can use to request CSLF co-sponsorship. The CSLF is now starting to use social media, including Twitter and Facebook. All of this is done by the United States Department of Energy with no budget from the CSLF.

Chairman McConnell asked delegates how often they or their colleagues used the information produced by the Task Force. Several delegates indicated that they used informational materials produced by the Task Force and found it useful. This initiated a more general discussion on communications about CCS. It was pointed out that opponents of CCS are often well-funded and, in some places, the public fears geologic storage. The marketplace for messaging about CCS, however, is not homogeneous and there are different audiences with varied interests and opinions and this varies by country. One opportunity for communications is seen as science journalists. The performance of planned large-scale demonstrations may also influence public attitudes. The fact that CCS is being developed and demonstrated globally (and not just in a single country) is seen as a positive message. An issue that also needs to be addressed is that people ask how they specifically benefit when a CCS project is to be located in their local communities. The difficulties that engineers and other technical people have communicating with the public in terms the public understands were also discussed.

Barbara McKee noted that the IEA and the Global CCS Institute also have communications activities and suggested closer coordination in this area.

9. Financing CCS Task Force Report

Task Force Chairman Bernard Frois of France reported on the work of the Financing CCS Task Force. This Task Force was created two years ago and focuses its work on CCS at commercial scale in both developing and developed countries. The Task Force has held four successful roundtables on financing CCS. These involved people with considerable relevant expertise from law firms, insurance companies and banks, as well as industry.

Pag. 39

 Pag. 40

The Task Force has had a number of findings. One finding was that people in different types of organizations involved in CCS do not talk to each other and that was one achievement of the roundtables. A key finding was also the differences among projects and that no one financing method or incentive would work for all. Problems and solutions differ. Moreover, money was not the only issue; regulatory frameworks are absolutely essential. Clear policies are needed. CCS is predicted to be cost-competitive with other sources of low-carbon power such as on or offshore wind, solar power and nuclear in the EU in the early 2020s. However, costs are considerable, but rewards are not clear and all risks must be addressed. In the roundtables, funding models in different parts of the world were presented, in particular by the Asian Development Bank, the World Bank, Alberta, Japan, and several private companies. Each example shows the value of adapting tools to regional and project features. Rather than waiting for the perfect first step on CCS, it is critically important to launch CCS demonstration projects and build confidence in the technology and improve the understanding of its value.

After the presentation and at the request of Chairman McConnell, James Wood of the United States Department of Energy described the CCUS projects in his portfolio in terms of how those became financeable. Mr. Wood said that eight projects have moved forward over the last year from an early stage of analysis to construction, FEED studies or detailed estimates. Two of these projects were polygeneration involving the creation of value through the sale of electricity, urea fertilizer and CO_2 for EOR. Other projects included industrial projects with high-concentration CO_2 emissions and off-take agreements for CO_2 for EOR or methanol. While EOR was used for several of the projects; however, it was not seen as a total solution and will not be used in the FutureGen project. It is now also estimated that 85 billion barrels of unrecovered oil could be recovered through CO_2 used for EOR in the United States. That may also be an opportunity in China. In response, several delegates pointed out that not every country has an opportunity for EOR using CO_2.

10. Report from the Task Force on CCUS in the Academic Community

Task Force Co-Chairman Marcelo Ketzer of Brazil reported on the Task Force’s activities. The objective of the Task Force’s activities was to identify courses in the area of CCS and Climate Change inside the academic programs currently available in universities worldwide. Courses were mapped in the Americas; Europe; Africa (South Africa); Asia (Japan, Korea); and Oceania (Australia, New Zealand). A new annex on China is to be added to the report. Differences were found in number and types of courses offered in each country. These courses were identified through an internet search of university websites. For each university, all the offered courses were summarized on tables in accordance with four themes: (i) Capture; (ii) Storage; (iii) Environment; and (iv) Economy, Social, Political and Legal aspects. The methodology has an important limitation. This work was done searching the web, using tools such as Google. This is not necessarily complete or accurate. Delegates were asked to take this document to their own countries and contacts in order to validate and improve this document. Maintaining this document will be an ongoing effort because there will always be new courses and others will no longer be offered.

After the presentation, the discussion centered on how CCUS-related courses were identified, differences among courses offered in different countries, and how the information gathered could be used.

 Pag. 40

Pag. 41

11. Report and Approval of Proposed Projects

Trigve Riis, Chairman of the Technical Group, described six projects that were being recommended by the Technical Group for recognition by the CSLF. These projects were:

Project	Type	Nominators
Jänschwalde	Oxycombustion Pilot (30 megawatts) with no storage	Germany, European Commission
Zero Emissions Porto Tolle (ZEPT)	Post-combustion (660 megawatts) with saline formation storage	Italy, European Commission
CGS Europe	Collaborative project involving knowledge transfer and information exchange to facilitate large-scale CCS deployment in EU member states and associated countries	France, Italy
SaskPower Integrated CCS Demonstration at Boundary Dam Unit 3	Integrated project (110 megawatts) with post-combustion capture and utilization of CO_2 for EOR	Canada, United States
Rotterdam Opslag en Afvang Demonstratieproject (ROAD)	Integrated CCS chain project (250 megawatts) with post-combustion capture. CO_2 pipelined 25 km to saline aquifer storage site beneath North Sea seabed	Netherlands, European Commission
CO_2 Capture Project – Phase 3	Partnership of seven major energy companies working to advance the technologies that will underpin the deployment of industrial-scale CO_2 Capture and Storage (CCS)	United Kingdom, United States

The Policy Group approved these projects for recognition by the CSLF.

The Meeting was adjourned for the day.

Pag. 41

Wednesday, 21 September

Chairman McConnell opened the meeting and called on the Secretariat to summarize the Policy Group meeting on the previous day.

12. Summary of Previous Day's Session

Secretariat Director Barbara McKee gave a brief summary of the discussion held on the previous day covering the four Task Force reports and the recognition of projects.

In discussing the report of the Task Force on CCUS in the Academic Community, which had extensively identified courses on CCUS, Ms. McKee stated that identification of the professors who teach the courses could have even more value than identifying the courses. The Task Force should consider how a network of these professors could be assembled, perhaps using the internet. The goal would be to enable them to communicate with each other in order to exchange ideas, improve courses, and spread the teaching of CCUS. This could provide valuable support to CCUS and to the CSLF. Since this is capacity building on a global scale, it should be coordinated with the Capacity Building Task Force. There was consensus that this would be an action item for the Task Force on CCUS in the Academic Community.

Updates from Collaborating International Organizations

13. IEA CCS Activities Update

Juho Lipponen of the IEA Secretariat, the Head of the IEA's CCS Unit, described its activities. He said that while energy demand and CO_2 emissions continue to grow rapidly, the role of CCS is currently very limited, but critical in order to address climate change. The IEA has developed a work programme with activities in several different areas, including CCS strategy and policy, legal and regulatory, technical and economic, capacity building, outreach and stakeholder relations. He also described several new reports from the IEA, including reports on the Industrial CCS roadmap, incentives for CCS, the IEA Model CCS Regulatory Framework, the cost of CCS in power generation, and early commercial plants. He also described the roundtable meetings and workshops that comprise IEA's outreach activities. A number of planned new reports will also cover CCS, including the World Energy Outlook 2011.

14. Global CCS Institute Work Plans

Barry Jones of the Global CCS Institute gave an update on the work of the Institute. He discussed the work done in four areas:

The Status of CCS. The Institute continues to publish its Global Status of CCS reports. The 2010 edition was published in March and the 2011 edition will be released in October. This is intended as a comprehensive overview of the state of development of large-scale projects around the world and of the technologies that make up the CCS chain, as well as the status of policy, legal and regulatory developments to support CCS. The Global CCS Institute also produces reports which give an overview of the status of CCS in various different technology areas or industry areas. In addition, the Institute works on costs. The Institute maintains a comprehensive database of large-scale integrated projects, which is frequently updated.

Capacity and Policy Development. The Institutes contributes to the CSLF Capacity Building Fund as well as trust funds of the Asian Development Bank and the World

Bank. It also undertakes capacity development initiatives itself focusing on China, India, Malaysia, Indonesia, South Africa, and Mexico. The Institute also conducts baseline studies needed before capacity development projects can be undertaken. The Institute is also active in the regulatory area to complement work done by the IEA. It has produced a Regulatory Test Toolkit, which provides a process for national or provincial government administrations to undertake. The Institute is also actively engaged in the lead up to COP 17 in Durban and has recently gained accreditation as an observer under the UNFCCC process.

Project Support. The Institute supports selected projects in order to share knowledge about project development with the global CCS community, and publishes on its website very detailed reports on aspects of project development. The Institute also shares that information through webinars, workshops and seminars which are conducted in countries around the world, bringing project developers together with interested governments and companies. The Institute has also published a number of aids to public acceptance and public engagement.

Knowledge Sharing. The Institute has a comprehensive knowledge-sharing platform, which comprises a public website with a wealth of information about CCS and other knowledge-sharing methods. The Institute also has specialized communities that have much more specialized needs, for example, a Japanese knowledge-sharing network for very targeted and private discussions among the Japanese membership.

15. World Bank CCS Activities Update

Natalia Kulichenko-Lotz, Senior Energy Specialist of the World Bank's Energy, Transport and Water Department, described the Bank's CCS work program. The World Bank has a trust fund for CCS, established in December 2009, with total contributions of US$11 million with donations from Norway and the Global CCS Institute. The primary objective is to support capacity- and knowledge-building for developing countries and to facilitate inclusion of CCS in their low-carbon strategies. The work has two components: (1) a country-level component focusing on country- and project-specific activities, and (2) an analytic component. Projects are being undertaken in nine different countries. The analytic component consists of a report on barriers to deployment of CCS in developing countries, studies of specific countries and regions and the development of a financing model for CCS projects. The largest World Bank CCS program is in China and considerable work has been done in China with the China Power Investment Corporation.

16. CCUS Action Group Update

Ann Boone of Australia and James Godber of the United Kingdom gave an update on the activities of the CCUS Action Group. The Action Group consists of governments, businesses, non-governmental organizations and institutes and is led by the governments of Australia and the United Kingdom. The Action Group has made a number of recommendations to advance CCS:

1. Reduce the financial gap;
2. Funding support in developing economies;
3. Develop legal and regulatory frameworks;
4. Acknowledge importance of marine treaty amendments;
5. Share knowledge;
6. Investigate carbon dioxide (CO_2) storage;

Pag. 44

7. Support CCS in industry; and
8. Report on progress.

To date, twelve governments have committed to taking action on these recommendations. The CSLF, Global CCS Institute and IEA are working together to develop a work plan for implementation. The next steps are: CEM 3 Meeting in London in 2012, a report on progress of recommended actions, recommendations from working group on funding support in developing countries and announcements from individual countries.

CSLF Planning

17. Revised CSLF Strategic Plan

Barbara McKee gave a presentation on the draft Second Update of the CSLF Strategic Plan. Ms. McKee said the plan is being updated because the CSLF Charter term is being extended beyond 2013, CO_2 utilization is being added to the scope of the CSLF activities and there is an increased focus on commercial deployment. The draft plan is being presented now to the Policy Group for approval. In this plan, the CSLF organization is unchanged and the Secretariat continues to provide administrative support and requested activities. Various action plans were developed for the Policy Group, the Technical Group and the Secretariat to address key policy and technical barriers. Specific responsibilities are to be assigned for each Action Plan.

The Second Update of the Strategic Plan was accepted by the Policy Group with one edit requested by China to more accurately refer to the second commitment period of the Kyoto Protocol.

18. Planning for the CSLF Ministerial Roundtable

Barbara McKee briefly described the planning process for the Ministerial and thanked those involved in the planning, including the Ministerial Steering Committee; Chairman McConnell; the Li Xin, the Chairman of the Chinese National Organizing Committee; the Chinese hosts; and the organizations that prepared papers for the Ministers (the Asian Development Bank, the Global CCS Institute, the Clinton Foundation and the Secretariat staff). She then invited the authors of the papers not from the Secretariat who were present to give brief overviews of their papers. Barry Jones of the Global CCS Institute gave a brief overview of the paper “Status, Gaps and Measures to Close Gaps” prepared by the Institute. Tony Wood of the Clinton Global Initiative gave an overview of the paper “Driving CCUS RD&D Deployment: What Will It Take” prepared by the Clinton Foundation.

Li Xin of China expressed appreciation to the Secretariat and the Ministerial Steering Committee for their work, as well as to those who prepared the papers for the Ministers. He also noted that there were nearly 500 registered participants.

Jeff Chapman of the United Kingdom CCS Association and Co-Chair of the CSLF Stakeholders Forum gave a brief overview of the planned program for the Forum. He also noted that the stakeholders were working on a preliminary definition of CCUS.

Pag. 44

 Pag. 45

19. Draft Ministerial Communiqué

Chairman McConnell noted that issues remained to be resolved on the Ministerial Communiqué. The Policy Group went through most of the Communiqué on a line-by-line basis. After discussion, these issues were resolved and a number of final edits were made by the Policy Group and the attached Communiqué was approved.

20. New Business

There was no other new business.

21. Closing Remarks/Adjourn

Chairman McConnell adjourned the meeting and stated that the Stakeholders Forum would be in the afternoon.

ACTION ITEMS ARISING FROM THE POLICY GROUP MEETING

Item	Lead	Action
1	Capacity Building Governing Council and Secretariat	Raise further money for the CSLF Capacity Building Fund.
2	Policy Group delegates	Provide the names and contacts of organizations that could potentially donate to the CSLF Capacity Building Fund.
3	Communication and Public Outreach Task Force	Coordinate with the IEA and Global CCS Institute.
4	Policy Group Delegates	Take the report from Task Force on CCUS in the Academic Community to home countries for validation and improvement.
5	Task Force on CCUS in the Academic Community	Consider how a network of professors could be assembled and coordinate with the Capacity Building Task Force
6	Secretariat	Make edits to the CSLF Strategic Plan suggested by China.

 Pag. 45

CARBON SEQUESTRATION LEADERSHIP FORUM

Meeting of the
Carbon Sequestration Leadership Forum (CSLF) Ministers

Collaborating for a Decade of Research, Demonstration and Deployment on Carbon Capture Utilization and Storage

Communiqué
22 September 2011 at 1730

We, the Ministers and Heads of Delegation of the CSLF Members, are convinced that we must advance towards the demonstration and deployment of Carbon Capture Utilization and Storage (CCUS) as early as possible. CCUS is one of the low carbon technology options critical to the global quest to reduce carbon dioxide emissions to the atmosphere. We are committed to taking necessary actions individually and collaboratively to make that happen.

CCUS is a necessary technology essential to enabling us to achieve our climate goals and which has been proven safe and effective in all current demonstration projects and applications around the world. We must urgently increase the number of large CCUS demonstrations to enable the deployment of CCUS commercially by the end of this decade.

We met today to discuss and address the key challenges facing CCUS and identify activities necessary to support further research, development, demonstration and deployment. While it is clear that significant progress is being made on CCUS, challenges remain, but these are challenges that can—and will—be overcome.

Including Carbon Capture and Storage in International Agreements

Ministers applaud the decision at Cancun to recognize Carbon Capture and Storage (CCS) as a measure in the Clean Development Mechanism (CDM). We call upon delegates to the 17th United Nations Framework Convention on Climate Change (COP 17/CMP 7), to be held in Durban, South Africa, to recognize the key role of CCS as a low carbon technology in mitigating climate change and to expedite the inclusion of CCS as a measure in the CDM and in other appropriate financial mechanisms created to mitigate greenhouse gas emissions.

Building and Financing Commercial-Scale CCUS Projects

We are fully committed to the CSLF strategy to build and operate multiple successful commercial-scale CCUS project demonstrations by 2020. Many such projects are currently under development. Demonstration projects will initially require a mix of public and private financing. The long term deployment of CCUS projects will require the development of conducive policies in order to underpin the necessary financial investment. We are committed to developing these policies. Recognizing the international economic turmoil and the significant need for financial incentives to realize CCUS, financing will remain a key challenge in developed and particularly in developing countries. Increased international concerted action is needed to overcome this challenge. We today reaffirmed our commitment to work with the private sector to build and finance the needed demonstration projects over the next decade.

Building on the Success of the CSLF

Recognizing the continuing need to address challenges, Ministers agreed to extend the term of the CSLF for an indefinite period beyond its prior expiration date of 2013. While much progress has been achieved since the CSLF was founded in 2003, more remains to be done to enable deployment of this vital suite of low carbon technologies.

Ministers recognize the success of the CSLF in providing governments with an international forum to collaborate and create shared commitments to CCUS research, development, demonstration and deployment. This includes ongoing CSLF initiatives to:

- Share information internationally on important CCUS projects;
- Build the capacity for CCUS in the developing country CSLF Members;
- Explore methods for financing CCUS projects, particularly in developing countries; and
- Develop global roadmaps for research, development and demonstration of CCUS technologies.

We are particularly pleased that a total of 30 active and completed, now expanded to 36, diverse CCS projects throughout the world have now been recognized by the CSLF and are sharing their results globally through the CSLF.

Expanding Collaboration through the CSLF

Ministers agree to extend and amend the CSLF Charter to include facilitation and deployment of technologies for utilization of captured carbon dioxide (CCUS).

Importance of Stakeholders and Growing International Collaboration

We are acutely aware that stakeholders in industry, society and the academic community are critically important to the development and commercial deployment of CCUS. While the CSLF is a means of international collaboration by governments, collaboration at the international level between governments and industry is also vitally important. We applaud the efforts of stakeholders to advance CCUS and to be involved in CSLF activities. We strongly encourage their continued involvement in CSLF.

We also welcome additional international collaborations on CCUS through the International Energy Agency, Global Carbon Capture and Storage Institute, the Clean Energy Ministerial (CEM) and multilateral financial institutions. We believe that the increasing number of such collaborations reflects the growing global recognition of the criticality of CCUS and we see these additional collaborations as complementary to the work of the CSLF. We also strongly encourage coordination among these international collaborations. Further, we acknowledge the CCUS recommendations of the second CEM meeting and we look forward to the implementation of those recommendations.

Overcoming the Challenges

We support strategies for the CSLF to resolve barriers for successful implementation of CCUS projects at a time of significant global economic challenge.

- We will work with the private sector to develop and implement methods to finance projects, including those in developing countries.
- We will work to develop legal and regulatory mechanisms to assure safety and appropriately allocate liabilities between the public and private sectors appropriate to our national circumstances.
- We will strengthen cooperation on both technology and policy in order to reduce the financial costs, to lower the energy penalty and to allay public concerns associated with the deployment of CCUS technologies.
- We commend the CSLF's capacity building initiative, and are pleased to announce funding for 12 projects today.
- We task the CSLF to undertake CCUS development initiatives in sectors such as power generation, industry and enhanced oil and gas recovery.

Carbon Sequestration Leadership Forum

CSLF-T-2011-08

www.cslforum.org

Minutes of the Technical Group Meeting
Beijing, China
Tuesday & Wednesday, 20-21 September 2011

LIST OF ATTENDEES
Technical Group Delegates

Australia:	Niki Jackson
Brazil:	Beatriz Espinosa, Viviana Coelho
Canada:	Stefan Bachu, Eddy Chui
China:	Sizhen Peng, Jiutian Zhang
European Commission:	Jeroen Schuppers
France:	Didier Bonijoly
Germany:	Jürgen-Friedrich Hake
Italy:	Giuseppe Girardi, Sergio Persoglia
Japan:	Ryo Kubo, Shingo Kazama
Korea:	Chang-Keun Yi
Netherlands:	Harry Schreurs
Norway:	Trygve Riis (Chair), Jostein Karlsen
Poland:	Janusz Michalski
Saudi Arabia:	Khalid Abuleif, Ali Al-Meshari
South Africa:	Tony Surridge (Vice Chair)
United Kingdom:	Philip Sharman
United States:	Joseph Giove, George Guthrie

CSLF Secretariat
John Panek, Adam Wong, Matt Gerbert

Observer Participants
Gary Kirby, Principal Geologist, British Geological Survey, United Kingdom
Li Zheng, Professor, Tsinghua University, China
Mike Miyagawa, Projects Advisor, Global CCS Institute
Tim Dixon, Manager for CCS and Regulatory Affairs, IEA Greenhouse Gas R&D Programme

Tuesday, 20 September

1. Technical Group Chairman's Opening Statement

The Chairman of the Technical Group, Trygve Riis of Norway, called the meeting to order and welcomed the delegates and observers to Beijing. Mr. Riis introduced Vice Chair Tony Surridge of South Africa and noted that Vice Chair Clinton Foster of Australia was unable to attend. He expressed his appreciation to the Ministry of Science and Technology, and the National Development and Reform Commission of the People's Public of China for hosting this meeting. Mr. Riis provided context for the meeting with

 Pag. 49

a brief summary of the previous CSLF Technical Group Meeting in May 2011 in Edmonton, Alberta, Canada. Four new projects have been nominated and will be reviewed for CSLF recognition. Two other projects were already nominated and reviewed for CSLF recognition at the meeting in Edmonton, and will be brought to the Policy Group later today. Mr. Riis will go to the Policy Group to present all six projects for CSLF recognition. Another topic that will be discussed today is the Technical Group's Five-Year Action Plan, in which 12 proposed Action Plan Components will be ranked by priority for the future.

2. Introduction of Delegates and Observers

Technical Group delegates and observers present for the session introduced themselves. 17 of the 25 CSLF members were present at this meeting, including representatives from Australia, Brazil, Canada, China, the European Commission, France, Germany, Italy, Japan, Korea, the Netherlands, Norway, Poland, Saudi Arabia, South Africa, the United Kingdom, and the United States. Observers representing Brazil, Canada, China, Hong Kong, Japan, the Netherlands, the United Kingdom, and the United States were also present, along with representatives from the Global CCS Institute, IEA GHG, and UNIDO.

3. Adoption of Agenda

The Agenda was adopted with one minor addition. Item 16 on the agenda was amended to include two presentations: one by the Global CCS Institute and one by the IEA GHG.

4. Review and Approval of Minutes from Edmonton Meeting

The Technical Group minutes from the May 2011 meeting in Edmonton, Alberta, Canada, were approved as final with no changes.

5. Review of Edmonton Meeting Action Items

John Panek of the CSLF Secretariat reported that all action items from the Edmonton meeting had been completed or were in progress.

6. Report from CSLF Secretariat

Mr. Panek gave a presentation that provided an update on CSLF Secretariat activities. The 2011 CSLF Technology Roadmap has been developed and was distributed during registration for this meeting. The document can also be found on the CSLF website. Another document is the September 2011 CSLF Strategic Plan Implementation Report (SPIR), found in the conference book. The document includes updates and reports from CSLF recognized projects, task forces, and a variety of other activities.

Based on recommendations from the Technical Group at the Edmonton meeting in May 2011, the In Salah CO_2 Storage Project, Algeria; the Sleipner CO_2 Project, North Sea; and the Weyburn-Midale CO_2 Project, Canada; will each receive a CSLF Global Achievement Award during the 2011 CSLF Ministerial Meeting Opening Ceremony. The CSLF has also received project submission forms from four projects for CSLF recognition. This is in addition to the two projects that were received prior to the Edmonton meeting and approved by the Technical Group at that meeting. That brings the total number of projects up for CSLF recognition to six.

 Pag. 49

Attendees were also encouraged to go to the CSLF website to sign up for daily updates from the CSLF on carbon capture, utilization and storage (CCUS) activities. Mr. Panek then noted that in the September 2011 CSLF Strategic Plan Implementation Report (SPIR), there are several photographs from the recent CSLF Storage and Monitoring Projects Interactive Workshop help in March 2011 in Saudi Arabia. Ten CSLF recognized projects participated, and their presentations can also be found on the CSLF website. Mr. Panek thanked Saudi Arabia for hosting such a wonderful event.

7. **Approval of Projects Nominated for CSLF Recognition**

Rotterdam Opslag en Afvang Demonstratieproject (ROAD) Project
Harry Schreurs of the Netherlands gave a presentation about the Rotterdam Opslag en Afvang Demonstratieproject (ROAD), nominated by the Netherlands and the European Commission. The goal of ROAD is to demonstrate that an industrial-scale, integrated carbon capture and storage (CCS) chain (i.e., capture on a coal-fired power plant and offshore storage) can be applied in a reliable and efficient way within a 10-year timeframe (by 2020) and can make a substantial contribution to climate change objectives. The project will share knowledge and experiences with other industries, countries, general public, NGOs and other stakeholders. ROAD is one of the six large-scale CCS demonstration projects within the European Energy Programme for Recovery (EEPR). Captured CO_2 will be transported via pipeline and injected into depleted gas reservoirs under the North Sea. After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for this project.

CGS Europe Project
Gary Kirby, Principal Geologist, British Geological Survey, United Kingdom, gave a presentation about the CO_2 Geological Storage (CGS) Europe Project, nominated by France, Italy, Norway, and the European Commission. CGS Europe is a collaborative project involving extensive structured networking, knowledge transfer and information exchange, and is designed to facilitate the large-scale demonstration and deployment of CCUS, and to support implementation of the Directive on geological storage of carbon dioxide in all relevant EU Member States and associated countries. Building on the sound basis of the CO_2 GeoNet Association, the CGS Europe Project will create a pan-European network of experts in the geological storage of CO_2 and a centralized knowledge base which will provide an independent source of information, research and advice for national, European, and international stakeholders. It will enable access to the most up-to-date results of CO_2 storage studies, the sharing of experiences and best practices, support of implementation of regulations, the formulation of relevant new research and the development of appropriate new projects. After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for this project.

SaskPower Integrated CCS Demonstration Project at Boundary Dam Unit 3 Project
Stefan Bachu of Canada gave a presentation about the SaskPower Integrated CCS Demonstration Project at Boundary Dam Unit 3 Project, nominated by the Canada and the United States. The goal of this project is commercial co-production of electricity and CO_2 for sale using indigenous coal resources. The Boundary Dam ICCS Demonstration Project is expected to be the first application of full stream flue gas treatment for a pulverized coal unit. Operations of the highly integrated system will demonstrate not only CO_2 capture technology, but its interaction and optimal thermodynamic integration with the heat power cycle and with power production at full commercial scale. The

captured CO_2 will be used for Enhanced Oil Recovery. After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for this project.

CO_2 Capture Project – Phase 3
Philip Sharman of the United Kingdom gave a presentation about the CO_2 Capture Project – Phase 3, nominated by the United Kingdom and the United States. The CO_2 Capture Project (CCP) is a partnership of several major energy companies working together to advance the technologies and to improve operational approaches in order to reduce costs and accelerate the deployment of CCUS. The CCP is currently in its third phase of activity – CCP3 (2009-2013). During the course of CCP3, the program will culminate in at least two field demonstrations of capture technologies and a series of monitoring field trials which will provide a clearer understanding of how to better monitor CO_2 in the subsurface. After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for this project.

8. **Report from Projects Interaction and Review Team (PIRT)**

The Acting PIRT Chair, Stefan Bachu, gave a presentation that summarized the PIRT's recent accomplishments. At the Edmonton meeting, the PIRT reached an agreement that the Task Force on Assessing Progress on Technical Issues Affecting CCS should be separated from the PIRT, and report directly to the Technical Group. Also at the Edmonton meeting, the PIRT approved two projects for CSLF recognition: the Jänschwalde Project and the Zero Emission Porto Tolle (ZEPT) Project. The PIRT also discussed the need to simplify the CSLF Project Submission Form and Gaps Analysis Checklist.

At the previous day's PIRT meeting, the four projects that were just approved by the Technical Group were initially reviewed and approved by the PIRT. After approval by the Technical Group, the projects then go for review by the Policy Group. A discussion regarding the level of detail on the CSLF Project Submission Form also occurred. While some argued that the forum should be simpler, there were other arguments to keep it as detailed as possible, particularly if there is a need to uncover what the projects will do and what gaps in knowledge will be address. There was no resolution to the issue, and thus it will be brought up again during the next PIRT meeting.

Dr. Bachu stated that there are now four categories of CSLF recognized projects:

1. Completed Projects
2. Active Projects
3. Inactive Projects
4. Projects that were Withdrawn by Sponsor

Dr. Bachu also briefly mentioned the PIRT's discussion on the Technical Group's Five-Year Action Plan. A decision was made at the PIRT meeting to divide the 12 proposed activities into two categories. One category would be for items taken up by other organizations. The other category would be for items identified by only the CSLF. The PIRT would like to establish a priority list for urgency and importance of these activities within two months. Afterwards, volunteer delegates would be needed within a month after to jumpstart these activities in preparation for the next Technical Group meeting in the first part of 2012.

The PIRT also made recommendations for the 2011 CSLF Technology Roadmap. The PIRT recommends updating the Technology Roadmap every three years. The main content should include an introduction over the current status of CO_2 capture and storage technologies. The module on ongoing activities should be removed and become a web-based document that can be updated annually by delegates and member countries by request of the CSLF Secretariat.

The PIRT was pleased with the recent CSLF Technology Workshop held in Saudi Arabia. Regarding future technology workshops, the PIRT recommends that workshops should be held opportunistically in conjunction with other events, preferably, CSLF meetings. For example, if the next CSLF Technical Group meeting is going to be in Bergen with a visit to the Mongstad Test Center, then that is an opportunity to have a workshop on CO_2 capture.

At the conclusion of the presentation, Mr. Riis opened the floor for questions or comments. Philip Sharman added his thoughts on the CSLF Project Submission Forum. Mr. Sharman stated that while a more simplified list may help at the project approval stage, a longer and more in-depth list is needed at the project evaluation stage and would be useful to refer to. He believed that a full list is more useful to have at the beginning, and that it is more useful to have the project proponent's view of what their project is aiming to assess, even if the CSLF must simplify the list during the approval process.

Chairman Riis announced that during a recent Technical Group Executive Committee teleconference, it was decided that the next CSLF workshop would be organized, in co-sponsorship with the Global CCS Institute, on November 3, 2011 in London, United Kingdom. This workshop is being organized in conjunction with an IEA GHG Executive Committee meeting. Invitations to participate in the workshop will be sent out to relevant large-scale CCS projects which involve integration, as this will be the topic of discussion.

Mr. Panek added that a list of CSLF recognized projects with a strong integration component had been sent to the Global CCS Institute and that invitations would be sent out within the next two weeks. In anticipation of the projects receiving recognition at this meeting, those projects proposed for recognition were included on the list.

Chairman Riis mentioned that the goal is to have about one workshop each year. At the next Technical Group meeting in Bergen, Norway in June 2012, the plan is to have a CSLF workshop on capture in conjunction with the meeting. The third topic to eventually have a workshop on is CO_2 transportation.

Vice Chair Tony Surridge noted that South Africa plans to have a workshop on transportation towards the end of 2012, in October or November. He suggested that it would be another opportunity to hold a CSLF workshop on CO_2 transportation in conjunction with this meeting.

9. Report from Risk Assessment Task Force

The Task Force Chair, George Guthrie of the United States, gave a brief update on the Risk Assessment Task Force (RATF). The RATF meeting earlier in the day discussed three main topics. The first was on interactions with the IEA GHG risk assessment network. The RATF also reviewed the status of their Phase 2 activities, and then discussed the Joint Policy Group and Technical Group Task Force on Risk and Liability.

Dr. Guthrie provided a background to the RATF. The Task Force was initiated in 2006 to examine the risk assessments, standards, procedures, and research activities. A Phase 1 report was completed in 2009 and is available on the CSLF website. Phase 2 activities were initiated in the fall of 2010. With Phase 1, there were several recommendations that the RATF took action on, and some of these led to Phase 2 activities. Dr. Guthrie then reviewed the status of the recommendations. The first recommendation was the notion that risk assessment should be considered in the context of outreach with stakeholders. This recommendation was passed to the Policy Group. The RATF also approved five outreach documents from the Policy Group, which were then approved by the Technical Group at the Pau, France meeting in March 2010. Those documents are available at the CSLF website. During the RATF meeting, a discussion focused on a need for additional outreach activities or outreach documents. The second recommendation out of Phase 1 was that the link between risk and liability should be recognized and considered because of the liability tie on this. RATF felt that this was a Policy Group activity, and thus recommended it to the Policy Group. This led to the formation of the new joint Policy and Technical Group Task Force on Risk and Liability. The RATF is also on the action plan number five of the list of 12 actions from the PIRT. The final recommendation out of Phase 1 was the notion of storage integrity goals, and whether or not there was any possible path forward on developing acceptable risk levels for sites. A paper was developed, which Dr. Guthrie promised to discuss later.

With Phase 2, there were three main tasks. The first task was on the gap assessment relative to CCS tools. Various approaches were used. One of those was leveraging the IEA GHG risk assessment network activities. This has been a good link for the CSLF, as the RATF has received good information back from the workshops, and has had the opportunity to talk at their workshops about the CSLF and its interest in risk assessment. Two short overviews were developed in response to the gap assessment. One of them looked at gaps that were specific to risk assessment in the context of enhanced oil recovery. The second one is a short overview on risk issues related to various phases of CCS projects. The first one will be completed by the end of this year for review by the RATF and will be a room document at the Bergen, Norway meeting in June 2012. The second one on CCS project phases is to prepare for the liability piece coming from the Policy Group in recognition that there could be different phases of liability for a project. The RATF wanted to identify the different risk issues that feed into that liability. The second task for Phase 2 is a feasibility assessment of looking at general technical guidelines for risk assessment that could be applied to specific sites. A document on performance based standards for CO_2 site performance, safety, and integrity was prepared by colleagues in France. This document has had an extensive number of reviews, and comments, and is now ready to also be included in the Phase 2 report. The final task in Phase 2 was to gather further information on what various organizations are doing in the area of technical risk. The RATF decided that this issue should be set aside right now, as this issue would go beyond the scope of what the RATF had for Phase 2, and it was not clear what contribution the CSLF could make to this. This is being considered as a possible activity for Phase 3. However, it has not been resolved whether or not there is a need or for a Phase 3 for the RATF, as this should not be forced as a way of continuing the Task Force.

Dr. Guthrie then showed the status and timelines for Phase 2 documents. The final report should be ready by the spring of 2012. A similar time path is being used for the overview of projects and phases. The paper on performance based standards will be sent out at the same time. The RATF also discussed a proposed path forward for the Joint Policy Group and Technical Group Task Force on Risk and Liability. The proposal was submitted to the Secretariat. Dr. Guthrie showed the five proposed steps that are in the proposal, which will be recommended during the Joint Policy and Technical Group Meeting later in the week. The proposal includes five activities. The first one to establish the Joint Task Force has been completed. The group would have an individual that would then be carrying out a lot of the work for the Task Force. This includes a background activity of looking at analysis and critical review of prior work on liability, and comparison of liability frameworks that have been established to date. That would then lead into a more detailed interview of key experts from various disciplines to try to get a better understanding of perspectives on risks, damages, and liabilities. The results of the interviews would then need to be assessed. These would all be used to feed into a set of facilitated workshops that would bring experts together to identify gaps, and methods to address those gaps. The three activities would be combined to propose a path forward for a Phase 2 version of this Joint Task Force, the goal being to have a report in a Phase 2 path forward proposed at the Joint Policy and Technical Group Meeting in 2012.

Didier Bonijoly of France suggested releasing the document from France on performance based standards for CO_2 site performance, safety, and integrity earlier, as it would become less relevant later. After a brief discussion, it was decided that the report will go out immediately to all Technical Group members with a 14-day cycle and, if hearing no objections, will be considered adopted by the Technical Group.

10. Report from Task Force to Assess Progress on Technical Issues Affecting CCS

Stefan Bachu, as Acting Chair of the Task Force to Assess Progress on Technical Issues Affecting CCS, gave a presentation that summarized the Task Force's recent meeting. The main topic discussed was the working groups on covering gaps in knowledge. There was agreement by the Task Force that it will no longer cover scientific gaps, but instead, focus on technical and deployment issues.

The Leader of the Working Group on CO_2 Transportation (Harry Schreurs of the Netherlands) reported that he has contacted the three CSLF-recognized projects that have transportation components and the replies indicated that the projects have information on:

- Selection of the transportation corridor;
- Obtaining rights of way; and
- Handling public concerns.

Mr. Schreurs also suggested that CO_2 Transportation should be the subject of a future CSLF Technical Workshop.

Discussion ensued about CO_2 compression should be considered part of the capture process or part of transportation. It was agreed that CO_2 compression is actually part of both since it occurs first at the capture facility ("behind the plant gate") but it may occur also along the transportation pipeline (booster stations) and in some cases it may occur at the storage site before injection.

Dr. Bachu, as Leader of the Working Group on CO_2 Storage and Monitoring, gave a progress report on the Working Group's activities. A questionnaire has been sent to all 25 CSLF-recognized projects that have a storage component and responses have been received from 17 projects. Based on responses, it appears that there are no show-stopper gaps in knowledge, with only technical issues to be addressed/resolved. The major emerging issue from the responses is that CO_2 capture and storage would be a major cost that would put the respective operators at a significant disadvantage compared to those in the same industry that would continue to vent the CO_2 into the atmosphere. A preliminary conclusion from the survey is that the Project Submission Form should be simplified and should reflect more technical and deployment aspects of CCUS and less scientific aspects.

Pag. 55

11. Schedule and Plan for 2012 CSLF Technology Roadmap Update

A discussion occurred on the plans for the next CSLF Technology Roadmap (TRM). Acting PIRT Chair Stefan Bachu stated that the PIRT recommends that the roadmap be updated every three years, making the next major update in 2013 instead of 2012 (the last major update was in 2010; the 2011 update was minor and concerned only Module 2 of the TRM). The PIRT also believed that the update regarding projects and country activities should be taken out and produced separately as a standalone web-based document to be updated annually at the request and reminder of the Secretariat. This would remove the need for annual TRM updates and will allow the TRM to focus on CCS achievements, challenges and the road ahead. Dr. Bachu also suggested that the table of contents be revised by the Secretariat and be reviewed by a small group of delegates. During ensuing discussion, suggestions were made to release the TRM with each Ministerial meeting. However, some delegates objected to this suggestion, pointing out that time intervals between Ministerial-level meetings are irregular and dictated by other considerations and, therefore, it is unsure when each Ministerial meeting would occur. For example, Ministerial-level meetings were held in 2003 (CSLF founding), in 2004, in 2009, and now in 2011. Ultimately, Chairman Riis announced that a smaller group would be formed to consider this subject and make a decision before the next Technical Group meeting.

12. Technical Group Five-Year Action Plan

Chairman Riis opened the floor for a discussion regarding the Technical Group Five-Year Action Plan, in which 12 Actions were listed. Phillip Sharman believed that a number of the 12 Actions have been addressed by other organizations. Thus, maybe the CSLF can consider the work of other organizations that are already making good inroads into these topics and are producing reports. Therefore the CSLF can focus on looking at the lessons learned and perhaps sharing some of the issues in workshops.

Joseph Giove of the United States wanted to seek a point of clarification on the language in two of the actions: #6 and #7. Action #6 states that the Technical Group will "recommend standards" and Action #7 states that the Technical Group will provide "identification and recommendation of requirements." Mr. Giove pointed out that "recommends" fell outside of the purview of the group. John Panek stated that the Secretariat would adjust the language. Mr. Panek also noted that for Action #2, the Global CCS Institute has agreed to have the CSLF projects on their mapping website so that the CSLF will have a section of projects which they can maintain. Dr. Bachu again emphasized that the PIRT would like to divide the 12 proposed actions into two categories. One category would be for items taken up by other organizations. The other category would be for items identified by only the CSLF.

Chairman Riis then summarized the discussion. The Secretariat, together with the Technical Group Executive Committee, will review the text and make improvements, such as removing words like 'recommends' and 'standards'. Afterwards, the edited Technical Group Five-Year Action Plan will be sent to delegates for final comments. The delegates are to rank each of the Actions based on level of importance (with 1 as highest priority and 12 as lowest), with one ranking list per CSLF Member. Mr. Riis also requested for volunteers to lead each of the Actions. To that end, Dr. Bachu stated that Canada would like to lead the Action on "Technical Challenges for Conversion of CO_2 EOR to CCS" and Mr. Giove stated that the United States would like to lead the Action on "CO_2 Utilization Options". Dr. Bonijoly stated that France would like to lead the

Pag. 55

Action on "Competition of CCS with Other Resources" (subject to confirmation from the home office). It was understood that, after ranking, any Actions that did not have volunteers to lead would most likely not be acted on.

Wednesday, 21 September

13. Summary of Previous Day's Session

Chairmen Riis felt that in order to save time, no summary of the previous day's session was necessary.

14. Guidelines for Safe and Effective CCS in China

Li Zheng, Professor at Tsinghua University, China, gave a presentation on China's technology and implementation of CCS. Dr. Li provided a context of CCS in China, discussing the various challenges and issues faced. He provided information, including pictures, on various CCS demonstration projects in China. Led by a joint partnership between Tsinghua University and WRI, China has successfully conducted a practice for CCS knowledge transfer in a systematic way. The group believes that CCS is not purely a technical issue, and understanding its multi-dimensional characters is essential to ensure its final application. Dr. Li stated that CO_2 capture projects should start from the easy ones and proceed to the difficult ones, and that utilization, such as enhanced oil recovery, should be prioritized to ease early CCS development. A book will soon be released that includes seven chapters on knowledge points across CCS technical chain and chronological project chain, and 19 sets of guidelines giving recommendations for important issues in conducting a safe and effective CCS project.

15. Work Plan to Support CCUS Action Group Recommendations

Chairman Riis stated that at the Edmonton meeting, the Technical Group discussed how to proceed and proposed to have an informal meeting with representatives from IEA, IEA GHG, and Global CCS Institute. The organizations were contacted, but no meeting has occurred. The action is currently being monitored, but at this time, there is no clear plan for further action from the Technical Group.

16. CSLF Collaborative Activities

Mike Miyagawa of Global CCS Institute stated that in September, the Global CCS Institute opened a regional office in Tokyo, Japan. This is in addition to their regional offices in Paris, France and North America. The new Japanese office will not only cover Japan, but also neighboring countries like Korea and China.

Tim Dixon of IEA GHG gave a presentation of IEA GHG and its activities. The IEA GHG is a collaborative research programme founded in 1991 as an IEA Implementing Agreement financed by its members. The goal of the organization is to provide its members with definitive information on the role that technology can play in reducing greenhouse gas emissions. IEA GHG activities include publication of more than 120 studies and reports, sponsorship of ten research networks, and co-sponsoring the biennial Greenhouse Gas Technologies (GHGT) conferences, and an annual summer school on CCS for graduate students. Mr. Dixon then discussed various work the IEA GHG has done with the CSLF. The first study idea, originated by the CSLF Technical Group and undertaken by the IEA GHG, was on storage capacity coefficients. The CSLF also provided two additional study ideas in 2010. The first was on CO_2 storage in basalts, and

 Pag. 57

the second was on the effect of shale gas and shale oil production on CO_2 storage. The suggested studies were approved by IEA GHG Executive Committee in 2011, with the second one being expanded to cover the interaction between CO_2 storage and other resources. Mr. Dixon invited the CSLF to submit additional new study ideas by December 2011. Mr. Dixon then briefly showed the IEA GHG's current studies and networks.

17. Next CSLF Technical Group Meeting

Chairman Riis stated that the next Technical Group Meeting would be in Bergen, Norway. The meeting will include a visit to the Technology Center in Mongstad, which has been CSLF recognized and will officially open at the end of 2011. Mongstad is a one hour drive from Bergen. In addition, the plan is to also hold a CSLF workshop on capture. The original plan was to hold this meeting during the first week of June 2012. However, there was a request to move it to the second week of June. The final dates for the meeting will be determined and announced within the next month.

18. New Business

Tony Surridge of South Africa announced that South Africa will be hosting a CCS week from the 24^{th} to the 28^{th} of October. The week will include, on Monday, a CCS project workshop. On Tuesday and Wednesday there will be a conference to disseminate local work being done in South Africa. On Thursday there will be a policy regulatory workshop sponsored by of the Department of Energy. And on Friday there are two workshops: one on risk and the other on public outreach. Details and registration are available online at the South African Center for Carbon Capture and Storage (http://www.sacccs.org.za/). The CCS week is being supported by the CSLF Capacity Building program as well as the South African Center for Carbon Capture and Storage.

19. Current Meeting Action Items and Next Steps

John Panek gave a presentation on the action items from the meeting. Four projects were approved for CSLF recognition and sent to the Policy Group, where they were also approved. Other action items from the meeting are as follows:

Item	Lead	Action
1	Secretariat	Add category for withdrawn projects – "Withdrawn by Sponsor"
2	PIRT	Decision to keep current project submission form
3	Delegates	Proposal to endorse proposed activity "Risk and Liability Assessment for Geologic Storage of Carbon Dioxide – A Proposed Work Plan for CSLF"
4	Technical Group Executive Committee	Consensus for Technical Group Executive Committee to appoint a group to develop a Technology Roadmap Schedule (3 year cycle) • Module 2 to be web based and removed from Roadmap

 Pag. 57

 Pag. 58

Item	Lead	Action
5	Secretariat	Secretariat will adjust language of Action Plan to remove "recommendation" • Technical Group Executive Committee will ask Technical Group for additions and priorities • Request volunteers to take lead on individual Actions (Canada - #7, France - #8, & United States - #12 already volunteered)
6	Secretariat	Risk Assessment report will be provided to the Secretariat. Report will go out to all Technical Group members with a 14-day cycle and, hearing no objections, will be adopted by the Technical Group.

20. Closing Remarks / Adjourn

Chairman Riis thanked the delegates, observers, and Secretariat for their hard work. Mr. Riis expressed his appreciation to the Ministry of Science and Technology, and the National Development and Reform Commission of the People's Public of China for hosting this meeting. Mr. Riis gave a special thanks to Harry Schreurs of the Netherlands for his years of active work in the CCS community. Mr. Schreurs will be retiring in March 2012. Chairman Riis then adjourned the meeting.

 Pag. 58

CSLF-P/T-2011-03
Revised Draft: 25 November 2011
Prepared by CSLF Secretariat

POLICY GROUP
TECHNICAL GROUP

Revised Draft
Minutes of the Joint CSLF
Policy and Technical Group Meeting

Beijing, China
23 September 2011

Barbara N. McKee
Tel: 1 301 903 3820
Fax: 1 301 903 1591
CSLFSecretariat@hq.doe.gov

Pag. 60

CSLF-P/T-2011-03
Revised Draft: 25 November 2011

CSLF IS GOING GREEN*

MINUTES OF THE JOINT CSLF POLICY AND TECHNICAL GROUP MEETING
BEIJING, CHINA
23 SEPTEMBER 2011

Note by the Secretariat

Background

The Policy and Technical Groups of the Carbon Sequestration Leadership Forum held a joint business meeting on 23 September 2011, in Beijing, China. Initial draft minutes of this meeting were compiled by the CSLF Secretariat and were circulated to the Policy Group and Technical Group delegates for comments. Comments received were incorporated into this revised draft. Presentations mentioned in these minutes are now online at the CSLF website.

Action Requested

Policy Group delegates are requested to approve these revised draft minutes.

* **Note:** This document is available only electronically. Please print it prior to the CSLF meeting if you need a hardcopy.

Pag. 60

 Pag. 61

CSLF-P/T-2011-03
Revised Draft: 25 November 2011
Prepared by CSLF Secretariat

DRAFT
Minutes of the Joint Meeting of the
Policy Group and Technical Group
Beijing, China
Friday, 23 September 2011

LIST OF ATTENDEES

Policy Group Delegates

Chairman:	Charles McConnell (United States)
Australia:	Ann Boon, Margaret Sewell
Brazil:	Daniel Falcon Lins
Canada:	Marc D'Iorio, Milenka Mitrović
China:	Xin Li, Sizhen Peng
European Commission:	Wiktor Raldow
France:	Bernard Frois
Germany:	Hubert Höwener, Peer Hoth
Italy:	Liliana Panei
Japan:	Hirotada Bessho, Shigenori Hata
Korea:	Byung Ki Park, Wonchang Yang
Mexico:	José Miguel González Santaló
Netherlands:	Paul van Slobbe
Norway:	Tone Skogen, Kristoffer Stabrun
Poland:	Janusz Michalski, Marek Wejtko
Saudi Arabia:	Abdulmuhsen Alsunaid, Abdullah AlSarhan
South Africa:	Elizabeth Marabwa, Muzi Mkhize
United Arab Emirates:	Keristofer Seryani
United Kingdom:	Jeremy Martin, James Godber
United States:	James Wood

Technical Group Delegates

Australia:	Niki Jackson
Brazil:	Beatriz Espinosa, Viviana Coelho
Canada:	Stefan Bachu, Eddie Chui
China:	Ping Zhong
European Commission:	Jeroen Schuppers
Italy:	Giuseppe Girardi, Sergio Persoglia
France:	Didier Bonijoly
Japan:	Ryo Kubo
Korea:	Chang-Kuen Yi
Norway:	Trygve Riis (Chairman)
Saudi Arabia:	Khalid Abuleif
United States:	Joseph Giove, George Guthrie

 Pag. 61

CSLF Secretariat

Barbara McKee, Jeffrey Price, John Panek, Richard Lynch, Adam Wong, Jeffrey Jarrett, Kathryn Paulsgrove

Observer Participants

Dietrich M. Gross, Jupiter Oxygen (United States)
John Lyman, Atlantic Council (United States)
Andrew Paterson, CCS Alliance (United States)
David Wendt, Jackson Hole Center for Global Affairs (United States)
Tony Wood, Clinton Foundation

1. Opening Remarks

Chairman McConnell welcomed the delegates to the last of several days of meetings. He said that the Ministerial meeting the previous day was terrific and that we would have a chance at this meeting to review the Ministerial, as well the meetings of the Policy Group and Technical Group.

The logistics of the planned site visit in the afternoon to the Huaneng Carbon Project were also discussed for the benefit for those planning to attend.

2. Adoption of Agenda

The Agenda was adopted without change.

3. Review and Approval of Minutes from London Meeting

The draft Minutes of the previous Joint Policy and Technical Group meeting held in Warsaw, Poland in October 2010, had been circulated for comment to the Policy Group prior to the meeting. The final draft, which incorporated comments received, had been posted on the CSLF website. The Minutes were approved without further change.

4. Review of Warsaw Action Items

Barbara McKee, Director of the CSLF Secretariat, reviewed the status of the Action Items. She stated that all of the Action Items had been completed, except that:

- The Policy Group needed to consider a Task Force on Closing Policy-Related Gaps;
- Members were needed for the new Task Force on Risk and Liability; and
- The Secretariat and Communications and Public Outreach Task Force needed to identify best practices to most effectively move media communications forward.

The Technical Group noted that, in addition to a final 2010 Technology Roadmap called for in the minutes, a Technology Roadmap had also been completed in 2011.

5. Report from Policy Group

Chairman McConnell of the Policy Group presented a report on the Policy Group meeting. That meeting consisted of task force reports, reports from collaborating organizations, CSLF planning and planning for the Ministerial.

Reports from Policy Group Task Forces included the following:

Pag. 63

- Capacity Building Task Force and Governing Council. The CSLF Capacity Building Fund now totals US$3 million and decisions have been made to fund projects in four countries. CSLF capacity building events are open to all Members. New projects are being sought and a funding strategy is to be developed for the next three years.
- Financing CCUS Task Force. The focus of this task force is on understanding commercial-scale financing needs with activities to date including workshops, expert dialogues and reports. A number of key findings have been reached including that CCUS can be cost-competitive with other low-carbon technologies.
- CCUS in the Academic Community. This task force has identified many CCUS-related courses worldwide and developed an extensive data base of courses on all aspects of CCUS. Further work will be to validate the data base and consider creating a network of professors to accelerate and improve CCUS education.
- Communications and Public Outreach. This task force has implemented a strategic plan to address barriers to public awareness and acceptance. Positive comments were received on the work, but much more needs to be done to follow up. The key issue is how to collaborate to improve communications on CCUS.

Reports were heard from four collaborating organizations: the International Energy Agency, the Global CCS Institute, the World Bank and the CCUS Action Group. Work of these organizations complements that of the CSLF. Several questions, however, need to be addressed:

- Is international collaboration adequate?
- Where can improvements be made?
- What synergies can be exploited?
- How is this reflected in outcomes or milestones in the CSLF Strategic Plan?

The Second Update of the CSLF Strategic was discussed and approved. This Update reflects the amended charter. It is goal-oriented with specific milestones. A fundamental question is raised as to how the CSLF, as a voluntary multilateral organization, can maintain clear progress toward common goals.

All six of the projects recommended for recognition by the Technical Group were approved. The total number of projects recognized since 2004 now total 36 and these projects cover all aspects of CCUS.

The Policy Group was also given an overview of plans for the September 21 Conference of Ministers as well as the four reports to the Ministers. Final edits were made to the Ministerial Communiqué.

Comments

A number of comments were made by delegates on the presentations on the reports by the Policy Group Task Forces:

- Capacity Building Task Force and Governing Council. José Miguel González Santaló of Mexico stated that the effort on capacity building has been very intensive and that he expects there will soon be more proposals and that the organizational arrangements now work. Barbara McKee of the Secretariat responded that considerable effort had to go into developing the Terms of Reference and procedures for the Task Force and Governing Council and developing criteria for approval of projects to ensure and verify that they met real

Pag. 63

 Pag. 64

needs of Members. Abudulmuhsen Alsunaid of Saudi Arabia reiterated that the process is now going forward and working. He also stated that part of the capacity building effort could also benefit developed countries, which also needed to build capacity. Governing Council Chair Tone Skogen of Norway noted that if no more money is forthcoming the plan may end and asked how the CSLF can leverage other means of funding. Jeremy Martin of the United Kingdom agreed with the previous comments and stated that he thought that it was too early to judge results. Li Xin of China thanked the donor countries and stated that he agreed with the previous comments. He also said that there were opportunities to learn from other projects and from other countries' proposals. Chairman McConnell noted that in the Ministerial there was agreement that capacity building was one of the most important issues.

- Communications and Public Outreach. Barbara McKee asked what would be needed to accelerate work in this area. Task Force Chair John Grasser of the United States restated the need for public affairs professionals to assist in CSLF efforts in this area and made a formal request for assistance from such professionals. Mr. Grasser also said that he has been in contact with the Global CCS Institute on this issue. He also reiterated that communications activities are expensive and that funding is not adequate in this area. Such funding as is available currently comes from the United States Department of Energy's internal budget, but it is considered well spent. Chairman McConnell stated that there was a need to leverage efforts in this area, that there will always be believers and non-believers and that it is important to segment audiences. Tone Skogen said that the CSLF should consider the experience of the European Zero Emissions Platform, which has a large communications task force and has produced information for the public. The need for simplified messages and outreach to science journalists was also mentioned.
- CCS in the Academic Community. Barbara McKee asked whether it was clear what the next steps were. Task Force Co-Chair Tim Dixon of the IEA GHG responded that the Task Force now has a work plan and needs to assign responsibilities at the next task force meeting.

6. Report from Technical Group

Technical Group Chairman Trygve Riis of Norway presented the report from the Technical Group. He said that since the last meeting in Warsaw, the following meetings have been held:

- Workshop and PIRT meeting in Al Khobar, Saudi Arabia, February 2011. This was a very successful workshop on storage and monitoring of CO_2 with excellent participation from storage projects.
- Technical Group meeting with Task Force meetings in Edmonton, Canada, May 2011. Two projects were nominated for CSLF recognition: Zero Emission Porto Tolle (ZEPT) and the Jänschwalde Project. The Technical Group also visited the CSLF-recognized Quest project.

The Technical Group Executive Committee also has telephone meetings each month.

In Beijing, the Technical Group meeting consisted of a PIRT meeting, task force meeting and a meeting of the entire Technical Group. Four new projects were nominated for CSLF recognition:

 Pag. 64

Pag. 65

- SaskPower CCS Project;
- CGS Europe Project;
- Rotterdam Opslag en Afvang Demonstratieproject (ROAD); and
- CO_2 Capture Project – Phase 3.

The 2011 Carbon Sequestration Leadership Forum Technology Roadmap (TRM) provides a pathway to the commercial deployment of integrated CO_2 capture, transport, and storage technologies. The current TRM update also reports on project and country activities. A major revision will be done every three year, with the next in 2013, which coincides with Ministerial meetings. Module 2 with projects and country reports will be web-based and on the CSLF website and will be updated at least once a year. The Technical Group Executive Committee will propose a revised format for the TRM.

The Task Force on Assessing Technical Issues has four working groups:

- Capture Technologies (United States lead);
- Transport and Infrastructure (Netherlands lead);
- Storage and Monitoring (Canada lead); and
- Integration (Global CCS Institute lead).

In particular, there is good progress in the Storage and Monitoring Working Group, chaired by Stefan Bachu with substantial resource support from Norway. The Transport Working Group needs a new Chair. Discussions about compression are being considered, but it is unclear whether this should be in the capture or transport working group.

The Risk Assessment Task Force endorsed the work plan for a new Policy Group/ Technical Group Task Force on Risk and Liability Assessment for Geological Storage of Carbon Dioxide.

The Global CCS Institute asked CSLF to cosponsor a workshop on integration in London, which will be held on 3 November 2011. Several CSLF recognized projects may attend. Invitations to projects are to be sent out Wednesday.

A possible technical workshop on capture may be held in June 2012 in conjunction with the next Technical Group meeting in Bergen, Norway, with a visit to TCM Mongstad. The Technical Group is also exploring the potential for a workshop on transport. The intention is to hold a technical workshop at least once a year.

The Technical Group has set out a five-year plan consisting of 12 Action Plans:

Action Plan 1: Technology Gaps Closure
Action Plan 2: Best-Practice Knowledge Sharing
Action Plan 3: Energy Penalty Reduction
Action Plan 4: CCS with Industrial Emissions Sources
Action Plan 5: CO_2 Compression and Transport
Action Plan 6: Storage and Monitoring for Commercial Projects
Action Plan 7: Technical Challenges for Conversion of CO_2 EOR to CCS
Action Plan 8: Competition of CCS with Other Resources
Action Plan 9: Life Cycle Assessment and Environmental Footprint of CCS
Action Plan 10: Risk and Liability
Action Plan 11: Carbon-neutral and Carbon-negative CCS
Action Plan 12: CO_2 Utilization Options

The plan will be revised and sent out to TG delegates. Technical Group delegates will report back on any additional actions, the most important actions for each country,

Pag. 65

Pag. 66

coverage by other international organizations and interest in taking the lead on any of the Action Plans. The goal is to complete the program plan for at least one of the actions before Bergen and use this as a template for others.

Daniel Falcons Lins stated that Brazil will soon approach new researchers to participate in Technical Group Task Forces, but is very busy preparing for the Rio+20 conference in June 2012, for which it expects about 50,000 participants.

7. Report from the Risk and Liability Task Force

George Guthrie and Bernard Frois, Co-Chairs, presented the report of this new Task Force and then asked for discussion.

Dr. Guthrie explained the background behind the request from the Technical Group Task Force on Risk Assessment for guidance on what information was needed. He stated that the Task Force on Risk Assessment needed input from the Policy Group on how the technical risks they were looking at related to the financial issues associated with converting these risks into potential liabilities. He also said that the Task Force on Risk Assessment was looking into a number of issues associated with potential technical risks that may relate to liability. This was being considered in the context of technical issues associated with different phases on a project from planning through injection through post-injection to long-term stewardship. In considering the issue, the Task Force on Risk Assessment has reviewed and supports the proposal made by the Secretariat.

Dr. Frois noted that there was discussion in the past on cooperation on this important issue. He said he understood that the new Task Force should link the risks, both financial and technological, to liability. The Task Force on Financing CCS has already achieved significant progress that can be a direct input into the new Task Force. He then stated that the Policy Group Task Force was pleased to respond to the request. He also stated that he wanted to produce a concrete result.

Dr. Guthrie then requested participation in the new Task Force.

After the discussion, Chairman McConnell asked the Secretariat to work with the co-chairs to explore what resources might be available for this project. The Co-Chairs were also asked to put together a communication on requesting input from the Members. Tone Skogen stated that she will take this idea home and will report back. The Co-Chairs were also to identify within 30 days the types of expertise necessary to carry out this project.

Dr. Frois also stated that the work of the Financial Task Force would continue and that Task Force would hold a workshop on 20 January 2012, in Paris at the offices of Societé Générale.

8. Follow-up to the Ministerial

In order to begin the conversation, Chairman McConnell provided some of his take-away insights from the Ministerial Meeting. He stated, most importantly, that the Ministers are committed and the stakeholders want this global CCUS venture to succeed. He further summarized the discussion:

- Ambassador Jones of the IEA said that dependence on fossil fuels will continue, and so will the growth in CO_2 emissions, if unabated. The need for CCS – and CCUS – will be critical if we are to abate these emissions. The graph from Ambassador Jones' presentation showed the role of CCUS. In addition, we need to pay more attention to capture from industrial sources. CCUS is also not just about coal; it must also be applied to natural gas combined cycle plants.

Pag. 66

Pag. 67

- The shift from CCS to CCUS is well accepted, but a good definition of CCUS must be developed. (The stakeholder definition is a good start.) It is also clear that not everyone has the same utilization opportunities (i.e., EOR).
- From Secretary Chu of the United States: Considerable innovation is taking place; opportunities for further innovation abound. The key question is how do we collaborate to accelerate and exploit those opportunities?
- We are not on track to build the necessary demonstration projects. Too many good proposed projects are being cancelled.
- From the Global CCS Institute: Many projects are still in the pipeline; we need to make those succeed.
- Large investments are needed for demonstration projects from both the public and private sectors, but there are huge barriers. Governments will not pay the entire price tag.
- Legal and regulatory frameworks for CCUS need to be developed. We heard from industry again and again that regulatory certainty is needed. Another issue mentioned repeatedly was liability for stored CO_2.
- We all need to work together. Collaboration to develop the technology for everyone is important.
- CSLF Members have much in common, but there are clear differences in our situations and approaches. That is good; we can learn from each other.
- We need to let the public know that CCUS is safe, but getting that across can be difficult. Successful and fully transparent demonstration projects we can point to are essential to that communication.
- We heard a lot about the problems; we heard some ideas about solutions; we did not hear about agreed-upon solutions. How can we get to those solutions? What is the role of the CSLF in moving to those solutions?

Delegates were asked for their impressions and what those mean to the future work of the CSLF. Bernard Frois stated that the problem is large, but the idea is to break a large problem into smaller problems.

Observers were also invited to make comments:

- Tony Wood, Clinton Foundation: It is important to find a way to move forward with work that is both high risk and low return until commercial incentives are adequate.
- Andrew Paterson, CCS Alliance: CCS and CCUS can achieve commercial parity and the capacity is available.
- Dietrich Gross, Jupiter Oxygen: Consider monitoring any CO_2 that might reach the surface.
- David Wendt, Jackson Hole Center for Global Affairs: Emissions standards for CO_2 are important.
- John Lyman, Atlantic Council: Be sure to involve NGOs in the process.

Pag. 67

 Pag. 68

9. New Business

Chairman McConnell asked if there was any new business.

Muzi Mkhize of South Africa raised a question about whether nitrogen could be used for Enhanced Oil Recovery (EOR). Mr. McConnell responded that, in his experience, it was used under different conditions. Daniel Falcon Lins of Brazil stated that EOR has been in use in Brazil since the mid-1980s and that Brazil would be glad to discuss its experience on the matter with South Africa.

10. Closing Remarks

Barbara McKee thanked her direct and indirect staff on the CSLF Secretariat, the Ministerial Steering Committee, Chinese colleagues, and Chairman McConnell.

Trygve Riis stated that he, as Chairman of the Technical Group, and the Technical Group Executive Committee had good support from the Secretariat and thanked the Secretariat for that support.

Li Xin, on behalf of China as host country, thanked colleagues for support in making the meeting successful and useful and wished participants a safe trip back home.

Chairman McConnell stated that he saw leading the CSLF forward as a personal obligation and a privilege. He took note of all the work that needed to be done and stated that it is a privilege to represent our countries moving CCUS forward. He believed that the Ministerial created momentum for the CSLF. Mr. McConnell thanked the participants and wished them a good trip home.

ACTION ITEMS ARISING FROM THE JOINT MEETING OF THE POLICY GROUP AND THE TECHNICAL GROUP

Item	Lead	Action
1	Communications and Public Outreach Task Force	Follow up on best practices on communications on CCS.
2	Members	Provide names of public affairs professionals to Secretariat.
3	Task Force on CCUS in the Academic Community	Set responsibilities for the next steps on CCUS in the Academic Community.
4	Risk and Liability Task Force	Request input from Members and explore available resources.
5	Risk and Liability Task Force	Identify what expertise is needed for this Task Force.
6	Members	Consider participation in Risk and Liability Task Force.

 Pag. 68

Carbon Sequestration Leadership Forum
www.cslforum.org

MINISTERIAL CONFERENCE
22 SEPTEMBER 2011

Collaborating for a Decade of Research, Demonstration and Deployment of CCS

CSLF Stakeholders Statement

Beijing, China, 22 September 2011

1. Since its establishment in 2003, CSLF has been playing a leading role in promoting the development of cost-effective technologies for capture of carbon dioxide (CO_2), its transport and long-term safe storage. CSLF Stakeholders have been supporting this governmental initiative from the very beginning and have invested billions of dollars in CCS and CCUS* (*Carbon Capture, Utilisation and Storage)* R&D, demonstration projects, early deployment programmes, public awareness campaigns and other activities.
2. A lot of ground has been covered and Stakeholders appreciate the CSLF contribution to making CCS a reality. However, taking into account the size of the problem confronting the world, much more needs to be done and urgently to protect the climate system from irreversible changes. Stakeholders are very concerned that Government support has become detached from the timetable set for CCS deployment, as incentive measures are not in line with the roadmap developed by IEA and agreed by G8. It is highly unlikely that there will be 100 commercial CCS plants by 2020. Without much stronger support from Governments, there is also a real danger that many more industrial Stakeholders will abandon their plans for CCS projects.
3. Early deployment of carbon capture technology in developed as well as in developing nations can be supported by CCUS strategies, such as enhanced oil recovery(EOR), or enhanced coal bed methane recovery. Revenues from the intermediate step of CO_2 utilization before ultimately storing it underground, will make carbon capture technology more attractive economically.
4. Investing in CCS today is the most cost-effective way to tackle climate change, and at the same time secure inward investment in low-carbon energy and also provide jobs and economic growth. Together with nuclear and hydropower, CCS is a large scale low-carbon technology, but unlike them, it has a considerable potential for worldwide deployment.
5. Stakeholders recognise the need for incentives to develop CCS projects in all countries, including developing countries. Climate change is a global concern and can be addressed only by a worldwide effort. More than 80 countries around the world have fossil fuel resources, and fast growing large economies in Asia in particular are heavily dependent on fossil fuels. Stakeholders steadfastly maintain the view that CCS technology is a core method to achieve the deep reductions in carbon dioxide emissions that are required to protect the world climate system from serious disruption.

**CCUS is a sub-set of CCS in which CO_2 is utilised to beneficial effect (e.g. EOR) prior to its permanent storage. To be qualified as a CCS technology CCUS must be subject to the same rigorous monitoring and verification procedures as CCS to ensure secure and permanent storage.*

Pag. 70

6. Development of CCUS technology aimed at cost reduction is particularly important. Stakeholders recognise the recent announcements from the USA in assigning research grants with this aim. Stakeholders encourage other CSLF members to adopt similar but coordinated research, development and demonstration policies with knowledge sharing to enable swift uptake of technology advancements. There still are barriers to overcome. The cost of capture, the need for more experience, and undeveloped transport infrastructure are primary concerns.
7. Whereas CSLF Stakeholders recognize that CCUS projects can be helpful in improving the economics of CCS, it is important to point out that to avoid the release of CO_2 emissions to the atmosphere, CCUS projects carried out under the CSLF shall result in sequestration of the CO_2 that is captured in such projects.
8. Stakeholders recognise the need for a balanced risk and reward environment for the investors in the CCS value chain and are concerned in particular by the exposure to both obligations and liabilities – these issues represent a heavy, unbalanced and an intolerable burden.
9. Stakeholders emphasise that funding of demonstration programmes must reflect the significant risks and uncertainties that first movers are faced with. Technology risks, exploration risks and lack of economies of scale amongst others make for a very high investment hurdle for initial projects. Given that this demonstration programme will bring incalculable benefits for society performance risks should be shared between Governments and industry Stakeholders in a fair way enabling the industry to invest in demonstration projects. In this context Stakeholders recognise the UK policy development in electricity market reform that creates the world's first market mechanism to support investment in low carbon power from CCS alongside other technologies which can underpin CCS investment in both demonstration and deployment.

In two years CSLF will celebrate its 10th Anniversary and Stakeholders challenge the Ministers to adopt an ambitious 2-year Action Plan. Its results will be reported at the next CSLF Ministerial in 2013. The Ministers should give support to:

- Provision of funding mechanisms for a sufficient number of large-scale demonstration projects.
- Design and implementation of policies that will create market-based support for CCUS deployment.
- Accelerate the development and implementation of policy frameworks including both regulation and financial support that is long-term sustainable and bankable for project developers.
- Develop risk sharing arrangements with the industry.
- Develop a comprehensive public outreach strategy for CCS.
- Support measures for international cooperation, in particular with developing countries.
- Encourage their colleagues at the forthcoming COP-17 meeting in Durban to examine a range of options for mechanisms that can support deployment of CCS projects in developing countries.

CSLF Stakeholders are fully committed to supporting the Ministers in the implementation of this Action Plan which will ensure that CCS will realise its full potential and make a significant contribution to making CCS a reality.

Pag. 70

Pag. 71

Carbon Sequestration Leadership Forum

www.cslforum.org

CARBON SEQUESTRATION LEADERSHIP FORUM

Meeting of the
Carbon Sequestration Leadership Forum (CSLF) Ministers

Collaborating for a Decade of Research, Demonstration and Deployment on Carbon Capture Utilization and Storage

Communiqué
22 September 2011 at 1730

We, the Ministers and Heads of Delegation of the CSLF Members, are convinced that we must advance towards the demonstration and deployment of Carbon Capture Utilization and Storage (CCUS) as early as possible. CCUS is one of the low carbon technology options critical to the global quest to reduce carbon dioxide emissions to the atmosphere. We are committed to taking necessary actions individually and collaboratively to make that happen.

CCUS is a necessary technology essential to enabling us to achieve our climate goals and which has been proven safe and effective in all current demonstration projects and applications around the world. We must urgently increase the number of large CCUS demonstrations to enable the deployment of CCUS commercially by the end of this decade.

We met today to discuss and address the key challenges facing CCUS and identify activities necessary to support further research, development, demonstration and deployment. While it is clear that significant progress is being made on CCUS, challenges remain, but these are challenges that can—and will—be overcome.

Including Carbon Capture and Storage in International Agreements

Ministers applaud the decision at Cancun to recognize Carbon Capture and Storage (CCS) as a measure in the Clean Development Mechanism (CDM). We call upon delegates to the 17th United Nations Framework Convention on Climate Change (COP 17/CMP 7), to be held in Durban, South Africa, to recognize the key role of CCS as a low carbon technology in mitigating climate change and to expedite the inclusion of CCS as a measure in the CDM and in other appropriate financial mechanisms created to mitigate greenhouse gas emissions.

Building and Financing Commercial-Scale CCUS Projects

We are fully committed to the CSLF strategy to build and operate multiple successful commercial-scale CCUS project demonstrations by 2020. Many such projects are currently under development. Demonstration projects will initially require a mix of public and private financing. The long term deployment of CCUS projects will require the development of conducive policies in order to underpin the necessary financial investment. We are committed to developing these policies. Recognizing the international economic turmoil and the significant need for financial incentives to realize CCUS, financing will remain a key challenge in developed and particularly in developing countries. Increased international concerted action is needed to overcome this challenge. We today reaffirmed our commitment to work with the private sector to build and finance the needed demonstration projects over the next decade.

Pag. 71

Building on the Success of the CSLF

Recognizing the continuing need to address challenges, Ministers agreed to extend the term of the CSLF for an indefinite period beyond its prior expiration date of 2013. While much progress has been achieved since the CSLF was founded in 2003, more remains to be done to enable deployment of this vital suite of low carbon technologies.

Ministers recognize the success of the CSLF in providing governments with an international forum to collaborate and create shared commitments to CCUS research, development, demonstration and deployment. This includes ongoing CSLF initiatives to:

- Share information internationally on important CCUS projects;
- Build the capacity for CCUS in the developing country CSLF Members;
- Explore methods for financing CCUS projects, particularly in developing countries; and
- Develop global roadmaps for research, development and demonstration of CCUS technologies.

We are particularly pleased that a total of 30 active and completed, now expanded to 36, diverse CCS projects throughout the world have now been recognized by the CSLF and are sharing their results globally through the CSLF.

Expanding Collaboration through the CSLF

Ministers agree to extend and amend the CSLF Charter to include facilitation and deployment of technologies for utilization of captured carbon dioxide (CCUS).

Importance of Stakeholders and Growing International Collaboration

We are acutely aware that stakeholders in industry, society and the academic community are critically important to the development and commercial deployment of CCUS. While the CSLF is a means of international collaboration by governments, collaboration at the international level between governments and industry is also vitally important. We applaud the efforts of stakeholders to advance CCUS and to be involved in CSLF activities. We strongly encourage their continued involvement in CSLF.

We also welcome additional international collaborations on CCUS through the International Energy Agency, Global Carbon Capture and Storage Institute, the Clean Energy Ministerial (CEM) and multilateral financial institutions. We believe that the increasing number of such collaborations reflects the growing global recognition of the criticality of CCUS and we see these additional collaborations as complementary to the work of the CSLF. We also strongly encourage coordination among these international collaborations. Further, we acknowledge the CCUS recommendations of the second CEM meeting and we look forward to the implementation of those recommendations.

Overcoming the Challenges

We support strategies for the CSLF to resolve barriers for successful implementation of CCUS projects at a time of significant global economic challenge.

- We will work with the private sector to develop and implement methods to finance projects, including those in developing countries.
- We will work to develop legal and regulatory mechanisms to assure safety and appropriately allocate liabilities between the public and private sectors appropriate to our national circumstances.
- We will strengthen cooperation on both technology and policy in order to reduce the financial costs, to lower the energy penalty and to allay public concerns associated with the deployment of CCUS technologies.
- We commend the CSLF's capacity building initiative, and are pleased to announce funding for 12 projects today.
- We task the CSLF to undertake CCUS development initiatives in sectors such as power generation, industry and enhanced oil and gas recovery.

 Pag. 73

Carbon Sequestration Leadership Forum

CSLF-T-2012-09
20 August 2012

www.cslforum.org

TECHNICAL GROUP

Revised Draft
Minutes of the CSLF Technical Group Meeting

Bergen, Norway
12 June 2012

Barbara N. McKee
Tel: 1 301 903 3820
Fax: 1 301 903 1591
CSLFSecretariat@hq.doe.gov

 Pag. 73

Pag. 74

Carbon Sequestration Leadership Forum
www.cslforum.org

CSLF-P-2012-09
20 August 2012

CSLF IS GOING GREEN*

MINUTES OF THE CSLF TECHNICAL GROUP MEETING
BERGEN, NORWAY
12 JUNE 2012

Note by the Secretariat

Background

The Technical Group of the Carbon Sequestration Leadership Forum held a business meeting on 12 June 2012, in Bergen, Norway. Initial draft minutes of this meeting were compiled by the CSLF Secretariat and were circulated to the Technical Group delegates for comments. Comments received were incorporated into this revised draft. Presentations mentioned in these minutes are now online at the CSLF website.

Action Requested

Technical Group delegates are requested to approve these revised draft minutes.

* **Note:** This document is available only electronically. Please print it prior to the CSLF meeting if you need a hardcopy.

Pag. 74

Pag. 75

Carbon Sequestration Leadership Forum

www.cslforum.org

CSLF-T-2012-09
Revised Draft 20 August 2012
Prepared by CSLF Secretariat

DRAFT

Minutes of the Technical Group Meeting

Bergen, Norway
Thursday, 12 June 2012

LIST OF ATTENDEES

Delegates

Australia:	Clinton Foster (Vice Chair), Richard Aldous
Brazil:	Paulo Negrais Seabra
Canada:	Stefan Bachu
China:	Ping Zhong, Xiaochun Li
Denmark:	Søren Frederiksen
European Commission:	Jeroen Schuppers
France:	Didier Bonijoly, François Kalaydjian
Germany:	Jürgen-Friedrich Hake
Italy:	Giuseppe Girardi, Sergio Persoglia
Japan:	Ryo Kubo
Korea:	Chong Kul Ryu, Chang-Keun Yi
Netherlands:	Paul Ramsak
Norway:	Trygve Riis (Chair), Jostein Dahl Karlsen, Tone Skogen
Poland:	Elżbieta Wróblewska
Russia:	Mikhail Puchkov
Saudi Arabia:	Ahmed Aleidan
South Africa:	Tony Surridge (Vice Chair)
United Kingdom:	Philip Sharman
United States:	Joseph Giove, Grant Bromhal

Representatives of Allied Organizations

IEA GHG:	Tim Dixon

CSLF Secretariat

John Panek, Richard Lynch

Invited Speakers

Menno Dillen, Research Director, Geophysics and Reservoir Technology Department, SINTEF, Norway
Gunnar Sand, Program Manager, SINTEF and UNIS, Norway
Robert Finley, Director, Advanced Energy Technology Initiative, University of Illinois, United States
Scott McDonald, Biofuels Development Director, Archer Daniels Midland, United States
Vince White, Research Associate, Energy Technology, Air Products and Chemicals, United Kingdom

Pag. 75

Pag. 76

Observers

China:	Mingyuan Li; Xiuzhang Wu
Korea:	Chonghun Han
Norway:	Arne Graue; Anne Kristen Kleiven; Claude Olsen; Åse Slagtern
United Kingdom:	Mark Crombie
United States:	Chris Babel; Mike Holmes; Jeff Jarrett; Ed Steadman

1. Chairman's Welcome and Opening Remarks

The Chairman of the Technical Group, Trygve Riis of Norway, called the meeting to order, welcomed the delegates and observers to Bergen, and introduced Vice Chairs Clinton Foster of Australia and Tony Surridge of South Africa.

Mr. Riis provided context for the meeting by mentioning that this was one of the Technical Group's most ambitious and wide-ranging meetings, including both a project visit and a technical workshop on CO_2 capture. In that regard, he mentioned that there was much work to do, with four new task forces having formed and the Technical Group's Action Plan moving forward. Additionally, delegates at this current Technical Group meeting would be reviewing three new projects that have been nominated for CSLF recognition, and if approved by the Technical Group would then be considered by the Policy Group at its meeting in Perth, Australia in October. Also, in addition to the business items on the agenda, there would be several presentations of interest related to carbon capture and storage (CCS) activities in Norway, which should be enlightening to all present.

2. Welcome from the Government of Norway

Tone Skogen, Deputy Director General of the Norwegian Ministry of Petroleum and Energy, welcomed the Technical Group to Bergen and provided a Norwegian Government perspective about deployment of CCS. Norway has ambitious goals for broad deployment of CCS and has decided that all future natural gas-fueled power plants will be CCS-compatible. The Norwegian Government has been proactive about CCS by providing funding through Gassnova and the Research Council of Norway for the CLIMIT program that is working toward accelerating the commercialization of CCS. Norway currently has two large projects (Sleipner and Snøhvit) that are storing, cumulatively, nearly two million tonnes of CO_2 per year in geologic structures beneath the North Sea and Barents Sea, respectively. The Norwegian Government has also closely cooperated with industry partners for carbon capture, utilization and storage (CCUS) development, and one result of this is the CO_2 Technology Centre at Mongstad which is a large-scale testing facility for CO_2 capture technologies.

Ms. Skogen closed her remarks by stating that in order for CCUS to succeed, public funding is needed for the first commercial-scale CCUS demonstration projects and that public-private cooperation is essential for success. Also, knowledge sharing and international collaboration is vital to enhance CCUS prospects globally.

3. Introduction of Delegates and Observers

Technical Group delegates and observers present for the session introduced themselves. Nineteen of the twenty-five CSLF Members were present at this meeting, including representatives from Australia, Brazil, Canada, China, Denmark, the European Commission, France, Germany, Italy, Japan, Korea, the Netherlands, Norway, Poland,

Pag. 76

Pag. 77

Russia, Saudi Arabia, South Africa, the United Kingdom, and the United States. Observers representing China, Korea, Norway, the United Kingdom, and the United States were also present.

4. Adoption of Agenda

The Agenda was adopted with the understanding that Bjørn-Erik Haugan's presentation on "CCS in Norway" would be presented during the June 13 visit to the CO_2 Technology Centre Mongstad project instead of at the Technical Group meeting. Also, the item on "Update on 2012 and 2013 CSLF Technology Roadmaps" was moved to near the end of the meeting.

5. Approval of Minutes from Beijing Meeting

The Technical Group minutes from the September 2011 meeting in Beijing, China, were approved as final with two minor changes to correct misspellings.

6. Review of Action Items from Beijing Meeting

John Panek of the CSLF Secretariat reported that all action items from the Beijing meeting had been completed. The Risk Assessment Task Force's Phase II Final Report was not sent out to delegates, but instead was brought before the Technical Group later in the meeting.

7. Report from CSLF Secretariat

John Panek gave a brief presentation on the November 2011 Global CCS Institute (GCCSI) / CSLF Project Integration Workshop in London. In all, there were about 50 attendees and the key feature of the Workshop was the large amount of interaction, not only between presenters and the audience, but also amongst the presenters themselves. The key messages from the Workshop were that technology integration is a real issue and that it is important to strike a proper balance between plant operation and integration, and that more work in needed in several areas, including plant heat/cooling in the CO_2 capture process, integration of environmental control technologies (i.e., SOx, NOx, and CO_2 removal) to maximize efficiency, identifying and understanding scale-up risks for CO_2 capture technologies, and determining the impacts of CO_2 composition/impurities as they apply to CO_2 transport and storage.

Mr. Panek called on Richard Lynch of the Secretariat to summarize the January 2012 CCUS Financing Roundtable (co-sponsored with the Global CCS Institute and Société Générale) in Paris. Mr. Lynch stated that the meeting had about 40 attendees, many from the international banking sector. The key message from the Roundtable was that the large first-of-a-kind "lighthouse" CCUS projects are having great difficulty achieving financial closure due to perceived risk. For these "lighthouse" projects, integration risk is a major concern. These first-of-a-kind projects are not so much meant to demonstrate individual technologies at large scale as to demonstrate their integration. Costs are high, in part, because technology suppliers are adding large contingency factors, largely in the form of additional onsite technical assistance. Also, warranties are being required by project sponsors that may not be necessary for future commercial-scale projects. Simplicity is best for financing plans. More moving parts in a financing plan increase the chance of show-stopping issues. However, added project complexity, in the form of polygen production, increases the revenue stream and helps alleviate project risk. This built-in contradiction is an issue that may not be easy to solve. As a result of this risk, no

Pag. 77

 Pag. 78

"lighthouse" project can be reasonably expected to go forward without substantial governmental support (direct and/or from incentives) to close financing gaps.

Mr. Panek then called on Tony Surridge of South Africa to describe the October 2011 CCS Week in South Africa. Dr. Surridge stated that the event was hosted by the South African Centre for Carbon Capture and Storage (SACCCS) and organized by SACCCS and South Africa's Department of Energy with financial support from the CSLF Capacity Building Fund. The objective of the event was to disseminate information around local and international CCS research and development and to showcase CCS activities currently underway in South Africa. The conference focused on the South African and the southern Africa regional CCS activities that are currently underway. There were four technical workshops focusing on important aspects of CCS: CO_2 injection projects; CCS legal and regulatory framework; CCS public engagement; and CCS risk assessment. Dr. Surridge stated that the main achievements of the week were the dissemination of CCS knowledge and experience among stakeholders and interested parties, as well as undertaking the first steps into risk assessment and public engagement.

Mr. Panek concluded the Secretariat Report by very briefly summarizing the March 2012 Capacity Building Workshops that were held in Mexico City, also financially supported by the CSLF Capacity Building Fund and organized by the CSLF, Mexico's Institute of Engineering (UNAM), and Mexico's National Autonomous University. This was an extended event, staged over two weeks, with the first week centered on geologic storage of CO_2 and the second week focused on CO_2 capture.

8. Update from Norway's CO_2 Field Lab Project

Menno Dillen, Research Director in SINTEF's Geophysics and Reservoir Technology Department, gave a detailed presentation on the CSLF-recognized CO_2 Field Lab Project. This is a pilot-scale project, located at Svelvik, Norway, which is investigating monitoring technologies for CO_2 leakage detection in a well-controlled and well-characterized permeable geological formation. Relatively small amounts of CO_2 are being injected to obtain underground distribution data that resemble leakage at different depths. The main objective is to assure and increase CO_2 storage safety by obtaining valuable knowledge about monitoring CO_2 migration and leakage. The outcomes from this project will help facilitate commercial deployment of CO_2 storage by providing the protocols for ensuring compliance with regulations, and will help assure the public about the safety of CO_2 storage by demonstrating the performance of monitoring systems.

Mr. Dillen stated that Phase 1 of the project ran from September 2009 to January 2011, and that activities in the first project phase included a baseline seismic survey in November 2009 as part of the site characterization, drilling and logging of a 300-meter deep exploration well, and updating models based on the logged data from the well. Phase 2a, which began in May 2011, has so far included a shallow CO_2 injection test with extensive sampling to develop a record of the behavior of the injected CO_2. A deep permeability test is planned to begin in September 2012. Initial results from the Phase 2a shallow injection test reinforce the necessity of proper site characterization, as part of the monitoring system missed the plume of CO_2. Based on this result, one learning from the project is that a diverse monitoring system will provide the greatest capability and flexibility for CO_2 leakage and migration measurements. Mr. Dillen closed his presentation by affirming that the CO_2 Field Lab Project is providing a good environment to test and compare monitoring technologies under controlled conditions. Mr. Dillen

 Pag. 78

 Pag. 79

noted that the nearby community was very positive about the work, and that funding was approximately €10 million for 4-5 years.

9. Report from Projects Interaction and Review Team (PIRT)

The PIRT Chair, Clinton Foster of Australia, gave a presentation that summarized the previous day's PIRT meeting, which resulted in the following outcomes:

- The Illinois Basin – Decatur Project, the Illinois Industrial Carbon Capture and Storage Project, and the Air Products CO_2 Capture from Hydrogen Facility Project were all approved by the PIRT and sent forward to the Technical Group for its consideration.
- A plan for future updates of the CSLF Technology Roadmap (TRM) was developed.
- A proposal for updating and simplifying the CSLF Project Submission Form and Gaps Analysis Checklist was discussed, but no firm conclusion was reached. As a result, approval of a revised Form and Checklist has been deferred until the next PIRT meeting, in October 2012 at the 2012 CSLF Annual Meeting in Perth, Australia.

Discussion on the TRM was temporarily deferred, as it was an agenda item for later in the meeting.

10. Approval of Projects Nominated for CSLF Recognition

<u>Illinois Basin – Decatur Project</u> (*nominated by United States and United Kingdom*)

Robert Finley, Director of the Advanced Energy Technology Initiative in the Illinois State Geological Survey at the University of Illinois, gave a presentation about the Illinois Basin – Decatur Project. This is a large-scale carbon CCS demonstration project of the Midwest Geological Sequestration Consortium (MGSC), one of the seven Regional Partnerships organized by the United States Department of Energy (DOE). The project is being led by the Illinois State Geological Survey. Up to 1 million metric tons of CO_2 will be injected over a 3-year period into a Cambrian–age geological formation called the Mt. Simon Sandstone at a rate of 1,000 tonnes per day and a depth of about 2 kilometers. After three years, the injection well will be sealed and the reservoir monitored using geophysical techniques. The CO_2 is being captured from the fermentation process used to produce ethanol at Archer Daniels Midland Company's corn processing complex in Decatur, Illinois, in the United States. The Mt. Simon Sandstone is the thickest and most widespread saline reservoir in the Illinois Basin, with a CO_2 storage capacity estimated from 11 to 151 billion tonnes. Monitoring, verification, and accounting (MVA) efforts began in 2008 and include tracking the CO_2 in the subsurface, monitoring the performance of the reservoir seal, and continuous checking of soil, air, and groundwater both during and after injection. Operational injection of CO_2 began in November 2011.

The goal of this project is to demonstrate the potential of the Mt. Simon Sandstone to be a significant CO_2 geologic sequestration reservoir for the Illinois Basin region in the United States. The key research targets for MGSC's large-scale injection test relate to CO_2 injectivity and volumetric storage capacity of the saline reservoir, the integrity of the seals to contain the CO_2 in the subsurface, and the entire process of pre-injection characterization, injection process monitoring, and post-injection monitoring to understand the fate of the injected CO_2. The focus is on demonstration of CCS project development, operation, and implementation while demonstrating CCS technology and reservoir quality.

 Pag. 79

 Pag. 80

After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for the project.

Illinois Industrial Carbon Capture and Storage Project (*nominated by United States and France*)

Scott McDonald, Biofuels Development Director for project sponsor Archer Daniels Midland, gave a presentation about the Illinois Industrial Carbon Capture and Storage Project. This is a large-scale project, also located in Decatur, Illinois, which will collect up to 3,000 tonnes per day of CO_2 from the Archer Daniels Midland ethanol production plant in Decatur and store it in the Mt. Simon Sandstone. Mr. McDonald noted that the captured CO_2 generated by this industrial process was more than 99% pure, in contrast to the lesser purity of CO_2 streams from power plants. Project scope includes the design, construction, demonstration, and integrated operation of CO_2 compression, dehydration, and injection facilities, and MVA of the stored CO_2. Engineering, permitting, and construction activities are underway and are scheduled to conclude by mid 2013. Operation of the CO_2 capture and storage facility will begin during the second half of 2013.

The goals of this project are to design, construct, and operate a new CO_2 collection, compression, and dehydration facility capable of delivering up to 2,000 tonnes of CO_2 per day to the injection site; to integrate the new facility with an existing 1,000 tonnes of CO_2 per day compression and dehydration facility to achieve a total CO_2 injection capacity of 3,000 tonnes per day (or one million tonnes annually); to implement deep subsurface and near-surface MVA of the stored CO_2; and to develop and conduct an integrated community outreach, training, and education initiative. Unlike the Illinois Basin – Decatur Project, which focuses on research aspects of large-scale CCS, this project is intended to be an industrial commercialization project. A significant feature of the project is its “negative carbon footprint”, meaning that there will be a net reduction of atmospheric CO_2. There is also a possibility that CO_2 from this and other Archer Daniels Midland ethanol facilities could be used in the future for enhanced oil recovery (EOR), as the Illinois Basin is a petroleum producing region.

After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for the project.

Air Products CO_2 Capture from Hydrogen Facility Project (*nominated by United States, Netherlands, and United Kingdom*)

Vince White, Research Associate in Air Products and Chemicals Inc.’s Energy Technology Division, gave a presentation about the Air Products CO_2 Capture from Hydrogen Facility Project. This is a large-scale commercial project that will demonstrate a state-of-the-art system to concentrate CO_2 from two steam methane reformer (SMR) hydrogen production plants, and purify the CO_2 to make it suitable for sequestration by injection into the existing West Hastings Field oil reservoir as part of an ongoing EOR project. To accomplish this, Air Products plans to retrofit its two Port Arthur SMRs with two vacuum swing adsorption (VSA) systems to separate the CO_2 from the process gas streams at these facilities so that the CO_2 can be compressed, dried, and delivered by pipeline. Air Products’ carbon capture processes would convert the initial gas streams, which contain more than 10% CO_2, to greater than 97% CO_2 purity with negligible impact on the efficiency of hydrogen production. The technology would remove more than 90% of the CO_2 from the process gas stream.

 Pag. 80

 Pag. 81

The commercial goal of the project is to recover and purify approx. 1 million tonnes per year of CO_2 for pipeline transport to Texas oilfields for use in EOR. The technical goal is to capture at least 75% of the CO_2 from a treated industrial gas stream that would otherwise be emitted to the atmosphere. A financial goal is to demonstrate real-world CO_2 capture economics.

After brief discussion, there was consensus by the Technical Group to recommend CSLF recognition for the project. Also, the United States delegation was requested to provide a revised Project Submission Form with enhanced details about this project, and the Secretariat was asked to send this information to all Technical Group delegates.

11. Report from Task Force to Assess Progress on Technical Issues Affecting CCS

The task force Chair, Clinton Foster, gave a brief presentation that described the background and activities of the task force. This task force was established by the CSLF Technical Group on recommendation by the PIRT. The objective was to complement the PIRT's assessment of the CCS readiness of the CSLF-recognized projects. The task force is comprised of four working groups: Capture Technologies (chaired by the United States), Transport and Infrastructure (chaired by Australia), Storage and Monitoring (chaired by Canada), and Integration (developed in cooperation with, and reported by the Global CCS Institute).

Dr. Foster reported that the task force has submitted its final report and recommended that the task force be discontinued. Technical findings from the task force would be used to assist new task forces and also as input for revisions to the TRM. Grant Bromhal of the United States mentioned that a section on Capture Technologies had been completed too late to make it into the final report. After brief discussion, Dr. Foster agreed that the task force final report would be revised to incorporate the updated Capture Technologies section. There was also consensus that the task force be ended. Dr. Foster expressed his appreciation to the chairs of the four working groups and also thanked the Research Council of Norway and the Global CCS Institute for providing additional resources.

12. Report from Risk Assessment Task Force (RATF)

Grant Bromhal, who had recently replaced George Guthrie as RATF Chair, gave a brief presentation that described the background and activities of the RATF. The RATF was formed at the November 2006 Technical Group meeting in London with the mandate to examine risk-assessment standards, procedures, and research activities relevant to unique risks associated with the injection and long-term geologic storage of CO_2. The RATF Phase I Report, completed in 2009, centered on examination of risk-assessment standards, procedures, and research activities relevant to unique risks associated with the injection and long-term storage of CO_2. The Phase I Report included an overview of risk assessment methodologies for engineered geologic systems, a literature review of risk assessment for CO_2 storage, identification of key potential risks, an overview of monitoring & mitigation options that support risk assessment, and a summary of ongoing and emerging activities in CSLF countries. One of the recommendations from the Report was that the link between risk assessment and liability should be recognized and considered. As a result, the CSLF Policy Group has formed a Task Force on Risk and Liability which will call on the Technical Group for assistance as needed.

Dr. Bromhal reported that RATF has submitted its Phase II Report, which includes a gaps assessment to identify CCS-specific tools and methodologies that will be needed to support risk assessment and a description of risk-assessment considerations related to

 Pag. 81

 Pag. 82

various phases of a CO_2 storage project. Appendices to the report include a collection of five "inFocus" outreach documents (developed by the CSLF Communications and Outreach Task Force) and a paper on "Performance-based Standards for Site Safety and Integrity". The Phase I Report had also recommended that the RATF gather information on what other organizations are doing in the area of technical risk and also conduct a feasibility assessment of developing general technical guidelines for risk assessment that could be adapted to specific sites and, local needs. However, both these activities were left undone, the former because it was deemed that the result would be a report that would very quickly become obsolete and of marginal use and the latter because the new Task Force on Risk and Liability would most likely include this as part of its mission.

Dr. Bromhal stated his intention of converting the Phase II Report into an article for the *Journal of Greenhouse Gas Control* and concluded his presentation by stating that the RATF had completed its mission and recommended that it be discontinued. There was consensus to end the RATF, and Dr. Bromhal was asked to pursue the idea of publishing the Phase II Report as a journal article.

13. Overview of Technical Group Action Plan

John Panek gave a short presentation that summarized progress on the Technical Group Action Plan since it was approved at the 2011 CSLF Ministerial Meeting in Beijing. In all there are twelve separate Actions, and the Secretariat polled Technical Group delegations to determine relative priorities. The highest ranked Action was "Storage and Monitoring for Commercial Projects", which has since been renamed as "Monitoring Geologic Storage for Commercial Projects", and a new task force chaired by Norway has formed on this Action.

Mr. Panek stated that three other Actions had also resulted in new task forces: "Technology Gaps Closure" (ranked second highest; new task force chaired by Australia), "Technical Challenges for Conversion of CO_2-EOR to CCS" (ranked fifth highest; new task force chaired by Canada), and "CO_2 Utilization Options" (ranked eighth highest; new task force chaired by the United States). The highest ranked Actions that do not currently have new task forces are "Risk and Liability" (ranked third highest) and "Energy Penalty Reduction" (ranked fourth highest).

Ensuing discussion did not result in the formation of any additional task forces or suggestions for additional Actions. There was interest in the Action on "Competition of CCS with Other Resources", but consensus was reached that the Technical Group should wait to see the forthcoming report from a similar IEA GHG study before considering a new task force on this topic. Philip Sharman of the United Kingdom stated that the Actions on "Energy Penalty Reduction" and "CCS with Industrial Emission Sources" were of interest but that he would need to check with the United Kingdom's Department of Energy and Climate Change (DECC) before he could volunteer to Chair a new task force for either of these. Clinton Foster indicated that the Global CCS Institute had shown some interest in the "Best Practice Knowledge Sharing" Action, and there was consensus that he contact the Institute to determine if it would like to lead a task force. Alternatively, CSLF members could access the Institute's work in this area. Finally, it was decided that no activity be undertaken on the "Risk and Liability" Action unless/until the Policy Group's task force in this area requests Technical Group assistance.

Mr. Panek stated that the Secretariat would provide a progress report on the Technical Group Action Plan for the next Technical Group meeting.

 Pag. 82

14. Report from Technical Challenges for Conversion of CO_2-EOR to CCS Task Force

Stefan Bachu of Canada, the Chair of this new task force, gave a short update on its mandate, timeline, and membership. EOR is a proven method for geologic storage of CO_2 and there are currently approximately 120 CO_2-EOR projects in the world, of which 112 are in the United States. The objective of the task force is to review, compile and report on technical challenges that may constitute a barrier to the broad use of CO_2 for EOR and to the conversion of CO_2-EOR operations to CCS operations. Dr. Bachu stated that economic and policy barriers are outside the scope of the task force.

Dr. Bachu stated that the task force's intention is to complete its activities and produce a final report in the third quarter of 2013, in time for the next CSLF Ministerial Meeting. Before that, the task force will have finalized its scope (i.e., identified subjects and produced a table of contents) by the 2012 CSLF Annual Meeting in October, produced a first draft of its report in time for the 2013 Technical Group meeting. Task force membership currently consists of Canada (as Chair), China, Norway, Mexico, Saudi Arabia, and the United States. Dr. Bachu mentioned that there was still time for other CSLF delegations to join if they would add to the expertise of the task force.

15. Report from CO_2 Utilization Options Task Force

Joseph Giove of the United States, the Chair of this new task force, gave a short update on its mandate, timeline, and membership. The purpose of the task force is to identify/study the most economically promising CO_2 utilization options that have the potential to yield a meaningful, net reduction of CO_2 emissions. There will be two phases of activity. The first phase (to be completed by the time of the 2012 CSLF Annual Meeting) will result in a summary of existing information regarding CO_2 utilization options, including a description of the state of each relevant technology and application; a preliminary assessment of the relative value of the utilization option to make a meaningful impact on CO_2 emission reduction; and an indication regarding the economic viability of such technologies. The second phase will provide a more thorough discussion of the most attractive CO_2 utilization options, based on economic promise and CO_2 reduction potential, possibly including an assessment of current and potential economic viability, the CO_2 reduction potential at various price points, the potential for co-production, and a discussion of research, development and demonstration (RD&D) needs.

Mr. Giove stated that the task force was looking at both consumptive and non-consumptive uses for CO_2, including as feedstock for chemicals and synthetic cement-like materials industries. In the short term, the task force decided the focus should not be solely on EOR, as a different task force already has that mission. As the new Technical Challenges for Conversion of CO_2-EOR to CCS task force scopes out its mission in greater detail in the future, it will be better known what elements of EOR can/should be covered by the CO_2 Utilization Options task force. Phase 1 activities would include a literature review, and a Phase 1 report is intended to be a deliverable at the upcoming 2012 CSLF Annual Meeting. Task force membership currently consists of the United States (as Chair), China, Germany, Netherlands, Saudi Arabia, South Africa, and the United Kingdom. Mr. Giove mentioned that the task force was open for other participants as well.

16. Report from Monitoring Geologic Storage for Commercial Projects Task Force

Lars Ingolf Eide of Norway, the Chair of this new task force, was unable to attend so Trygve Riis provided a short update on the scope, schedule, and membership. The objective of the task force is to perform initial identification and review of new and updated standards for storage and monitoring of injected CO_2, and the application of such standards should inform CO_2 crediting mechanisms. The planned scope includes identification and review of existing standards for geological CO_2 storage and monitoring on an annual basis; identification and review of existing guidelines for communication with and engagement of involved communities and regulators on an annual basis; identification of shortcomings and/or weaknesses in standards/guidelines; communication of findings to the ISO's CCS Working Group (that has already been established); production of annual summaries of new as well as updated standards, guidelines and best practice documents regarding geological storage of CO_2 and monitoring of CO_2 sites; and following the work of other CSLF task forces related to CO_2 storage.

Mr. Riis stated that the task force's intention was to complete an initial compilation of standards (based on a literature review) in time for the 2012 CSLF Annual Meeting. A final report on standards and guidelines would be finished in the third quarter of 2013, in time for the next CSLF Ministerial Meeting. At that time, a decision would be made on whether to continue the task force, and such a decision could depend on progress made by the ISO's CCS Working Group in this area. Current membership in this task force consists of CSLF delegates and stakeholders from Norway (including the Chair), China, Denmark, the European Commission, France, Germany, the United Kingdom, and the United States. Mr. Riis mentioned that additional members are welcome who can add to the expertise of the task force.

17. Report from Technology Gaps Closure Task Force

Richard Aldous of Australia, the Chair of this new task force, gave a short update on its mandate, timeline, and membership. The purpose of the task force is to identify and monitor key CCS technology gaps and related issues and recommend any R&D and demonstration activities (both short term and long term) that address these gaps and issues. The intention is to build on some of the results from the Task Force to Assess Progress on Technical Issues Affecting CCS, with results from this task force feeding into future versions of the TRM. The planned scope includes determining technology areas and sub-areas of interest, identifying gaps and opportunities in each area, and developing recommendations for faster progress in addressing these gaps. This could possibly include identifying opportunities for international collaboration on technology development.

Dr. Aldous stated that the intention was to have a preliminary report in time for the upcoming 2012 CSLF Annual Meeting that would list technology areas of interest to the task force, and identify and rank technology gaps in each of these areas. By the time of the 2013 Technical Group meeting, the task force would produce a draft report that would focus on the most important gaps, with recommendations how these gaps could be closed. This report would then be finalized by the third quarter of 2013, in time for the next CSLF Ministerial Meeting. Current membership in this task force consists of Australia (as Chair), Korea, Norway, and the United States, and Dr. Aldous stated his preference that each of these CSLF delegations appoint one expert on CO_2 capture and one expert on CO_2 storage.

Ensuing discussion centered on the name of this task force, and there was general agreement that the word 'gaps' was not precise enough, in that 'issues' were also part of the task force's mission. In the end, there was consensus that Dr. Aldous, as Chair of the task force, should determine a more descriptive name for this task force.

18. Presentation on the CCS Activities of University Centre in Svalbard

Gunnar Sand, Program Manager for SINTEF and Project Manager of CCS Activities for the University Centre in Svalbard (UNIS) CO_2 Lab, gave a short presentation about the CO_2 Lab and other CCS-related activities on the islands of Svalbard. Mr. Sand pointed out that Svalbard's community of Longyearbyen, at +78°13' latitude and with a population of just over 2,000, is the world's northernmost settlement and as such, makes an excellent research base for studying and monitoring climate change. Svalbard is actually an uplifted part of the Barents Sea and is made up of sedimentary rocks, including coal seams. There is coal mining there and also a coal-fueled power plant, the only one in Norway. The UNIS CO_2 Lab was established in 2007 with a vision of following the CO_2 from the source to the solution, turning Longyearbyen into a high profile green showcase demonstrating the CO_2 value chain, and developing high level field-based university studies in CCS. Mr. Sand stated that the geology of Svalbard is conducive for storage testing of CO_2 from the power plant, and initial activities of the UNIS CO_2 Lab have focused on storage reservoir characterization. Future activities are intended to include medium scale CO_2 injection with several monitoring wells.

Mr. Sand mentioned that the UNIS CO_2 Lab is also a partner in the European 'Euroscoops' Program that is proposing to implement permanent geological CO_2 storage at an industrial scale at five sites in Europe, including Longyearbyen. The activities at Longyearbyen will include developing/refining monitoring and modeling tools, conducting two injection campaigns (using water and gas), and conducting an extensive outreach program. It is anticipated that there will also be a visitor centre established at Longyearbyen to assist in these activities.

19. Update on 2012 and 2013 CSLF Technology Roadmaps

Clinton Foster provided a synopsis of the discussion on this topic from the previous day's PIRT meeting. There had been agreement on the overall importance of the TRM and that it needed updating. There has already been agreement, at the 2011 Technical Group meeting in Beijing, that the country-specific information from Module 2 of the TRM would be migrated to the CSLF website. A proposal for a new model of the TRM, based on suggestions by Richard Aldous, would chart CCUS pathways as far into the future as 2050. The current TRM only goes as far as 2020. Dr. Aldous stated that the reason for this lengthened timeline is that some countries have developed CCUS objectives that extend that far into the future. Proposed key elements for the next major revision of the TRM would include an executive summary, a relatively brief module that describes the current state of the technology, a module that describes possible scenarios for meeting long-term CCUS objectives, and a set of recommendations to national governments concerning actions needed to realize the most favorable scenarios. Dr. Foster stated that the intention is that the next major revision of the TRM would be a deliverable at the 2013 CSLF Ministerial Meeting.

There was general agreement that the TRM is one the most important products of the Technical Group, and that the Technical Group should put forth effort into getting a good, major revision completed in time for the next Ministerial Meeting. Ensuing discussion resulted in a consensus that the Technical Group was not yet ready to describe possible CCUS pathways beyond 2020, so the next major revision of the TRM would maintain that timeline. There was also consensus that, because this 2013 TRM would likely be a major undertaking, the Technical Group should focus on that and not produce a 2012 TRM. However, agreement was not reached on what the structure of the 2013 TRM should be, or the process for completing it. Several suggestions were offered concerning the TRM structure, including that the TRM should conclude with recommendations to policy makers about actions that should be taken to increase the technical knowledge base, which will lead to large scale CCUS deployment by the TRM target dates. Another suggestion was that this major revision of the TRM should be structured much like the one we have now, but not including the country and projects presentation, and with more concise descriptions of technologies.

Dr. Foster recommended that a TRM Steering Committee/Editorial Board, chaired by the Technical Group Chairman, be established to work out all details concerning the structure and schedule, and to oversee the development of the new TRM. There was consensus to do so, and that this new group would also include the Technical Group Vice Chairs, Task Force Chairs, and the CSLF Secretariat. Chairman Riis suggested that possible collaboration with other organizations (primarily the Global CCS Institute) should also be investigated.

20. Discussion of Ideas for Future Technical Group Workshops

Meeting attendees were reminded by Chairman Riis about the CO_2 Capture Interactive Workshop, which would take place in Bergen two days hence. Concerning future workshops, Stefan Bachu proposed that the topic of "Monitoring of CO_2 Storage" would be appropriate as there is knowledge to be gained from the experience of existing projects and from technological developments, and it would make for an interesting, informative, and useful event. After brief discussion, there was consensus for adopting this theme for the next technical workshop, and that it should be held in conjunction with the 2013 Technical Group meeting.

21. Date and Location of Next Technical Group Meeting

John Panek mentioned that the next CSLF Technical Group meeting would be part of the 2012 CSLF Annual Meeting in Perth, Australia. The actual date of the Technical Group meeting will be Thursday, October 25, with task force meetings scheduled for Wednesday, October 24. Preliminary information about the 2012 Annual Meeting is already available at the CSLF website (www.cslforum.org).

Sergio Persoglia of Italy stated that there was interest in his country to have the 2013 Technical Group meeting and Technical Workshop in Rome, sometime in the first half of the year. Chairman Riis thanked Dr. Persoglia for the information and asked him to further explore this possibility and inform the Technical Group at its next meeting in Perth.

22. New Business

Chairman Riis called on Tim Dixon of the IEA GHG to briefly describe his organization's recent activities that are relevant to the Technical Group. Mr. Dixon stated that a study had been completed on "Geological Storage of CO_2 in Basalts", and the final report was available to Technical Group delegates. Mr. Dixon was asked to provide the report to the CSLF Secretariat, and the Secretariat was requested to send the report to all Technical Group delegates. Mr. Dixon also informed the Technical Group that at the November 2011 United Nations COP17 Conference in South Africa, there was agreement that CCS would be included as part of the Clean Development Mechanism (CDM). Mr. Riis thanked Mr. Dixon and stated that this information might possibly be factored into future CSLF activities such as the TRM.

 Pag. 87

23. Review of Consensuses Reached, Action Items, and Next Steps

Consensus was reached on the following:

- The Illinois Basin – Decatur Project, the Illinois Industrial Carbon Capture and Storage Project, and the Air Products CO_2 Capture from Hydrogen Facility Project are all recommended by the Technical Group to the Policy Group for CSLF recognition.
- The Task Force for Assessing Progress on Technical Issues Affecting CCS is discontinued.
- The RATF is discontinued.
- Activity on the “Competition of CCS with Other Resources” Action in the Technical Group Action Plan is deferred pending review of a forthcoming IEA GHG report on this topic.
- Activity on the “Risk and Liability” Action in the Technical Group Action Plan is deferred unless/until there is a request for assistance from the Policy Group’s Risk and Liability Task Force.
- The next major revision of the TRM, planned for completion in time for the 2013 CSLF Ministerial Meeting, would keep the 2020 timeline described in the current TRM.
- There will not be a 2012 version of the TRM.
- The next CSLF Technical Workshop, anticipated during the first half of 2013, will have a “Monitoring of CO_2 Storage” theme.

Action items from the meeting are as follows:

Item	Lead	Action
1	Technical Group Chair	Provide the Technical Group’s recommendation to the Policy Group that the Illinois Basin – Decatur Project, the Illinois Industrial Carbon Capture and Storage Project, and the Air Products CO_2 Capture from Hydrogen Facility Project be recognized by the CSLF.
2	United States	Prepare a revised version of the Project Submission Form for the Air Products CO_2 Capture from Hydrogen Facility Project with enhanced details about the project.
3	CSLF Secretariat	Send the revised Project Submission Form for the Air Products CO_2 Capture from Hydrogen Facility Project to all Technical Group delegates.
4	Chair of Task Force to Assess Progress on Technical Issues Affecting CCS	Revise the task force final report to incorporate the updated Capture Technologies section.
5	Chair of RATF	Pursue the possibility of publishing the RATF Phase II Report as a journal article.
6	Australia	Contact the Global CCS Institute to determine if it would like to lead a new task force on “Best Practices Knowledge Sharing”.
7	CSLF Secretariat	Provide a progress report on the Technical Group Action Plan for the next Technical Group meeting.
8	Chair of Technical Gaps Closure Task Force	Determine a more descriptive name for the task force.

 Pag. 87

Pag. 88

Item	Lead	Action
9	Technical Group Chair	Establish and Chair a TRM Steering Committee/Editorial Board, to also include the Technical Group Vice Chairs, Task Force Chairs, and CSLF Secretariat.
10	Italy	Explore the possibility of Italy hosting the 2013 CSLF Technical Group meeting and next Technical Workshop.
11	IEA GHG	Provide a copy of the IEA GHG final report on “Geological Storage of CO_2 in Basalts” to the CSLF Secretariat
12	CSLF Secretariat	Send the IEA GHG final report on “Geological Storage of CO_2 in Basalts” to all Technical Group delegates.

24. Closing Remarks / Adjourn

Chairman Riis thanked the delegates, observers, and Secretariat for their hard work. John Panek expressed the Secretariat’s appreciation to Mr. Riis for acting as meeting host in addition to his Chairman’s role, and Mr. Riis called out Anne Kristin Kleiven, Åse Slagtern, and Aage Stangeland of the Research Council of Norway as the people who helped to make it all happen.

Mr. Riis reminded attendees of the upcoming visit to the CSLF-recognized CO_2 Technology Centre Mongstad Project on Wednesday, June 13th, and adjourned the meeting.

Pag. 88

Carbon Sequestration Leadership Forum
www.cslforum.org

Pag. 89

CSLF PIRT Meeting

Review of Plan for Updating the CSLF Technology Roadmap

Clinton Foster

Bergen, Norway

11-14 June 2012

Agenda 9

Pag. 89

Pag. 90

Technology Roadmap

- Module 0: CSLF
  - Purpose of CSLF and context - *known*
- Module 1: CCS Status
  - Fundamentals of CCS - *widely understood now*
  - Available many sources

  Module 2: Countries
  - Web-based – continuing in different format
- Module 3: Gap Identification
  - Role now fulfilled by new TG TF's
    - Focussed on current technological gaps in CCS
    - Specific technology-based reporting
- Module 4: TRM
  - Charter & Vision - discuss

Pag. 90

Pag. 91

Technology Roadmap: Evolution (1)

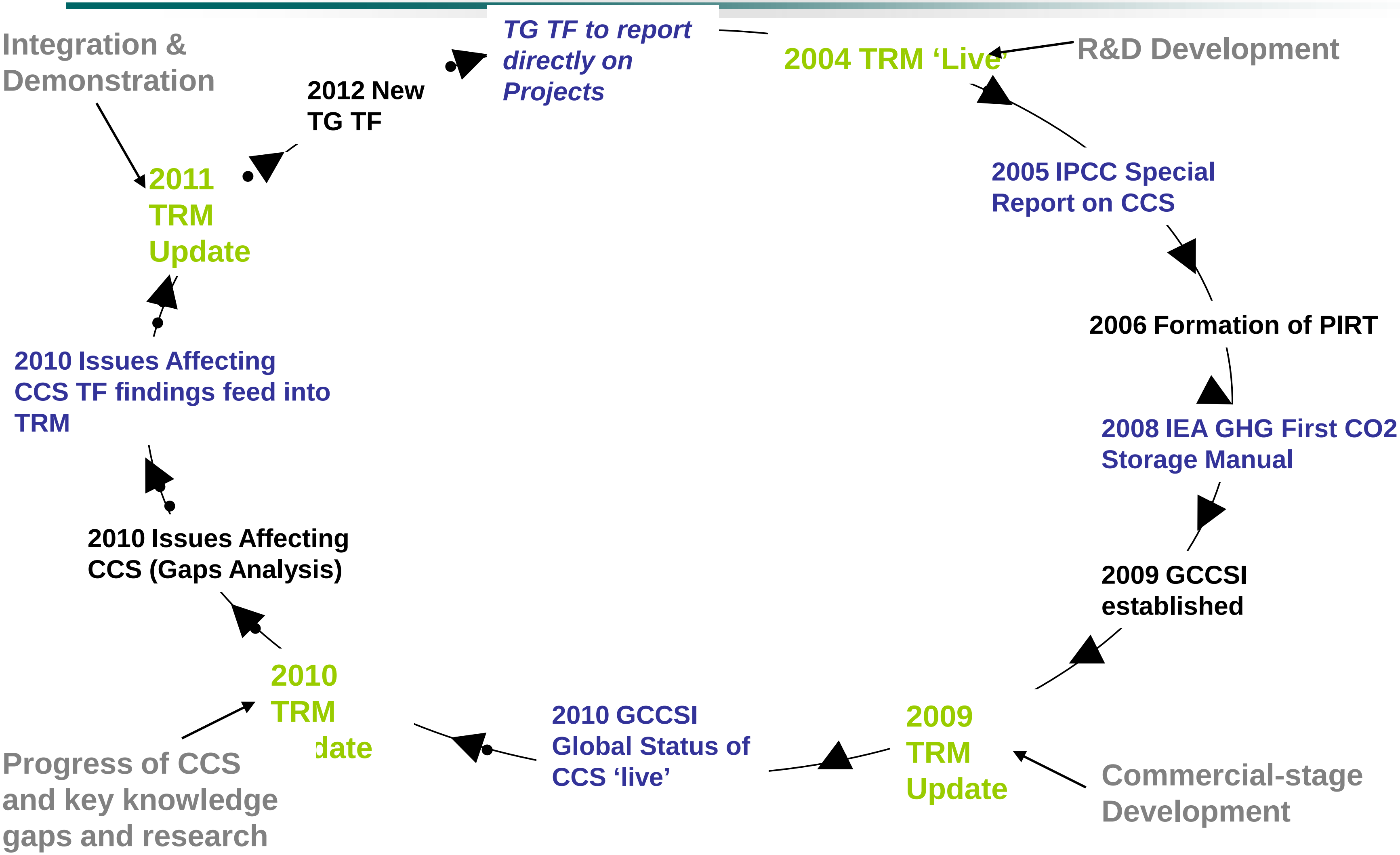
- Attempts to answer the question, "What does the CSLF Technical Group hope to accomplish by 2013, and how do we get there?"
- Incorporates vision and goals of the CSLF and the Technology Group.
- Integrates roles and responsibilities of CSLF Technical Group.
- Outlines key technical obstacles identified by various countries at the CSLF inaugural meeting, and potential projects in carbon sequestration.

George Lynch, CSLF Secretariat, Rome 2004

Pag. 91

Pag. 92

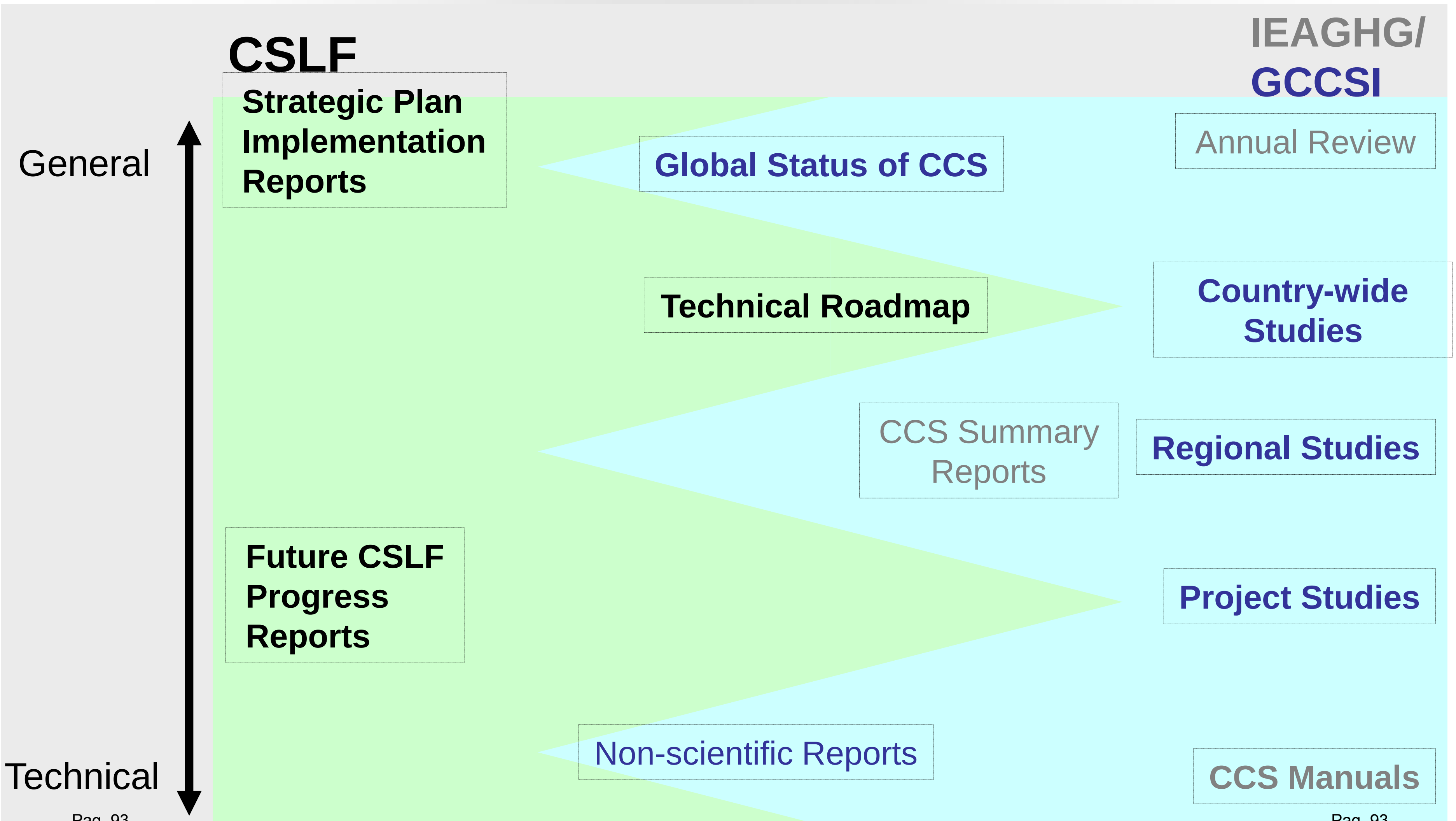
Technology Roadmap: Evolution (2)



Pag. 92

Pag. 93

Technology Roadmap: Evolution (3)



Pag. 93

Pag. 94

Technology Roadmap: Future

- Are we beyond the TRM in current mode?
  - Is general reporting CSLF role? Other agencies
- Obsolete?
  - Superseded by the new TG TF
  - Gather data from CSLF-recognised Projects and report to TG
- Other documents (CCS Fundamentals)
  - IEAGHG: from fundamentals to technical
  - GCCSI: from general policy to global overviews

Pag. 94

Pag. 95

CSLF Progress Report

- New TG Task Forces:
  - Focus on specific technologies identified as technology issues in CCS
  - Focus on reporting on progress on technology issues in CCS
  - Focus future CSLF-projects

Pag. 95

Carbon Sequestration Leadership Forum
www.cslforum.org

Pag. 96

The Technical Group Task Forces

Action Plan 1	**Technology Gaps Closure**
Action Plan 2	**Best-Practice Knowledge Sharing**
Action Plan 3	**Energy Penalty Reduction**
Action Plan 4	**CCS with Industrial Emissions Sources**
Action Plan 5	**CO_2 Compression and Transport**
Action Plan 6	**Storage and Monitoring for Commercial Projects**
Action Plan 7	**Technical Challenges for Conversion of CO_2 EOR to CCS**
Action Plan 8	**Competition of CCS with Other Resources**
Action Plan 9	**Life Cycle Assessment and Environmental Footprint of CCS**
Action Plan 10	**Risk and Liability**
Action Plan 11	**Carbon-neutral and Carbon-negative CCS**
Action Plan 12	**CO_2 Utilization Options**

Pag. 96

Pag. 97

CSLF Progress Report

- New TG TFs to derive information for *specific, focussed-technologies* from:
  - CSLF-recognised Projects
  - worldwide CCS progress

Build the 'Progress Reports' in real-time for policy-driven decision making for CSLF Ministers

(core goal of CSLF)

Pag. 97

Pag. 98

The Research Council of Norway

Norwegian instruments for promoting CCS development

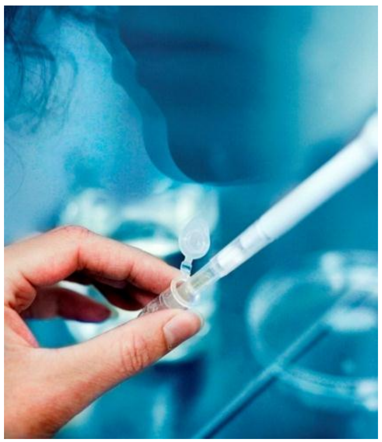
Mongstad June 13th, 2012

Åse Slagtern

Pag. 98

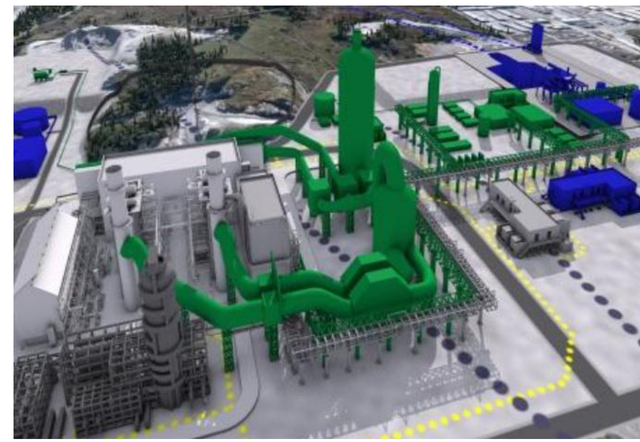
Norwegian Public funded CCS projects

- R&D



- TCM

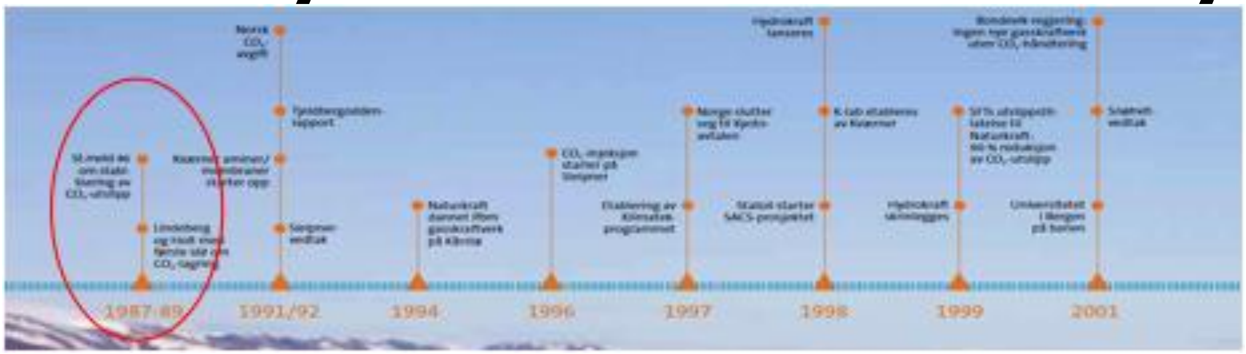
- Full scale CCS at Mongstad



- Public funding for CCS 2012
  - Mongstad: 2 900 M NOK (£ 330 Million)
  - CLIMIT, research centres, infrastructure, NORDICCS: 200 M NOK (£ 23 Million)

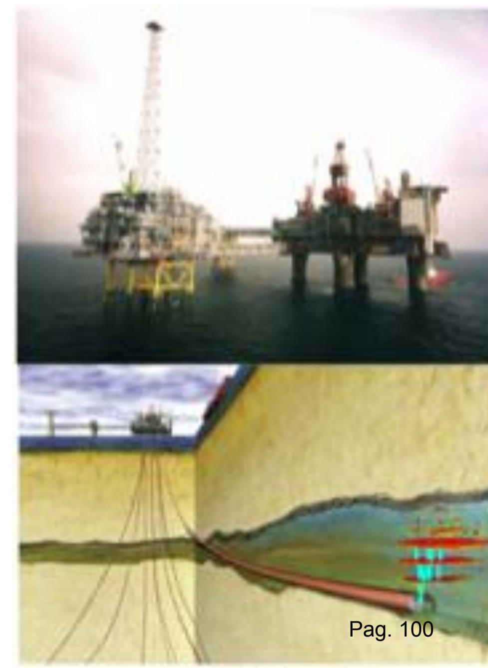
Pag. 100

The early start of CCS in Norway




Erik Lindeberg

- Erik Lindberg and Torleif Holt of SINTEF introduces gas power with CO_2-capture and EOR
- Parliament White paper 46 (1988/89)
- CO_2-tax is introduced (1991)
- Statoil decides CO_2-storage at Sleipner (1996)
- Early R&D followed by several large projects (KMB CO_2 (2002)


Illustrasjoner: Statoil

Pag. 100

Pag. 101

Norwegian CCS instruments

The Research Council of Norway

- CLIMIT Programme
  - R&D
  - Knowledge-building Projects for Industry
  - Innovation Projects for the Industrial Sector
  - Pilot/ Demo small scale
- Centres for Environment-friendly Energy Research (FME)
- National Infra structure/ESFRI ECCSEL
- Top-level Research Initiative NORDICCS

Gassnova

- CLIMIT Programme (Innovation Projects for the Industrial Sector; Pilot/ Demo small scale)
- Technology Center Mongstad (TCM)
- Carbon Capture Mongstad (CCM)

Market

- CO_2-price
- CO_2-tax
- .....
- .....

Financing bodies:

- **Ministry of Petroleum and Energy**
- **Ministry of Education and Research**

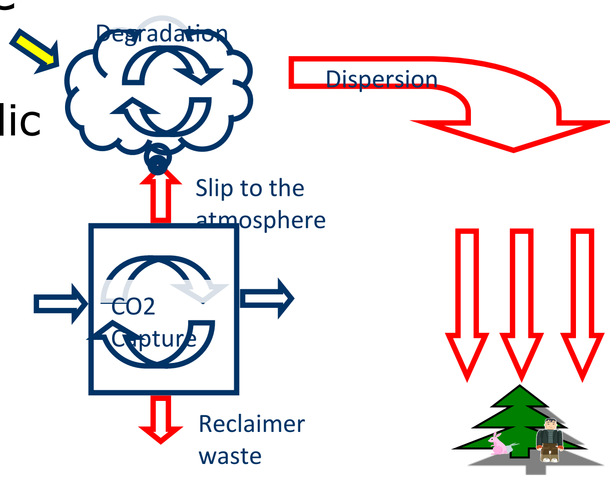
Pag. 101

Pag. 102

CLIMIT

Climit:
A financial instrument for realisation of CCS

- The Norwegian RD&D CCS programme since 2005
  - About 900 M NOK (125 M euro) in public funding for about 200 projects since 2005
- Climit-R&D - administrated by the Research Council of Norway
  - Budget 2012: 90 MNOK (12 M euro)
- Climit-Demo - administrated by Gassnova
  - 82 M NOK (11 M euro) is transferred to the program from public funds each year



CO_2 CO_2 CO_2 CO_2

Pag. 102

Post combustion Norway – R&D to application

- R&D projects conducted by the ACC (Aker Clean Carbon) and SINTEF
- Comprehensive program for the PhD program is established
- Pilot constructed at Tiller
- Significant cost reduction for capture using amines has been achieved

Pag. 104

CO_2 capture test facility at Norcem's cement plant in Brevik, Norway

- Pre-project on the design of test facilities for post-combustion CO_2 capture from cement production
- Norcem A/S, HeidelbergCement og ECRA (European Cement & Research Academy)
- 2010 – 2011, 13 500 kNOK/ 50 % support from CLIMIT
- Technologies:
  - Aker Clean Carbon, amine
  - Alstom Carbonate looping and Chilled Ammonia
  - Small scale testing of membrane technology
- Focus on utilization of waste heat from the cement production
- Phase II (2012- 2016) – currently application to Climit on construction and testing

Pag. 104

Pag. 105
CLIMIT

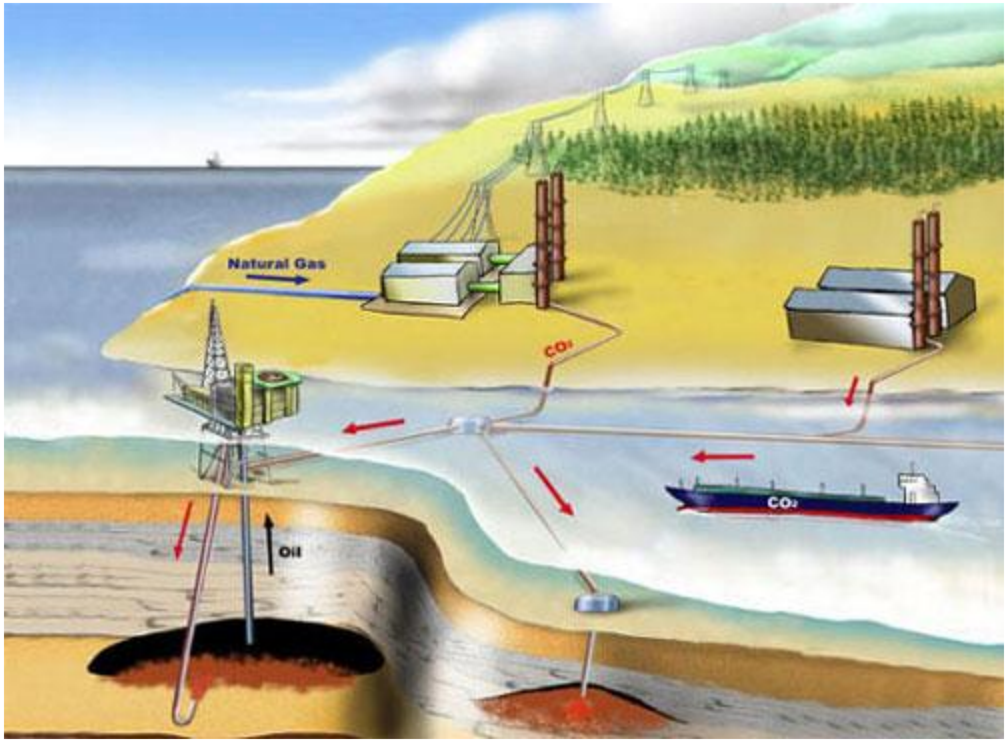
Innovative capture technologies – BIGCO2

BIGCO2 is an international collaborative research project lead by SINTEF in the period 2007-2011

Achievements have been obtained:

- Membranes
- CLC - Chemical looping combustion
- Pressurized combustion
- Improved post combustion
- Power cycles

BIGCO2 has contributed to SINTEF's international standing within CCS R&D and laid the basis for several new important projects



Pag. 105

Pag. 106

Longyearbyen CO_2 lab

- The well is drilled
- The reservoar is tested with water injection
- Injection of CO_2 is planned
- Increased knowledge about injection of CO_2, the reaction and flow of CO_2 in the reservoar

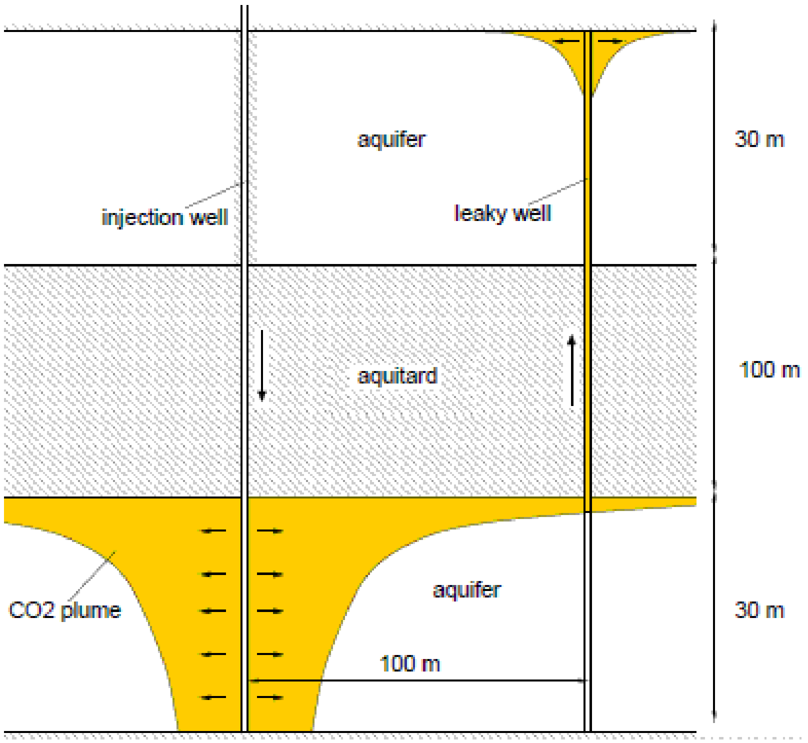
Pag. 106

The Research Council of Norway
Pag. 107

Risk assessment of CO_2-storage

CLIMIT

- MatMoRA: Geological Storage of CO_2: Mathematical Modelling and Risk Assessment
  - Project manager: UiB
  - Partners: SINTEF, Univ. Stuttgart, Princeton Univ., Hydro, Statoil, Shell
  - Budsjett: 20,5 mill NOK (2007-11)
- Results: Developed analytical and numerical tools to be used fir risk assessment related to CO_2-storage



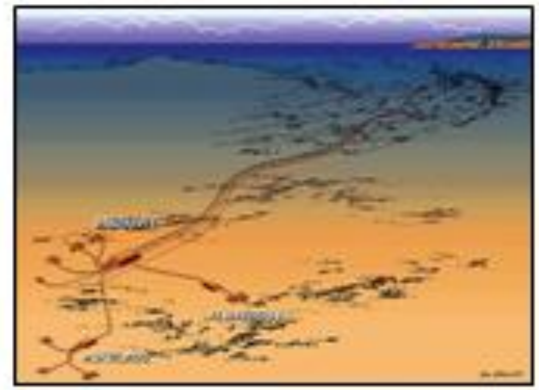
Pag. 107

Pag. 108

CLIMIT

Guidelines for CCS

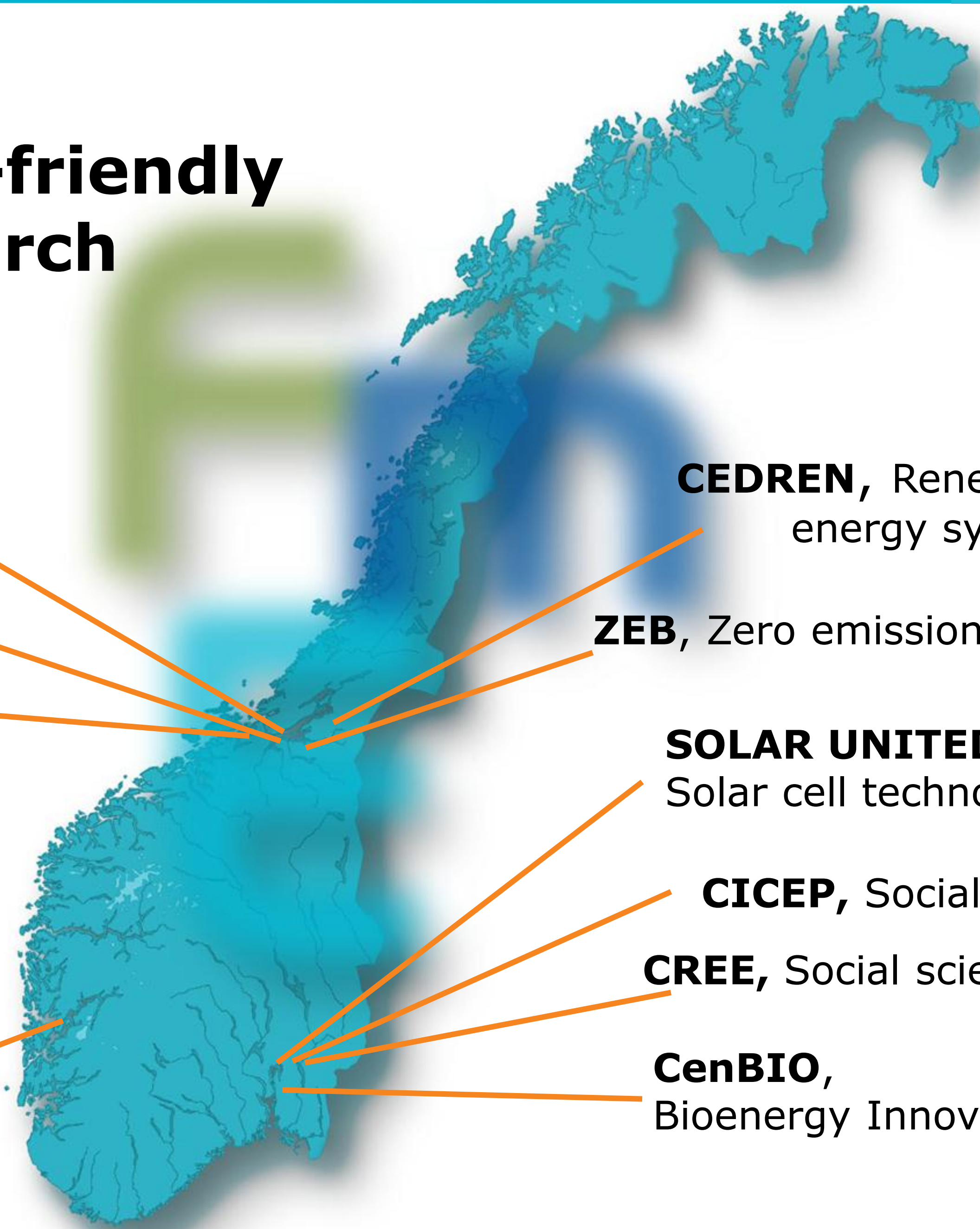
- **Project leader: DNV**
- **3 projects on guidelines for CCS:**
  - Qualification of new CO_2 capture technology
  - Transmission of dense, high pressure CO_2 in submarine and onshore pipeline
  - The CO_2 QUALTORE Guideline
    - Qualification of sites and project for geological storage of CO_2
    - *www.dnv.com/co2qualstore/*



Pag. 108

Pag. 109

Centres for Environment-friendly Energy Research



BIGCCS, CCS

NOWITECH, Offshore wind technology

CENSES, Social science

NORCOWE, Offshore wind energy

SUCCESS; CO_2 storage

CEDREN, Renewable energy systems

ZEB, Zero emission buildings

SOLAR UNITED, Solar cell technology

CICEP, Social science

CREE, Social science

CenBIO, Bioenergy Innovation

Pag. 109

Pag. 110

ECCSEL - a pan-European distributed research infrastructure

1. Norway (NTNU, SINTEF, RCN)
2. France (IFPEN & BRGM)
3. The Netherlands (TNO)
4. Germany (DLR)
5. United Kingdom (BGS)
6. Switzerland (ETHZ)
7. Spain (CIUDEN)
8. Italy (OGS, ENEA)
9. Greece (CERT/ISFTA)
10. Poland (PGI-NRI)

Estimated construction costs: 200-250 mill. Euro

Pag. 110

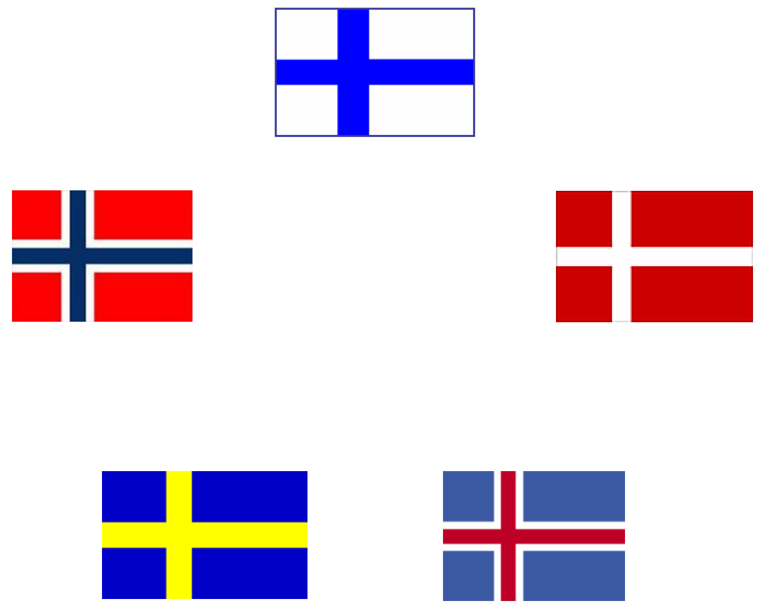
Pag. 111

TFI - NORDICCS

norden
Top-level Research Initiative

- NORDICCS is the Nordic CCS research and innovation platform involving the major CCS stakeholders in the five Nordic countries

- Duration: 4 yrs
- Budget: 46 million NOK



SINTEF
VTT
tel·tek
GEUS
Orkuveita Reykjavíkur
NORCEM HEIDELBERGCEMENT Group
SGU Sveriges geologiska undersökning
Statoil
HÁSKÓLI ÍSLANDS
GASSCO
IVL Swedish Environmental Research Institute
NTNU – Trondheim Norwegian University of Science and Technology

Pag. 111

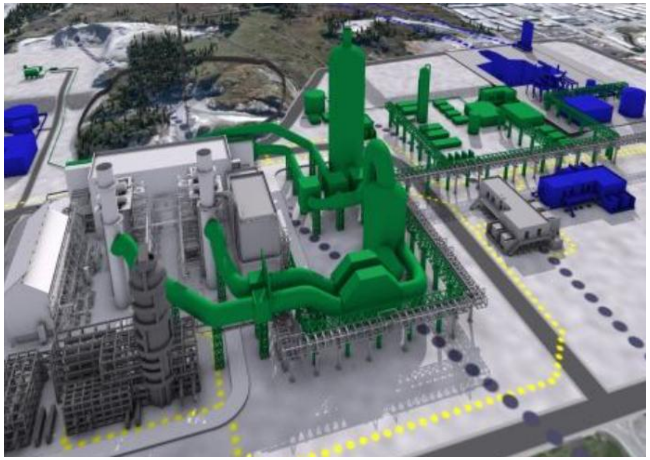
Pag. 112

Large CCS projects in Norway

- Large capture pilot - TCM
  - TCM (Technology Center Mongstad) with capacity 100 k ton/yr will be in operation spring 2012

- Full scale project
  - Full scale CCS at the Mongstad refinery is planned with decision of investment at latest 2016

- Offshore projects
  - Sleipner: 1 million ton CO_2 stored annually since 1996.
  - Snøhvit: 0,7 million ton CO_2 will be stored annually stored at full operation
  - CO_2 is separated from natural gas in both projects



Pag. 112

Summary/Conclusion

- The Technology Center Mongstad – the world's largest CCS test facility
- Although on a smaller scale , there has been done considerable investments in CCS research infrastructure in Norway the recent years (Climit, FME)
- New projects are starting up (NORDICCS, ECCSEL)
- Further interaction between TCM and the research community will follow
- More knowledge is still to be extracted from the ongoing full scale and demo CO_2-storage projects

R&D-efforts are still needed to:

- Mature the existing technology and reduce costs
- Develop new technologies
- Introduce the concept of large underground CO_2-storages

Pag. 114

CCS DEVELOPMENT IN NORWAY

GASSNOVA

Bjørn-Erik Haugan, CEO,

Gassnova SF, the Norwegian state enterprise for CCS

Pag. 114

Pag. 115

SLEIPNER: 16 YRS OF SUB SEA BED CO_2 STORAGE

Photo: StatoilHydro

Pag. 115

Pag. 116

GASSNOVA

NORWAY PUNCHING ABOVE IT'S WEIGHT IN CCS

- Oil and energy cluster
- R&D based industrial development
- Financial resources
- Making fossil fuels sustainable
- A driving force vs. the climate challenge

Pag. 116

Pag. 117

GASSNOVA

Gassnova SF
The Norwegian State Enterprise For CCS

CLIMIT : R&D programme

– R&D Grants

Projects

– Demo projects

– Govt/Industry Partnering

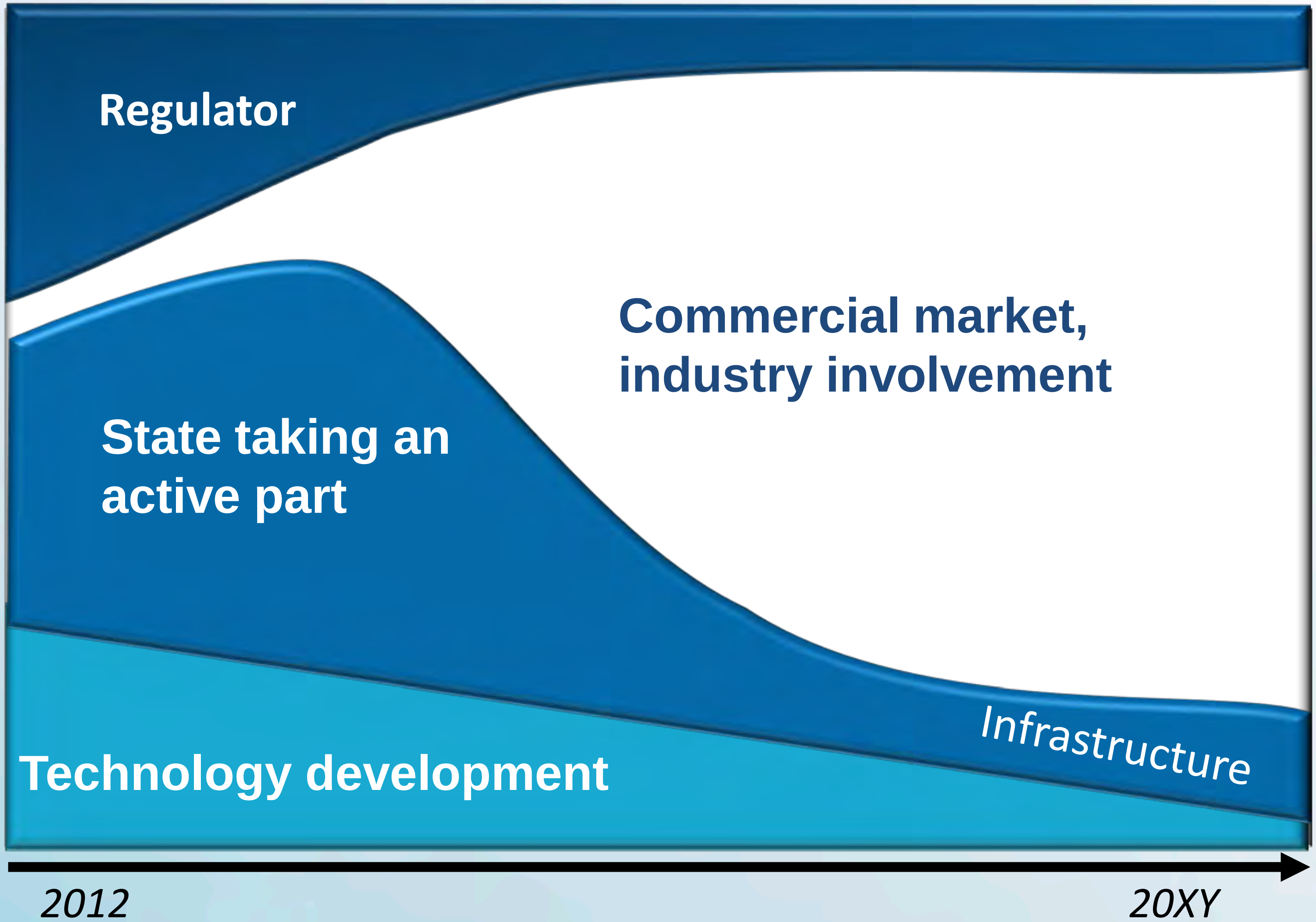
Advisor to the authorities

Pag. 117

Pag. 118

GASSNOVA

CCS IN NORWAY - STATE INVOLVEMENT

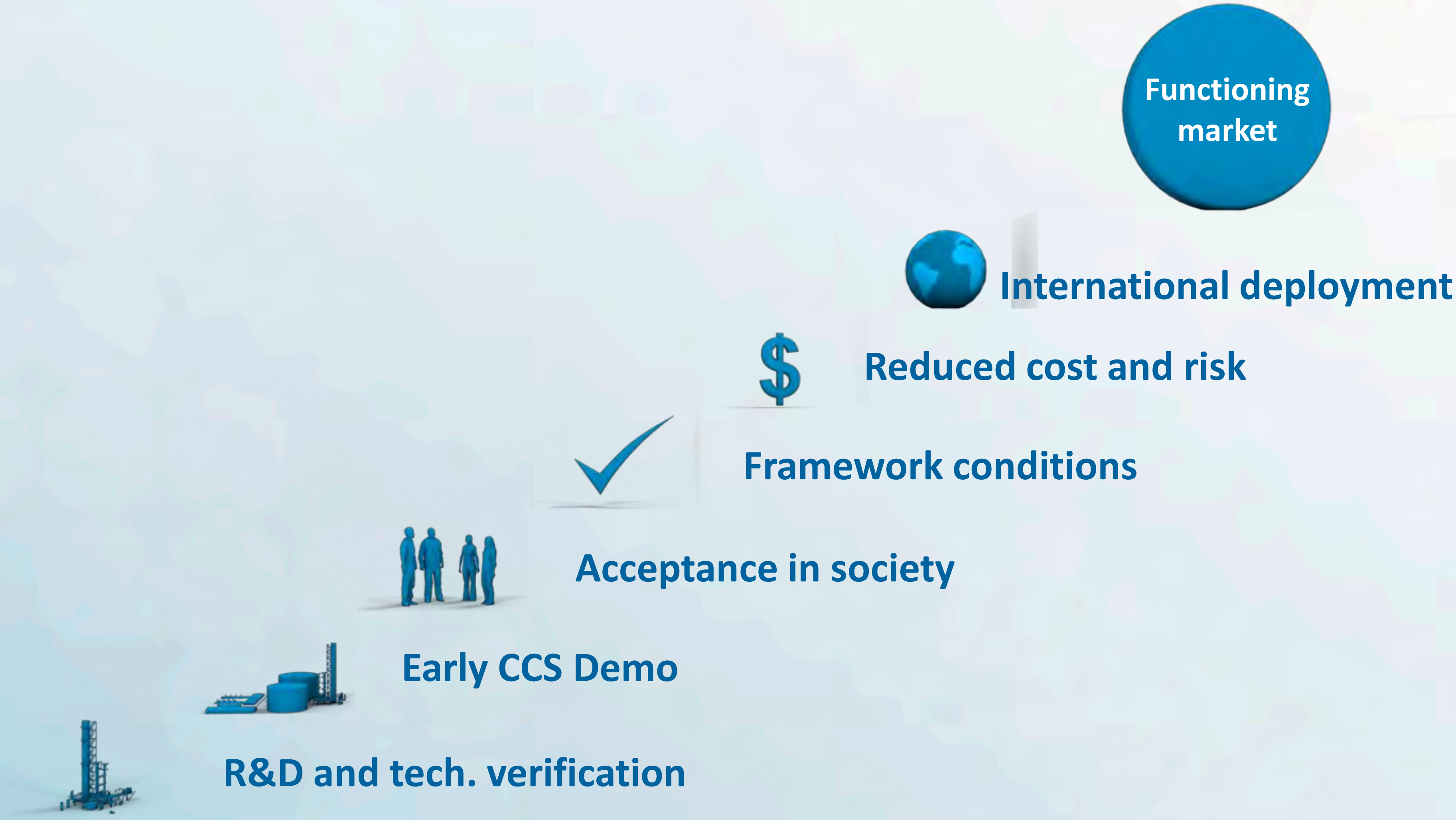


Pag. 118

Pag. 119

CCS For a Better Climate

GASSNOVA



Pag. 119

Pag. 120

GASSNOVA

PROJECTS

- **CO_2 Technology Centre Mongstad (TCM)**
  - Opened May 7th 2012
- **Full-scale CO_2 Capture Mongstad (CCM)**
  - Concept decision and technology qualification
  - FID 2016
- **Transport and storage Mongstad**
- **Norwegian CCS Study**

Pag. 120

Pag. 121

MONGSTAD

Pag. 121

Pag. 122

Pag. 122

Pag. 123

GASSNOVA

CO_2 TECHNOLOGY CENTRE MONGSTAD (TCM): AMBITIONS

- Verify CO_2 capture technology owned by vendors
- Reduce cost and risk
- Development of market
- International deployment

Pag. 123

Pag. 124

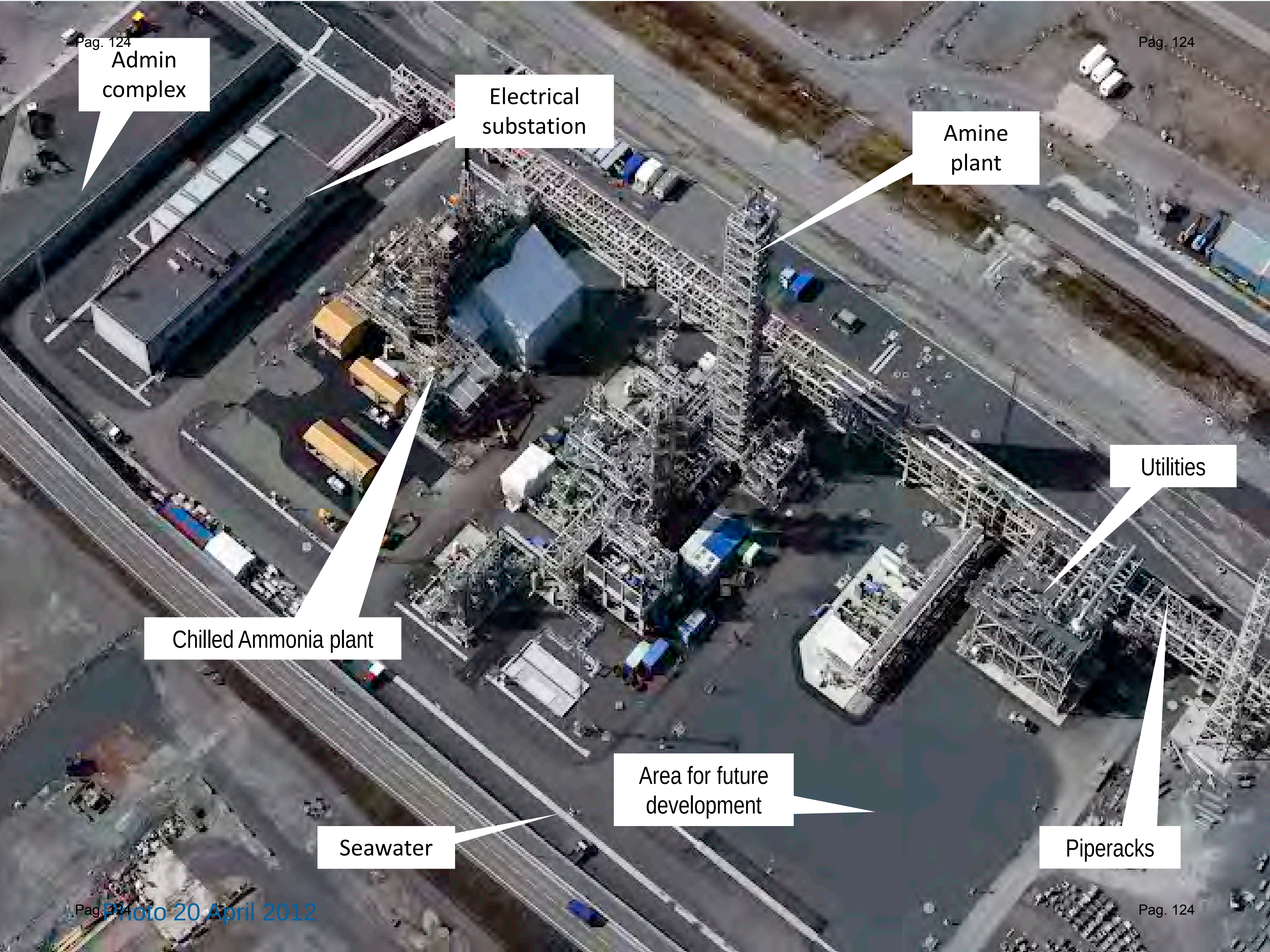


Photo 20 April 2012

Pag. 124

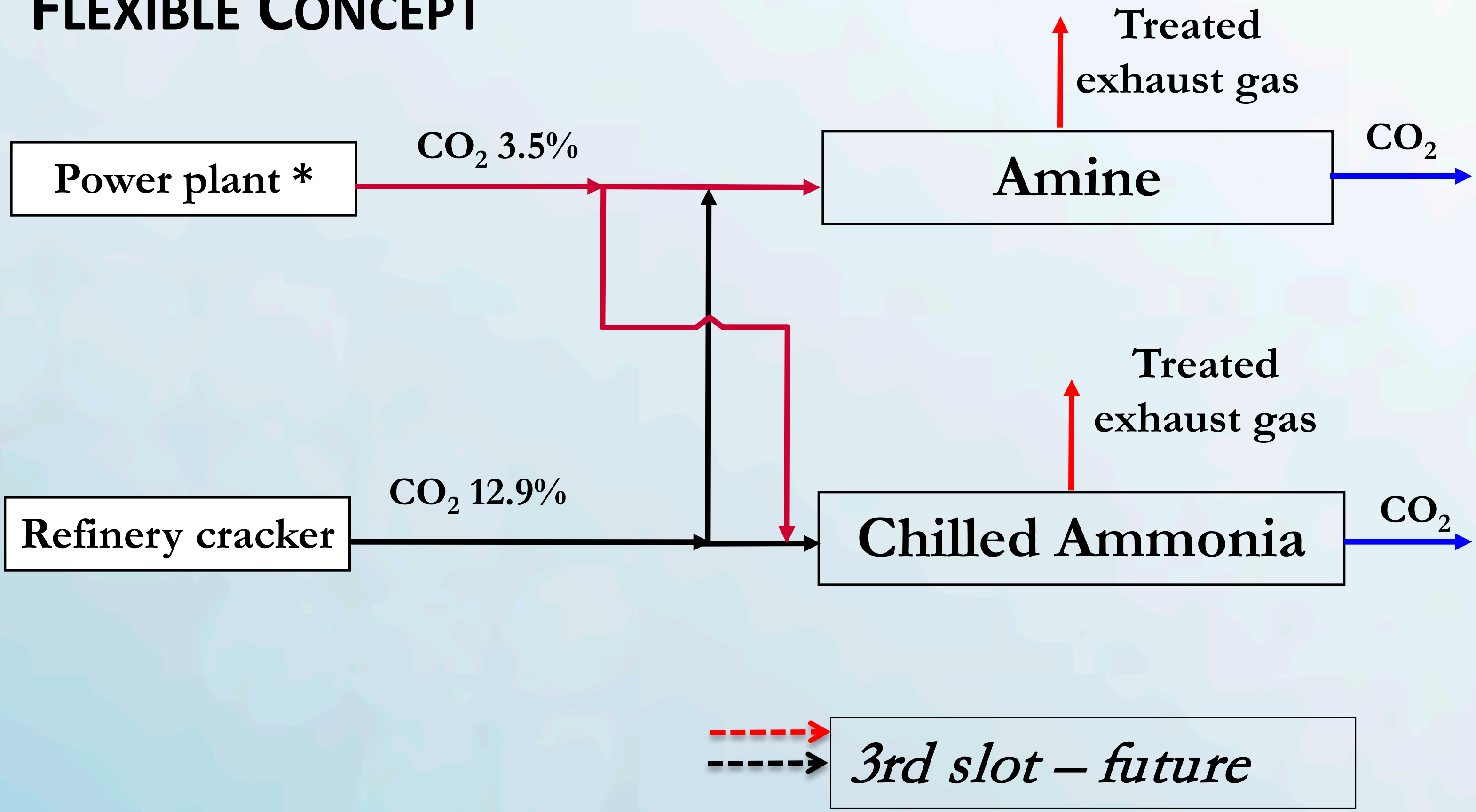
Pag. 125

CO_2 TECHNOLOGY CENTRE MONGSTAD

GASSNOVA

CAPACITY 100 KT/YR

FLEXIBLE CONCEPT

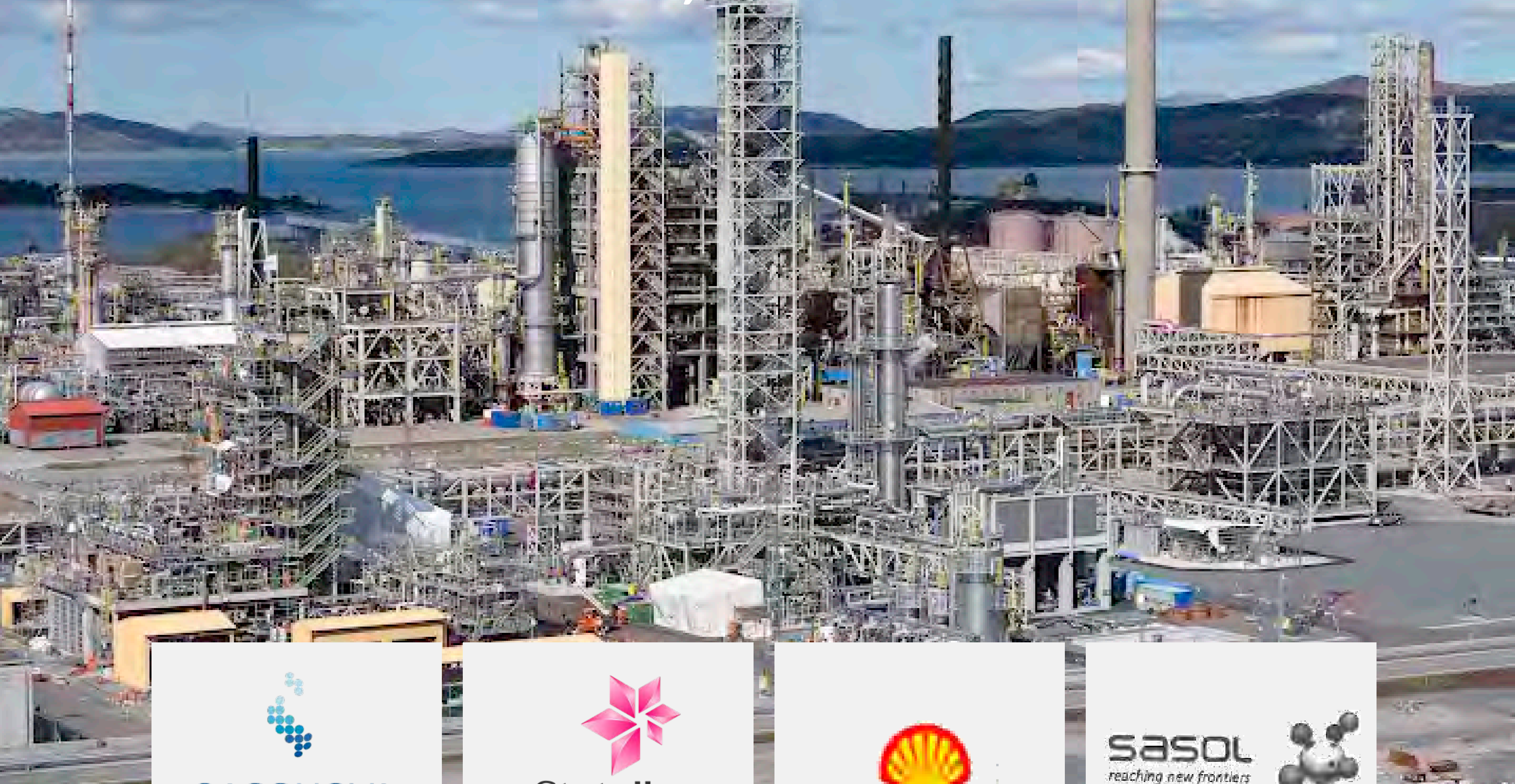


* CHP design capacity of 280MW electricity and 360MW heat

Pag. 125

Pag. 126

CO_2 TECHNOLOGY CENTRE MONGSTAD (TCM) OFFICIAL OPENING: 7 MAY, 2012



GASSNOVA	Statoil	Shell	Sasol (reaching new frontiers)
75.12%	20%	2.44%	2.44%

Pag. 126

Pag. 127

Pag. 127

Pag. 129

GASSNOVA

PRESS CLIP

Oil and Gas Journal, 08.05.2012

http://www.ogj.com/articles/2012/05/mongstad-carbon-dioxide-test-center-opens.html


OIL&GAS JOURNAL
International Petroleum News and Technology
Click to read THIS WEEK'S ISSUE! or SUBSCRIBE today! For PAST ISSUES click HERE
HOME GENERAL INTEREST EXPLORATION & DEVELOPMENT DRILLING & PRODUCTION PROCESSING TRANSPORTATION
HOME MORE PROCESSING NEWS MONGSTAD CARBON DIOXIDE TEST CENTER OPENS
Mongstad carbon dioxide test center opens
Social Media Tools
TOPIC INDEX
VIDEO LIBRARY
MOST POPULAR

Reuters, 07.05.2012

http://in.reuters.com/article/2012/05/07/us-norway-carboncapture-idINBRE8460SE20120507


REUTERS
Unambiguous Calls With Powerful Call To Action Only On
vantagetrade
ARTICLE
Know how to be on top of the stock market game
Fill in the form to find out how:
Norway opens major facility to test carbon capture
(Reuters) - Norway on Monday launched the world's largest facility of its kind to develop carbon capture and storage (CCS), the so-far commercially unproven technology that would allow greenhouse gases from power plants to be buried safely underground.
MORE REUTERS RESULTS FOR: "mongstad inauguration"

BusinessGreen, 07.05.2012

http://www.businessgreen.com/bg/news/2173094/-worlds-largest-ccs-test-bed-issues-uk-pioneers


businessGreen
Sustainable thinking
HOME NEWS IN DEPTH REVIEWS BLOGS VIDEO EVENTS
YINGLI SOLAR
Proven Experience Over 3 GW globally
Home News Energy Clean Coal
"World's largest" CCS test-bed issues call for UK pioneers
Technology Centre Mongstad in Norway invites companies in UK's £1bn carbon capture competition to trial cost-cutting techniques
By BusinessGreen staff
08 May 2012
Be the first to comment
Print Send Save
Get similar articles delivered to your inbox
UK carbon capture and storage (CCS) developers are being offered the chance to trial their technology at what is being hailed as the "world's largest dedicated testing centre".
The Week in Green
BusinessGreen Daily

Pag. 129


BBC
News Sport Weather Travel Future TV
NEWS SCIENCE & ENVIRONMENT
Home UK Africa Asia Europe Latin America Mid-East US & Canada Business Health
11 May 2012 Last updated at 00:56 GMT
Norway aims for carbon leadership
By Richard Black
Environment correspondent, BBC News, Mongstad, Norway

Pag. 129

Pag. 130

GASSNOVA

INTERNATIONAL COOPERATION

- **International deployment of technology:**
  - R&D&D projects potential funding by CLIMIT
  - Participation in international demo (TCM) and full scale projects (CCM)
  - Vendors and technology users
  - A world market for technology
- **A functioning market:**
  - Harmonized framework conditions and regulation
  - Carbon price

Pag. 130

Full Scale CO_2 Capture Mongstad (CCM) Investment decision 2016

Pag. 131

GASSNOVA

TECHNOLOGY QUALIFICATION PROGRAMME

- **Amine technologies:**
  - Aker Clean Carbon AS (Norway)
  - Mitsubishi Heavy Industries LTD (Japan)
  - Powerspan management Company LLC (USA), with Huaneng Clean Research Institute (China)
- **Chilled ammonia technology:**
  - Alstom Carbon Capture Gmbh (Germany)
- **Amino acid salt technology:**
  - Siemens AG, Energy sector (Germany)

Pag. 131

Pag. 132

Pag. 133

Thank you for your attention

Pag. 133

Pag. 134

Allegato 2.

Partecipazione alla IEA (International Energy Agency)

agenda della riunione del Working Party on Fossil Fuels

presentazione attività in Italia

nota sulla situazione del Progetto Porto Tolle

statement della Piattaforma tecnologica europea ZEP al COP17

Pag. 134

For Official Use **IEA/CERT/FF/WP/A(2011)2**

International Energy Agency
Organisation for Economic Co-operation and Development

Dist : November 2011

English Text Only

INTERNATIONAL ENERGY AGENCY
COMMITTEE ON ENERGY RESEARCH AND TECHNLOGY

For Official Use

WORKING PARTY ON FOSSIL FUELS

Agenda for the Sixty-First Meeting

12-13 December 2011

Keith Burnard
Senior Energy Technology Specialist
Energy Technology Policy Division
International Energy Agency

Tel: +33 1 40 57 67 85
Fax: +33 1 40 57 67 59
E-mail: keith.burnard@iea.org

Or. Eng.

DRAFT

The 61st WPFF meeting will be held in Paris, France, 12 - 13 December 2011.

Agenda of the 61st WPFF Meeting

Monday, 12 December 2011

13:30-15:00	**OPENING AND FORMALITIES** **Session 1. Opening and Formalities**
	1.1 Welcome to the 59th WPFF Meeting *Mr. Jostein DAHL KARLSEN, WPFF Chair*
	1.2 Adoption of the Agenda — IEA/CERT/FF/WP/A(2011)2 *Note by the IEA Secretariat*
	1.3 Draft Minutes of the 58th WPFF Meeting — IEA/CERT/FF/WP/M(2011)2 *Note by the IEA Secretariat*
	1.4 Welcome to IEA *Mr. Lew FULTON, IEA Secretariat*
	1.5 Report from the Committee on Energy Research and Technology (CERT) *Mr. Bert STUIJ, The Netherlands*
15:00-15:30	***Coffee break***
15:30-17:30	**IEA ACTIVITIES** **Session 2. IEA Activities**
	2.1 World Energy Outlook 2011 *Mr. Pawel Olejarnik, IEA Secretariat*
	2.2 Energy Technology Perspectives 2012 *Mr. Markus WRÅKE, IEA Secretariat*
	2.3 Coal and Gas Markets Outlook *Mr. Laszlo VARRO, IEA Secretariat*
	2.4 TBC *TBC, IEA Secretariat*
	Wrap-up Day 1 and announcements
17:35	**Close Day 1**

DRAFT
Tuesday, 13 December 2011

09:00-10:15	**WPFF STRATEGY AND WORK PROGRAMME** **Session 3 – Activities of the IEA's CCS Unit** 3.1 Incentive policies for CCS *Mr. Wolf HEIDUG, IEA Secretariat* 3.2 CCS in China - status and challenges *Mr. Dennis BEST & Ms. Ellina LEVINA, IEA Secretariat* 3.3 CO2-EOR and CO2 storage - taking stock of issues *Mr. Sean MCCOY, IEA Secretariat*
10:15-10:45	***Coffee break***
10:45-12:15	**Session 4. High-level Policy Dialogue on CCS Implementation** 4.1 Update on Joint Activities with China *Mr. Keith BURNARD, IEA Secretariat* 4.2 Prospects for CCS Demonstration in the UK *TBC, DECC, UK* 4.3 Stakeholder Perspectives in the UK *Mr. Jeff CHAPMAN, UK* 4.4 Australian Policy on Carbon Pricing *Ms. Niki JACKSON, Australia*
12:15-13:45	***Lunch***
13:45-15:30	**Session 5 – Next Generation Fossil-Fuel Technologies** 5.1 German R&D programme *Mr. Hubert HÖWENER, Germany* 5.2 Technology Routes to Future Fuels – Commercial Perspectives of Gas to Liquid and Coal to Liquid Energy Supply *Mr. Andreas EKKER, Shell* 5.3 Report of Visit to Shenhua's DCL Plant *Mr. Jostein DAHL KARLSEN, Norway* 5.4 Economics of Coal Liquefaction *Mr. Laszlo VARRO, IEA Secretariat*

DRAFT

15:30-16:00	***Coffee break***
	5.5 European Shale Gas *TBC, Poland*
16:20-17:00	**WPFF TECHNOLOGY NETWORK** **Session 6 – Reports from Delegates, Implementing Agreements and Expert Groups**
	6.1 Update on EC Fossil Fuel-related Activities *Mr. Pierre Dechamps, EC*
	6.2 European Commission – Update from RTD *Mr. Vassilios KOUGIONAS, EC*
	6.3 CCC IA and GHG IA *Mr. John TOPPER, CCC IA*
17:00-17:15	**CLOSING SESSION** **Session 7 – Wrap-up by chairman**
	7.1 Date and location of next meeting *Mr. Jostein DAHL KARLSEN, Norway*
17:15	***End of Meeting***

Pag. 139

ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

IEA Working party on Fossil Fuels

Sixty-First Meeting

CCS in Italy within EU frame work: EERA Joint Programme and Industrial Initiative

Giuseppe Girardi

ENEA
Sustainable fossil fuels and CCS

SOTACARBO
vicePresident

giuseppe.girardi@enea.it

iea International Energy Agency

12 – 13 December 2011, Paris

Pag. 139

ENEA research centres and Sotacarbo

Pag. 140

ENEA activities

- R/D/D
- Support/advice for MSE and Government
- European context: EII, EERA, ZEP, FP7

Pag. 140

Pag. 141

CCS: a key solution for the EU

Greater energy efficiency + Growth in renewables + Other + CCS

CCS needs to deliver **20%** of the required global GHG cuts by 2050!

Pag. 141

Power Generation and CCS in Italy

Pag. 142

- We **had** a clear vision for power generation in the decade:
  - 25% nuclear **CANCELLED**
  - 25% coal
  - 25% renewables
  - other: fossil fuels

NEW COAL POWER PLANTS:

- Torre Valdaliga Nord (near Rome): started
- Porto Tolle: authorizations ongoing; post combustion DEMO
- Other coal power plants planned
- 1 coal plant to be realized in Sardinia, with CCS

Pag. 142

CCS: the italian policy

Pag. 143

Law n.99 on "Regulations for the development and internationalization of enterprises and on the subject of energy:

- allowing the implementation of demonstrative projects on CO_2 capture, and permanent storage of CO_2 into suitable deep geological formations;
- realizing a coal fired with CCS demo plant in Sardinia region
- R/D Plan for industrial innovation

Other national initiatives

- Funds to Sotacarbo and Carbosulcis for common project with ENEA
- R&D national programs – on CCS - for the next four years
- Strong demonstration initiatives
  - ENEL/ENI
  - Sulcis integrated project - feasibility by ENEA/Sotacarbo
  - Sotacarbo/ENEA, firstly pilot

Pag. 143

Transposition of Directive 2009/31

Pag. 144

- **Transposition has been done** (decree n. 162, Sptember 2011) after a wide consultation with stakeholders, mainly regional governments and local administrations: now Italy is one of the two members States in Europa that have approved a national transposition law.
- **A national committee** will manage CO2 storage activities.
- Ministry of Economic Development will store and manage all the data concerning exploitation and storage activities of CO2.

Pag. 144

Italian programme on CCS

Pag. 145

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

	project/ responsible	NATION. FUND			REGIONAL FUND (Sardinia)	EC FUND
		Electr. System	Energy Strategy	R&D Progr.		
DEMO	**Porto Tolle** ENEL-ENI					NER 300 other
	Sulcis 400 MWe Sotacarbo/ENEA				X	NER 300 other
PILOT	**Precomb (and coal-to-liquid)** Sotacarbo/ENEA	X			X	other
	CBM-ECBM in Sulcis basin Carbosulcis-Sotacarbo-ENEA	X			X	other
	Brindisi post comb ENEL					other
	Oxycomb ITEA - ENEA					other
R&D	**pre-comb** ENEA-Sotacarbo-ERSE	X			X	X
	post-comb ERSE-ENEA-ENEL	X			X	X
	oxy-comb ENEA-ITEA-Sotacarbo-CNR				X	X
	ECBM-wells-aquifers ENI-Carbosulcis-OGS-Univ., ENEA,..	X			X	X

International Energy Agency

iea

Pag. 145

Pag. 146

EU - EIIs: European Industrial Initiatives

- To strenghten Research and industrial innovation in the energy sector
- To decrease costs and improve performances

<u>Iniziative already started</u>:

- European Wind Initiative
- Solar Europe Initiative (sia fotovoltaico che termodinamico)
- European electricity grid initiative
- Sustainable bio-energy Europe Initiative

- **CO2 capture, transport and storage**

- Sustainable nuclear fission initiative
- Fuel cells and hydrogen
- Energy efficiency
- Smart Cities initiative

Pag. 146

Pag. 147

EU - EERA CCS Joint Programme

Objectives

- Lower costs and higher efficiency
- public awareness and acceptance

Programme launched at last SET-Plan conference (Nov. 2010)

34 program members

- *24 participants*
- *10 associates*
- *12 countries*

HR commitment

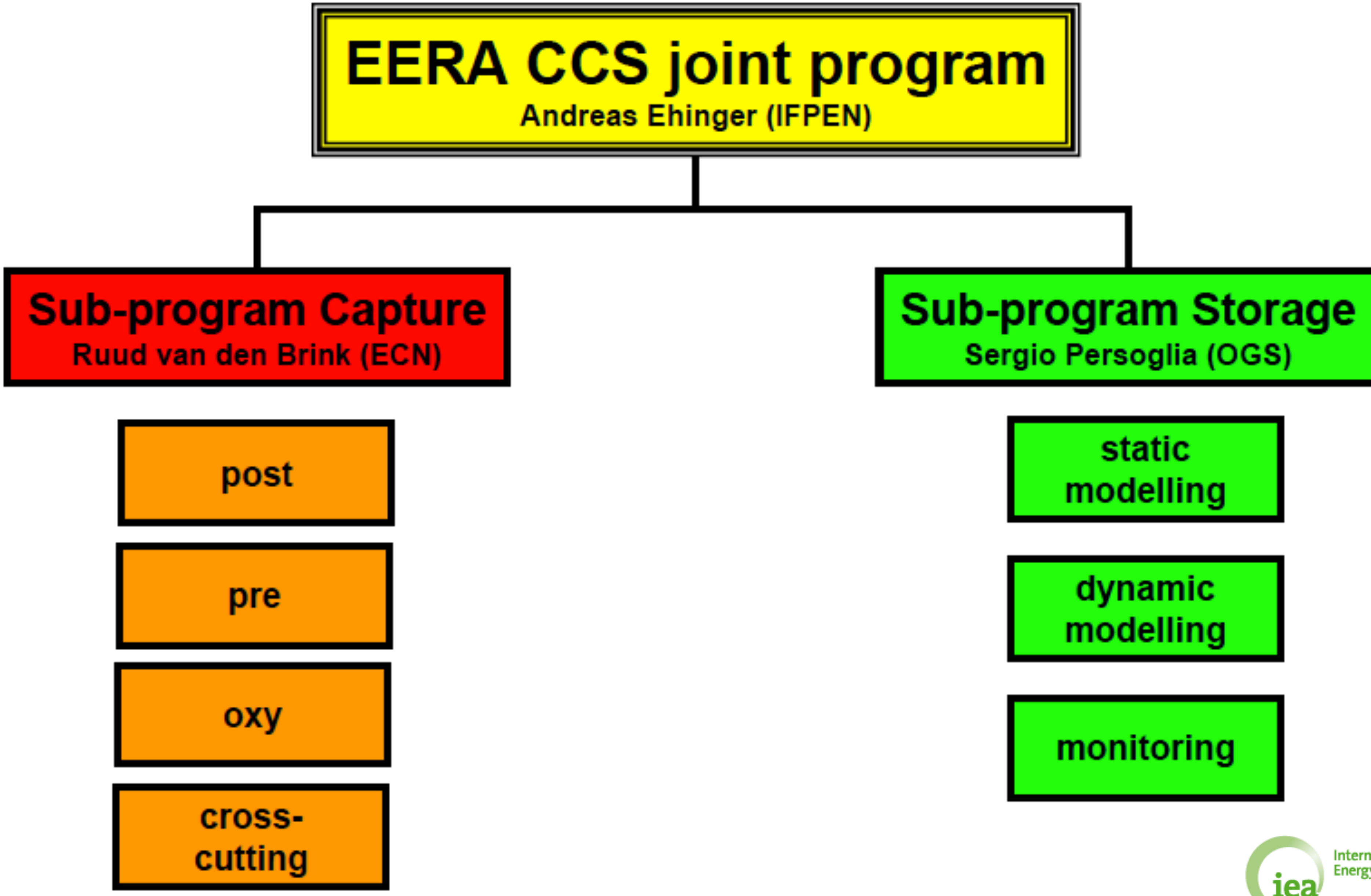
270 py/y

Several new applications

Pag. 147

Program structure

Pag. 148



Pag. 148

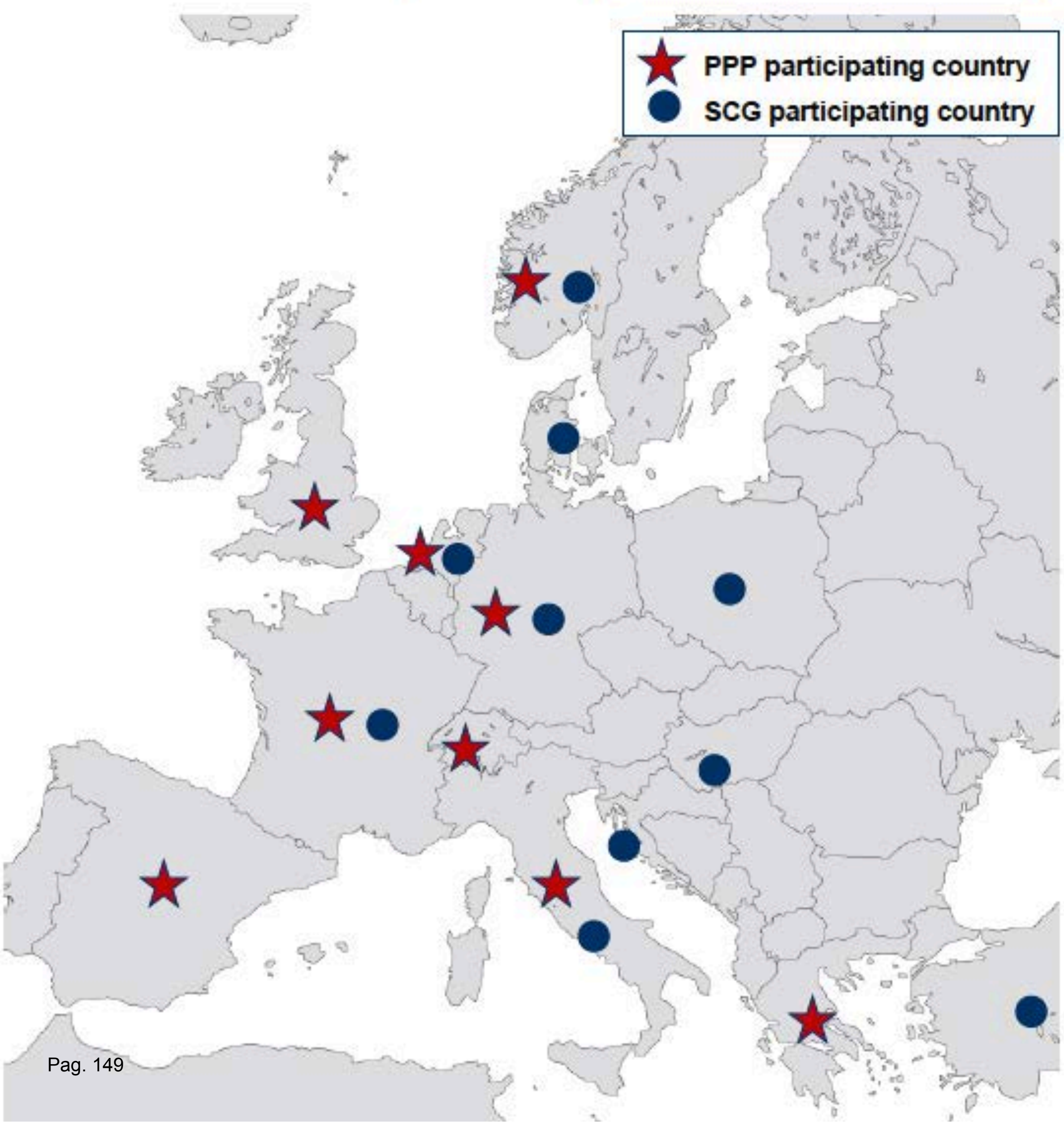
FP7

European Carbon dioxide Capture and Storage Laboratory Infrastructure

Pag. 149

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Countries participate in the Preparatory Phase Project



ECCSEL PPP Consortium

1. Norway (NTNU, SINTEF, RCN)
2. France (IFP & BRGM)
3. The Netherlands (TNO)
4. Germany (DLR)
5. United Kingdom (BGS)
6. Switzerland (ETHZ)
7. Spain (CIUDEN)
8. Italy (OGS, ENEA)
9. Greece (CERT/ISFTA)

International Energy Agency

Pag. 149

Pag. 150

Main activities of national R/D Programme

- "CERSE": technology innovation of the electricity system. Pre/post/oxy comb.
  - Combined production of hydrogen & power with CCS
  - Capture (pre and post combustion) technologies: sorbents/solvents/membranes
  - Coal to liquid / Plant integration
  - Feasibility analysis for a demonstrative power plant in Sardinia, with CCS
  - Oxy combustion: modelling and advanced tests
  - ECBM Site-Tests in Sardinia Sulcis Area)
  - Italian national road-map on CCS; public acceptance
- "Industry 2015" - Industry-oriented R/D program
  - advanced MILD combustion in coal oxyfired power plants.
- "Law 99/2009"
  - R&D programme for industrial innovation; support to demo projects
- PNR (to be launched)
  - Research projects
  - National research laboratories/infrastructures

Pag. 150

Pag. 151

ZECOMIX test plant

30 kg/h coal

Pag. 151
Pag. 151

Sotacarbo pilot plant

Pag. 152

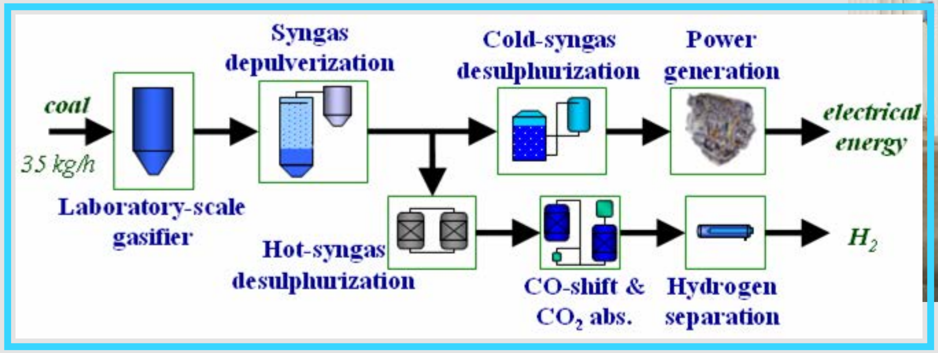
700 kg/h coal

Pag. 152

Sotacarbo bench scale plant

Pag. 153

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE



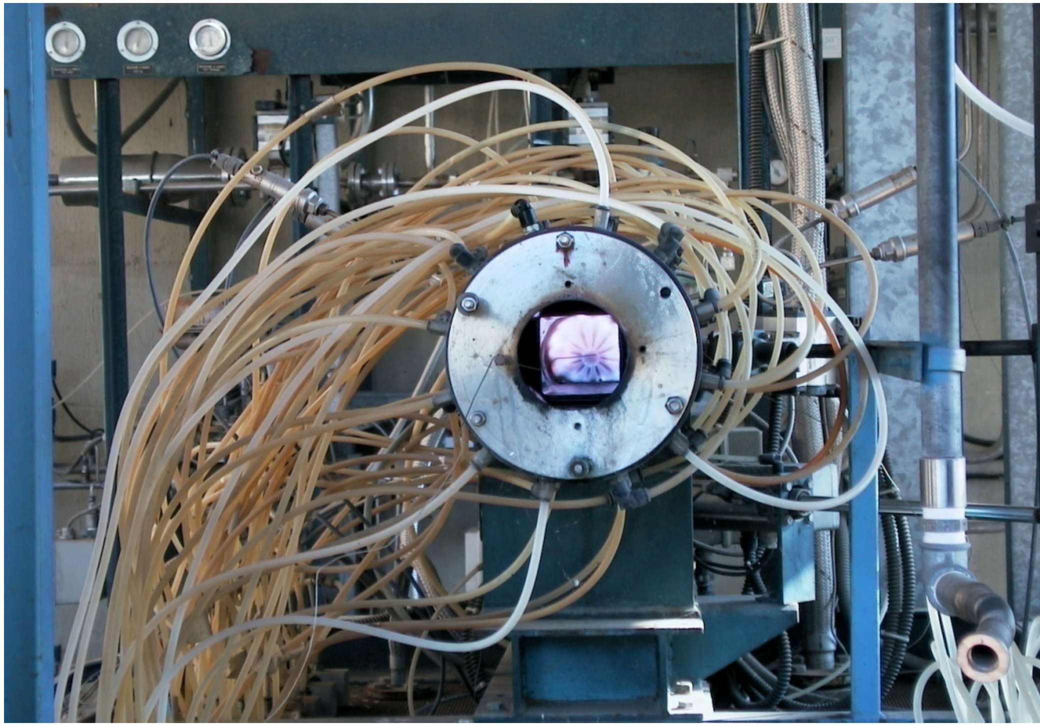
30 kg/h coal

International Energy Agency

Pag. 153

H2 combustion at ENEA

Pag. 154



MICOS test plant

IDEA test plant

Pag. 154

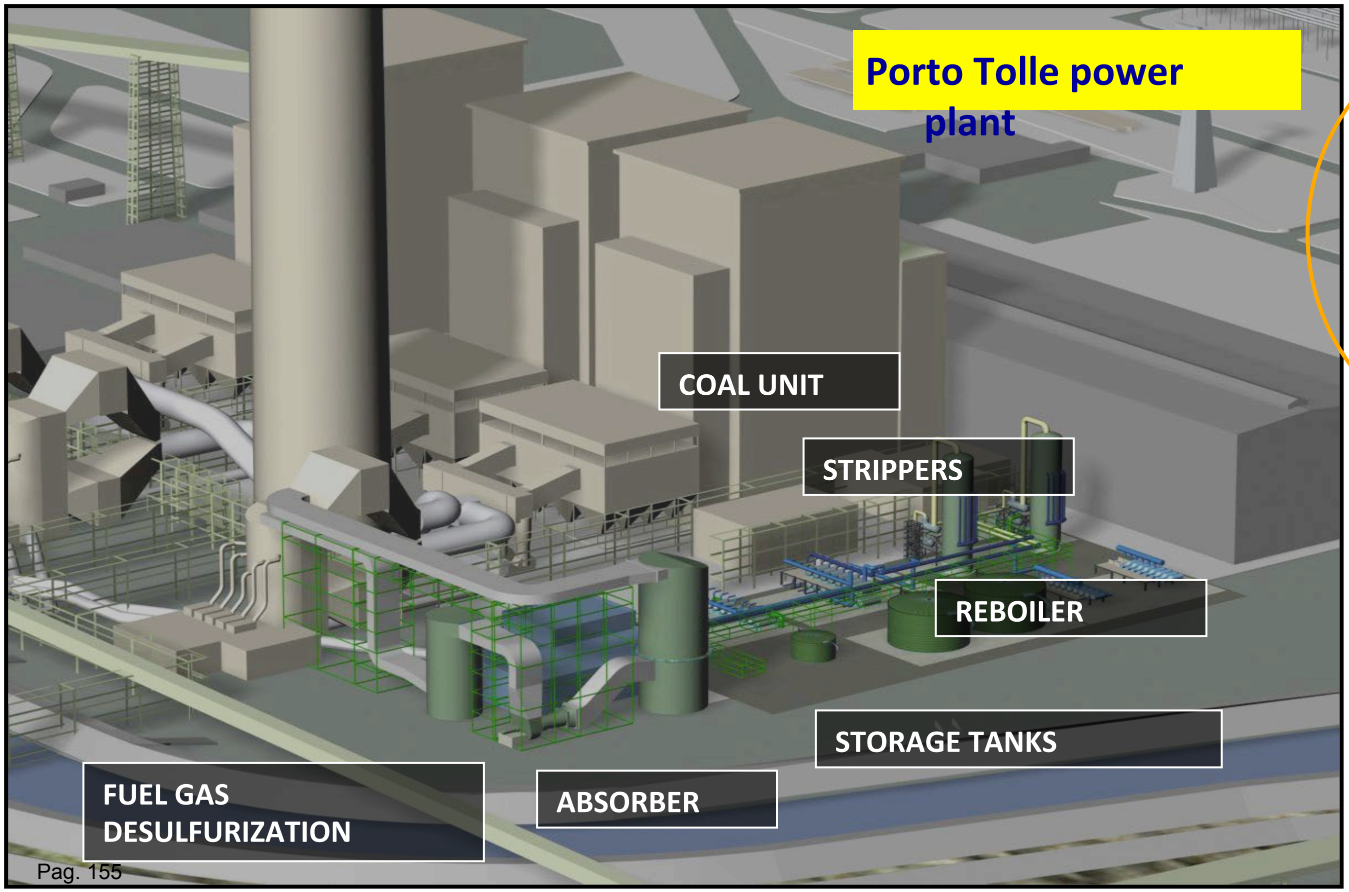
ZEPT: Zero Emission Porto Tolle (ENEL)

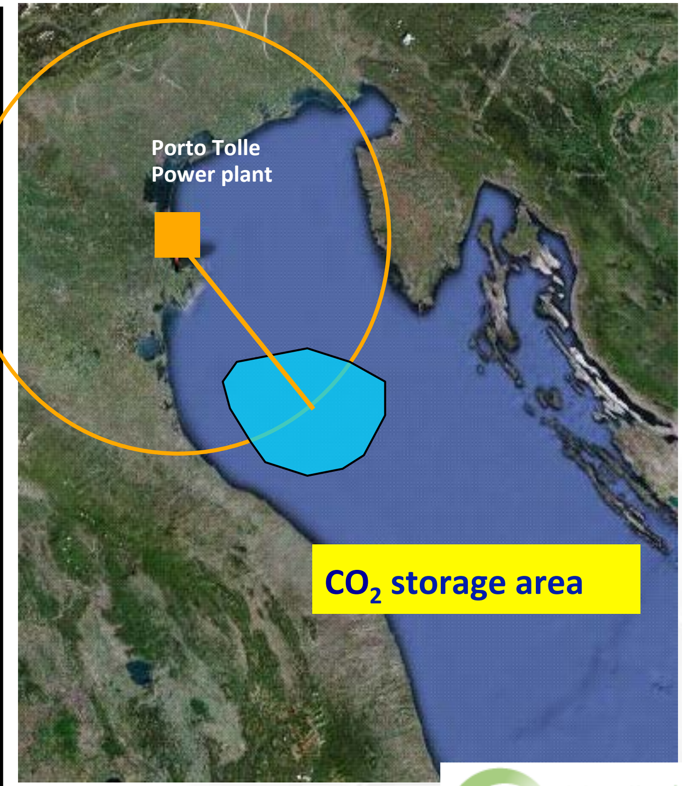
Pag. 155

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Project goal

To retrofit one 660 MW_e coal fired unit of Porto Tolle power station with CO_2 post combustion capture equipment and start CO_2 underground storage in an off-shore saline aquifer by 2015





International Energy Agency

Pag. 155

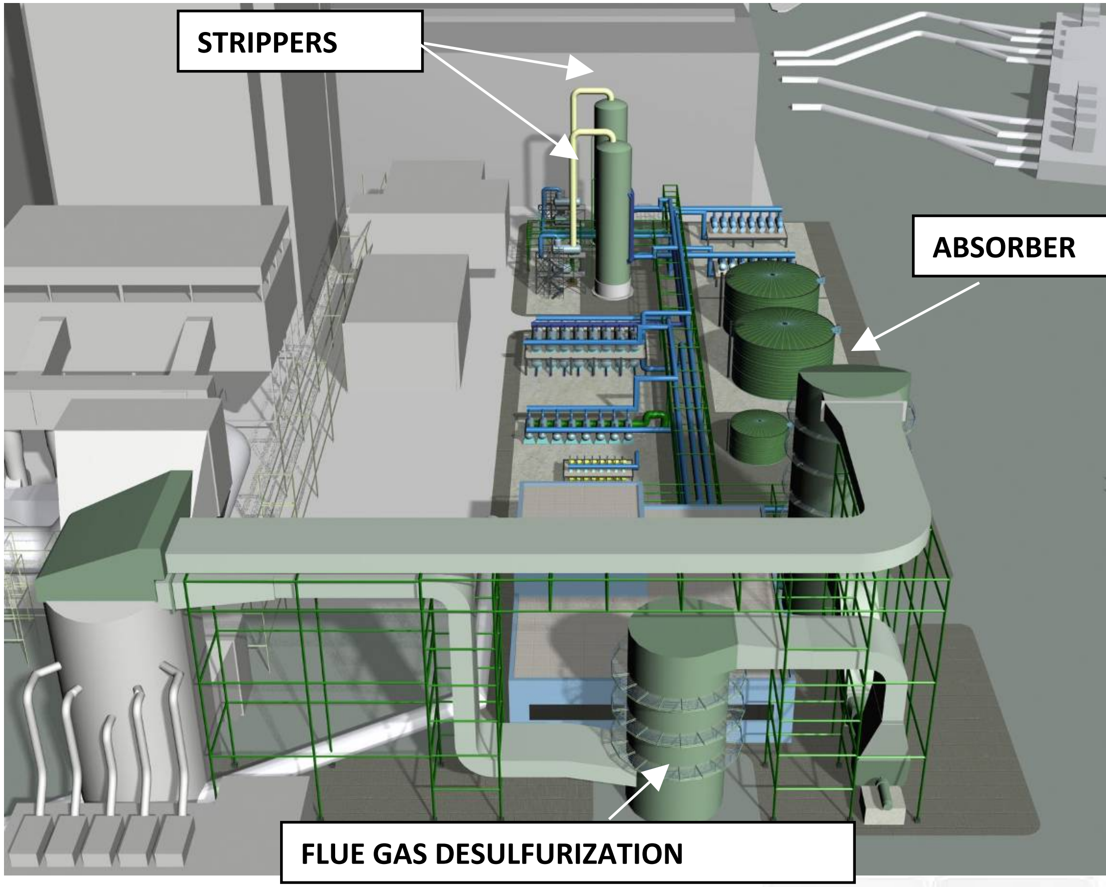
Pag. 156

ZEPT: Zero Emission Porto Tolle (ENEL)

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Demo main features

Type of Project	**Retrofit**
Power generation	**660 MWe**
Primary fuel	**Bituminous coal**
Secondary fuel	**Biomass**
Power Generation Tech	**USC-PC**
% of flue gas treated	**40%**
CO_2 Capture Tech	**Post Combustion Capture with Amine**
Stored CO_2	**Up to 1 Mt/y**
CO_2 Capture rate	**90%**
CO_2 Storage solution	**Deep saline aquifer**
Storage location	**North Adriatic Sea**
CO_2 value chain	**Pure storage**



International Energy Agency

Pag. 156

ZEPT: permitting and roadmap

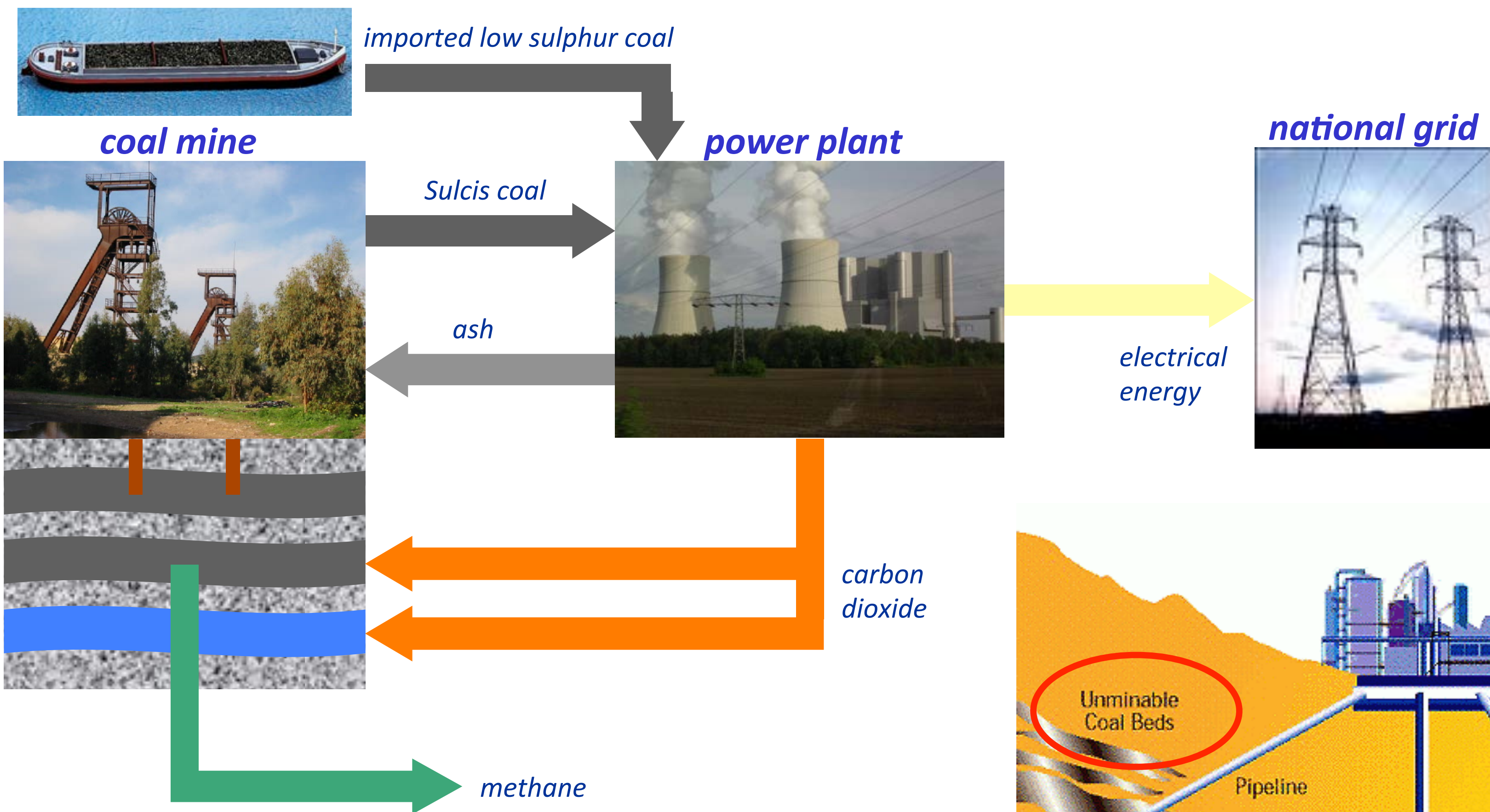
Pag. 157

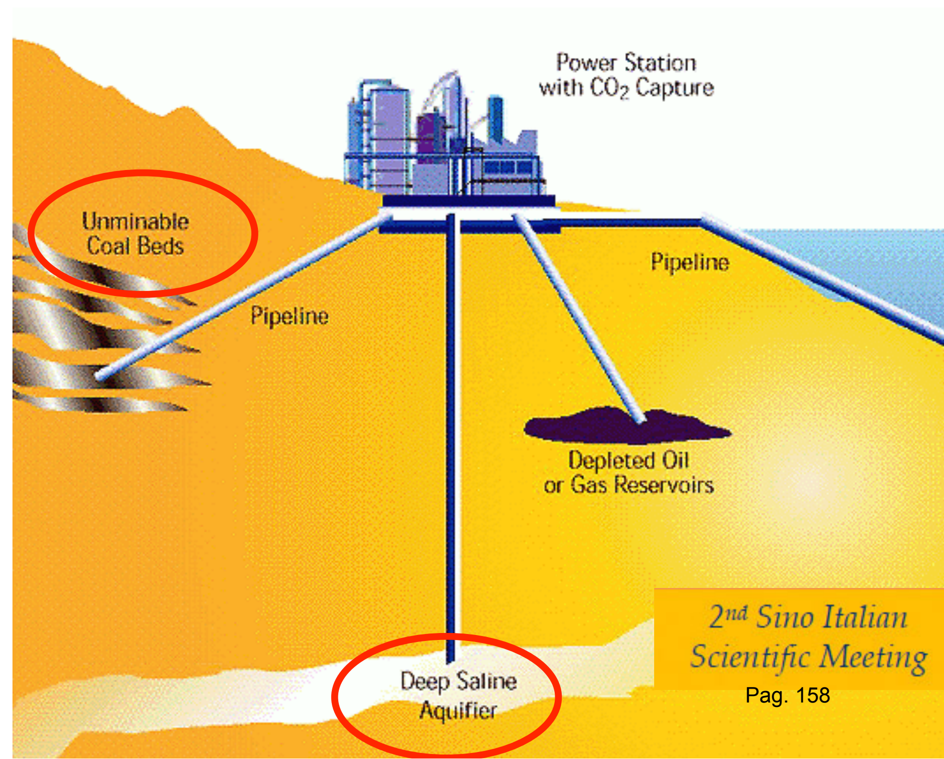
- 5 genuary ’11 - Ministry of economic development: authorization for porto tolle power plant, coal fired with biomass co-combustion
- 23 may ‘11 - National State Council: environmental authorization, already obtained (2009) repealed
  - Lack of comparative analysis with gas fired power plant
  - Difference between CO emission limits stated in the environmental authorization not justified
- 5 July ‘11: ENEL: restart of Environmental authorization procedure requested
- 15 July ’11 - parliement: new article (in more general law) approved
- 5 August – regional government of Veneto: modification to regional law on protected ares approved
- 3 Nov ‘11 – ENEL: supplementary documentation sent
- **By first half of 2012: starting of procedure for CO2 injection in the storage site**

Pag. 157

400 MWe coal plant with CCS in Sardinia

Pag. 158





plant size: 350-450 MW_e

(italian law n°9 23/07/2009)

Pag. 158

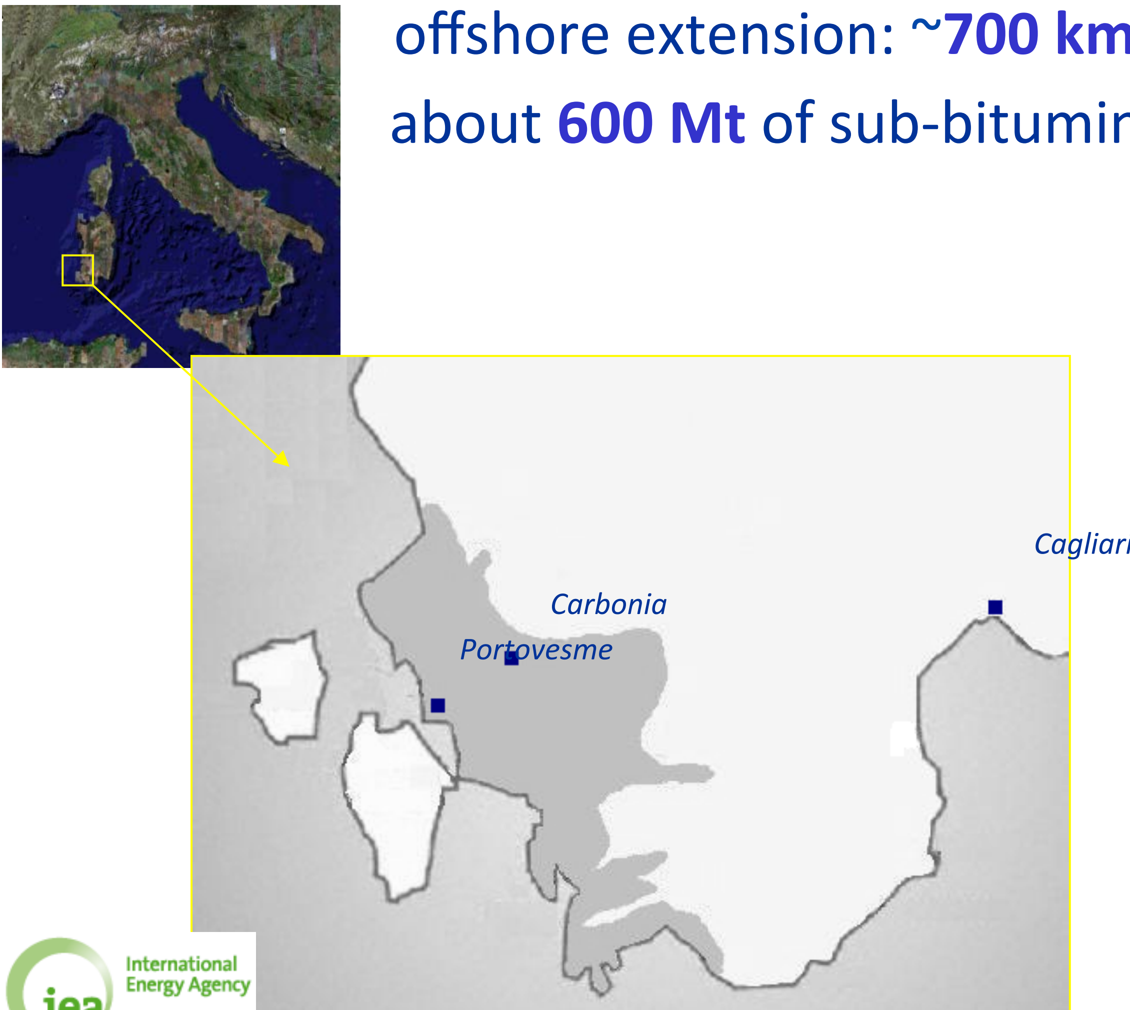
The Sulcis coal basin

Pag. 159

onshore extension: ~**700 km²**

offshore extension: ~**700 km²**

about **600 Mt** of sub-bituminous coal



Sulcis coal ultimate analysis	
Carbon	53.17
Hydrogen	3.89
Nitrogen	1.29
Sulphur	5.98
Oxygen	6.75
Chlorine	0.10
Moisture	11.51
Ash	17.31
LHV (MJ/kg)	20.83

Pag. 159

New CO2 storage project

Pag. 160

CO2 storage in Sulcis area
ECBM/aquifers pilot tests

- The project is aimed at **testing, at pilot scale, CO2 storage in deep coal layers and in the underlying aquifers in the Sulcis coal area**, located in South-West of Sardinia Region-Italy, managed by Carbosulcis.

- The presence of two superimposed formations that are both appropriate for CO_2 storage (**ECBM and deep aquifers**) is unique in Italy, a situation which provides additional safety in the form of a secondary, higher-level barrier should storage be conducted in the lower unit

Pag. 160

Pag. 161

International Energy Agency

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Thank you for your attention

Giuseppe Girardi
giuseppe.girardi@enea.it

Pag. 161

Pag. 162

Descrizione e obiettivo del progetto

Il progetto ZEPT (Zero Emission Porto Tolle) è finalizzato alla realizzazione e all'esercizio sperimentale per 10 anni di un impianto dimostrativo per la cattura, il trasporto e lo stoccaggio geologico permanente della CO_2. L'impianto catturerà la CO_2 prodotta da 250 MWe della sezione 3 del costruendo impianto a carbone pulito di Porto Tolle, per un totale di 10 Mt di CO_2 in 10 anni (circa 1Mt l'anno). La CO_2 così catturata verrà trasportata con una *pipeline* appositamente costruita, per venire poi iniettata e stoccata permanentemente in un acquifero salino profondo offshore.

Grazie al progetto ZEPT sarà dunque possibile dimostrare su scala industriale la tecnologia della cattura post-combustione, attualmente in fase di test in scala pilota nell'impianto di Brindisi (~10 MWth, uno dei più grandi al mondo). La realizzazione e l'esercizio sperimentale dell'impianto pilota di Brindisi fanno parte della prima fase del progetto ZEPT, attualmente in corso.

La tecnologia della post combustione che verrà dimostrata con il progetto ZEPT riveste una particolare importanza, perché, a differenza di altre tecnologie, può essere applicata anche ad impianti esistenti. Questa tecnologia, associata all'incremento dell'efficienza degli impianti a carbone (oggetto di ricerca da parte di Enel), apre ad un uso più ampio di questo combustibile riducendone l'emissione specifica di CO_2, in particolare in questa fase di riflessione sul futuro del nucleare.

Il progetto ZEPT, inoltre, verrà realizzato applicando la CCS all'impianto a carbone pulito di Porto Tolle. Questa centrale sarà caratterizzata da un'altissima efficienza e potrà impiegare biomassa in co-combustione con il carbone (fino ad un massimo del 5% in potere calorifico su due sezioni), consentendo di dimostrare la fattibilità di impianti ad emissioni nulle (o addirittura negative grazie al contributo della biomassa).

Permitting

Il 5 gennaio 2011 è stato ottenuto il Decreto dal MSE n. 55/01/2011 per l'autorizzazione alla realizzazione del Progetto di conversione della centrale di Porto Tolle nella configurazione con alimentazione a carbone e biomasse in co-combustione.

Il 23 maggio 2011 il Consiglio di Stato ha emesso la Sentenza n. 03107 che ha annullato il DEC/VIA n. 873 del 24 luglio 2009 per i seguenti motivi:

- carenza motivazionale nell'esame comparativo delle alternative progettuali (gas-carbone) previste dall'art. 30 L.R. Veneto n. 36/1997
- scostamento non motivato tra le prescrizioni imposte all'Enel dal provvedimento di VIA relativo alle emissioni di monossido di carbonio e i valori di riferimento indicati nel Bref (*Best Available Techniques for Large Combustion Plants Reference Document – Siviglia 2006*).

Il 05 luglio 2011 ENEL ha richiesto al MATTM un ulteriore supplemento di istruttoria VIA limitatamente ai due punti evidenziati nella Sentenza del CdS. Il 15 luglio 2011 è stata approvata la Legge n° 111 di conversione del DL n. 98 del 6/7/2011.

Successivamente il MATTM ha comunicato l'avvio della riapertura del procedimento in ottemperanza al disposto di cui alla pronuncia del Consiglio di Stato incaricando la Commissione Tecnica di Verifica dell'Impatto Ambientale di esprimere il parere tecnico con facoltà di richiedere ulteriore documentazione integrativa e richiedendo inoltre alla Regione Veneto e al MIBAC un eventuale aggiornamento del parere a suo tempo reso.

Pag. 162

 Pag. 163

Il 5 agosto 2011 è stata approvata la Legge Regionale n. 14 relativa alle modifiche dell'articolo 30 della Legge Regionale n. 36 dell'8 settembre 1997, "Norme per l'istituzione del Parco regionale del delta del Po".

Il 3 novembre 2011 Enel ha inviato la documentazione integrativa richiesta e il 21 novembre 2011 il MATTM ha chiesto di pubblicare.

Costi e strumenti di finanziamento del progetto

Il progetto ZEPT (Zero Emission Porto Tolle) presenta un costo complessivo di circa 1.200 M€, che includono le attività preliminari (compreso il pilota di Brindisi), la realizzazione dell'impianto dimostrativo in piena scala e 10 anni di esercizio.

Il progetto ZEPT (Zero Emission Porto Tolle) ha già ottenuto 100M€ di finanziamenti dal fondo EEPR (European Energy Program for Recovery). Tali fondi copriranno circa il 70% dei costi relativi alla prima fase del progetto mentre il restante 30% è finanziato con risorse Enel. La prima fase include la realizzazione e l'esercizio sperimentale dell'impianto pilota di Brindisi (inaugurato il 1 marzo 2011 alla presenza del commissario europeo per l'energia Oettinger e attualmente in esercizio), la realizzazione di un impianto di liquefazione della CO2 catturata, l'ingegneria per il dimostrativo in piena scala di Porto Tolle (cattura, trasporto e sistema di iniezione) e il pozzo esplorativo in alto Adriatico (necessario per accertare le caratteristiche e le potenzialità di stoccaggio del sito offshore prescelto). Ad oggi sono stati spesi 45 M€.

La fase successiva del progetto, che comprende la realizzazione e l'esercizio per 10 anni dell'impianto dimostrativo di cattura, trasporto e stoccaggio geologico di Porto Tolle, potrà essere finanziata con risorse sia pubbliche (fondi NER300, fondi Stato Membro con possibilità di attingere dai proventi delle aste ETS, Emission Trading System) sia private (contributo Enel).

La tabella che segue sintetizza l'ipotesi di piano finanziario[1] presentata nella candidatura per l'accesso al fondo NER300.

Costo totale	1.197
Benefici operativi (costo evitato acquisto permessi di emissione)	218
Finanziamento EEPR	100
Finanziamento NER300	327
Fondi Enel	130
Fondi Stato Membro, attingibili dai proventi aste ETS (in 13 anni, di cui 3 di costruzione e 10 di esercizio)	422

L'eleggibilità richiede l'entrata in servizio dell'impianto CCS 4 anni dopo *l'award decision* (prevista per la seconda metà del 2012).

La BEI ha attualmente in corso la *due diligence* delle candidature pervenute (13 per quanto riguarda la CCS). Nell'ambito dei chiarimenti finora richiesti, è stato comunicato un possibile impatto sui tempi a seguito degli eventi autorizzativi, ma non è stato possibile ancora quantificare slittamenti rispetto al programma presentato (entrata in esercizio fine 2015).

[1] Valori nominali

Pag. 164

Priorità ENEL

- Avviare entro la prima metà del 2012 le procedure per la richiesta del permesso esplorativo sul sito di stoccaggio. Questo prevede che entro tale data siano già operativi alcuni dei decreti attuativi previsti dal DLgs 14 settembre 2011, n. 1162. E' necessario inoltre che l'autorizzazione venga rilasciata quanto prima e comunque non oltre il tempo massimo previsto dal suddetto decreto (12 mesi), pena la perdita della possibilità di finanziare il pozzo esplorativo con i finanziamenti EEPR che dovranno essere utilizzati entro la fine di luglio 2014.
- La sospensione dell'autorizzazione della centrale di Porto Tolle potrebbe comportare una riprogrammazione dell'entrata in esercizio dell'impianto CCS oltre il 2016, cosa che ad oggi comprometterebbe l'eleggibilità del progetto per il finanziamento NER300. Tra le ipotesi da esplorare c'è quella di individuare e condividere con il Governo Italiano una richiesta da inoltrare alla Commissione Europea, finalizzata a rendere compatibili gli eventuali ritardi con l'aggiudicazione dei fondi NER 300 per la CCS, considerati anche i ritardi degli altri progetti europei insieme al basso valore della CO_2 in questo momento e, conseguentemente, la ridotta disponibilità di fondi rivenienti dalla vendita delle quote.
- Una volta completato il *ranking* da parte BEI (9 febbraio 2012) e prima dell'*award* da parte della Commissione, è necessario che il Governo Italiano rilanci in maniera forte l'impegno a finanziare il progetto per la quota prevista nella tabella precedente.

Pag. 164

Full integration of CCS into climate deal vital

Progress required on funding, knowledge transfer and CDM rules

November 22, 2011 - The companies, scientists, academics and environmental NGOs that together make up the Zero Emissions Platform (ZEP)[1] encourage Parties to the UNFCCC to step up their efforts to reach a new global climate change agreement with binding emission reduction commitments at the COP 17/CMP7, and stand behind all means and efforts to this end.

CO_2 Capture and Storage (CCS) is a vital component for dramatically reducing GHG emissions in all countries dependent on fossil fuels in their power and industrial sectors. For some industrial sectors CCS is the **only** large-scale abatement option that can be deployed. In addition, the use of CCS with renewable biomass is the **only** large-scale technology that can remove CO_2 already released into the atmosphere.

ZEP believes that the following issues related to CCS must be addressed during COP17/CMP7, to help speed up global widespread deployment of the technology:

1. **Knowledge transfer of CCS technology:** The global deployment of CCS can be accelerated using knowledge sharing frameworks, such as the one developed by ZEP in 2009[2] at the request of the European Commission. This work can help ensure greater qualitative stakeholder involvement in the UNFCCC's Technology Mechanism in order to help Non-Annex I countries deploy CCS.
2. **The UNFCCC Green Climate Fund** should recognise CCS and provide for its funding as a crucial abatement option.
3. **CCS in CDM:** The modalities and procedures proposed for CCS projects under the CDM should be adopted, thereby creating the rules and procedures to enable the permanent storage of CO_2 also in Non-Annex I countries.
4. **Nationally Appropriate Mitigation Actions (NAMAs)** should recognise CCS positively and appropriately.

CCS must be widely deployed to avoid irreversible global climate change

As a firm supporter of the European Union's clear and unconditional climate change policy, ZEP underlines the foundation provided by the EU Emission Trading Scheme, which encourages emission reductions by applying a price to greenhouse gas emissions. ZEP strongly recommends that other nations introduce similar or equivalent measures to price greenhouse gas emissions, to ensure emissions reduction goals can be met.

[1] The European Technology Platform for Zero Emission Fossil Fuel Power Plants supports combating climate change through the use of a portfolio of key technologies, including CO_2 Capture and Storage (CCS), renewable sources of energy and greater energy efficiency. ZEP advises the EU on all aspects related to the demonstration and deployment of CCS.
[2] www.zeroemissionsplatform.eu/information.html/publication/55-zep-ccs-knowledge-sharing

38/40 Square du Meeus
1000 Brussels, Belgium
info@zero-emissionplatform.eu
www.zeroemissionsplatform.eu

In order to keep global warming below 2ºC – cost-effectively – CCS must provide almost 20% of the global emission cuts required by 2050, according to the International Energy Agency (IEA). Indeed, the costs of doing so *without* CCS are estimated to be over 70% higher. While a gradual move toward achieving the 2ºC goal would require a US$36.5 trillion investment in energy infrastructure by 2035, the IEA also estimates that a 10-year delay in introducing CCS would add another $1.1 trillion.

ZEP's groundbreaking study[3] to establish a reference point for the costs of CCS in the EU from the early 2020s indicates that the EU CCS demonstration programme will not only prove the costs of CCS, but provide the basis for future cost reductions, enhanced by the introduction of second- and third-generation technologies. **CCS is therefore on track to become one of the key technologies for combating climate change** – within a portfolio of technologies, including greater energy efficiency and renewable energy.

Recent reports such as the IEA's "Projected Costs of Generating Electricity - 2010"[4] indicate that the costs of post-demonstration CCS with coal (€70-90/MWh) and gas (€70-120/MWh), as presented in ZEP's study, **will be cost-competitive with other low-carbon power options**, including on- and offshore wind, solar power and nuclear.

ZEP has worked closely with the European Commission and EU governments to facilitate the development of CCS in Europe in the power sector and energy intensive industries sector. It is particularly critical to deploy CCS broadly in Non-Annex I countries as rapid population growth and increasing access to energy and electricity is leading to a significantly greater consumption of fossil fuels. The deployment of CCS is vital if this increased fossil fuel consumption is not to lead to irreversible climate change.

The significant funding gap for CCS must be bridged; CO_2 storage rules under CDM

The size and capital-intensive nature of CCS projects means there is a considerable funding gap for most projects and this is inhibiting the development of the technology. The European experience shows the importance for CCS of putting a price on CO_2 emissions - to reduce the funding gap of projects - and to create supplementary funding mechanisms that can support projects.

We do not have the luxury to wait for a sufficiently high and predictable global carbon price to make CCS competitive with unabated CO_2 emissions from power plants and industrial facilities. A recent study by the World Bank found that, to date, CCS has so far received less than 0.001% of available funds from the main channels for climate finance.

ZEP therefore calls on Parties to urgently increase incentives for CCS projects, in both Annex I and Non-Annex I countries. At COP17, Parties can take an important step for CCS by adopting the modalities and procedures for CCS projects under the CDM thereby creating the rules and procedures to ensure the permanent storage of CO_2 to prevent

[3] www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html

[4] www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2207

38/40 Square du Meeus
1000 Brussels, Belgium
info@zero-emissionplatform.eu
www.zeroemissionsplatform.eu

Pag. 167

climate change. The greatest benefit of such modalities and procedures will go far beyond potential CER credits under the CDM given that they will set the precedent for how CCS can be included in other future mechanisms for low-carbon activities in Non-Annex I countries.

In this context, it is important that the UNFCCC Green Climate Fund recognises CCS and provides for its funding as a crucial abatement option. Non-Annex I countries should independently encourage CCS-related projects that are appropriate for their national circumstances and can help develop the required transport and storage expertise and infrastructure for a future broad deployment of CCS. CCS should be reflected positively and appropriately in Nationally Appropriate Mitigation Actions (NAMAs) registered under the UNFCCC if the technology is to fulfil its role as a potentially significant mitigation option. Such actions will display the feasibility and affordability of CCS, assisting efforts to ensure binding emission reduction commitments are politically acceptable in fossil-fuel-rich countries.

For all media/further enquiries, please contact:

Eric Drosin
Director of Communications
Tel.: +32-(0)493-511-982
Email: edrosin@zero-emissionplatform.eu

38/40 Square du Meeus
1000 Brussels, Belgium
info@zero-emissionplatform.eu
www.zeroemissionsplatform.eu

Pag. 167

Pag. 168

Allegato 3.

Partecipazione al Global CCS Institute (GCCSI)

accelerating CCS: 2013 — 2017 five-year strategic plan

Pag. 168

Pag. 169

GLOBAL CCS INSTITUTE

ACCELERATING CCS: 2013 — 2017 FIVE-YEAR STRATEGIC PLAN

July 2012

Draft for Member discussion and feedback

Pag. 169

Pag. 170

EXECUTIVE SUMMARY

The purpose of this draft Five-Year Strategic Plan is to outline the future mission of the Global CCS Institute. It focuses on the Institute being a Member-driven, fit-for-purpose organisation that will build on its track record to advance the successful demonstration and deployment of carbon capture and storage (CCS) so that the technology can play a vital role in the world's move to a low-carbon economy. As part of this, the Institute is developing a diversified funding model to meet Member requirements. The Institute is uniquely placed to act as a global champion for CCS, having developed experience and expertise since 2009.

International agencies confirm that CCS is a vital part of a portfolio of cleaner energy solutions. Nevertheless, progress on CCS has been slower than expected. Fossil fuels will continue to underpin the world's future energy and industrial production mix. Compounding this lack of progress is a relatively low profile and understanding of CCS by the wider community.

Building on its solid track record, the Institute has developed the following Strategic Framework to tackle the challenge of advancing CCS in both the developed and developing world:

1. Authoritative knowledge sharing: the Institute will generate, collect and share information, experiences and lessons learnt with the international CCS community by connecting people and networks;

2. Fact-based, influential advice and advocacy in support of the demonstration and deployment of CCS: the Institute will inform and advise global audiences about CCS and low-carbon policies to advance understanding of the technologies as well as appropriate incentives, funding, financing and risk solutions; and

3. Strengthening the capacity for CCS implementation: the Institute will address a range of complex challenges that impact CCS development, including appropriate policy and regulatory frameworks, establishment of effective business cases, and building capacity in developing countries.

Outcomes of this Strategic Framework will be:

- increased public understanding and acceptance of the important role of CCS in reducing global carbon dioxide emissions;

- increased government support for CCS with widespread policy adoption; and

- increased technical readiness of CCS and improved project economics.

In pursuing these goals, the Institute will build on its track record as an independent, 'public good' organisation, focused on activities of value to its Members. It will maintain and develop this through a new funding and business operations model that:

- maintains a broad Membership base including companies, governments and not-for-profit organisations and is focused on both the developed and developing world;

- is funded by a Membership fee structure that is scaled to fit this diverse mixture of organisations. This would be supplemented by additional contributions to support specific activities and by some commercially-based services to meet the needs of Members; and

- is actively engaged with its Members in setting direction and priorities to ensure all activities add value.

The Institute will seek to actively collaborate with other key international, regional and national organisations to undertake complementary activities and broaden Member value. An extensive period of consultation is underway and will include a series of opportunities for Member feedback to shape future plans and priorities.

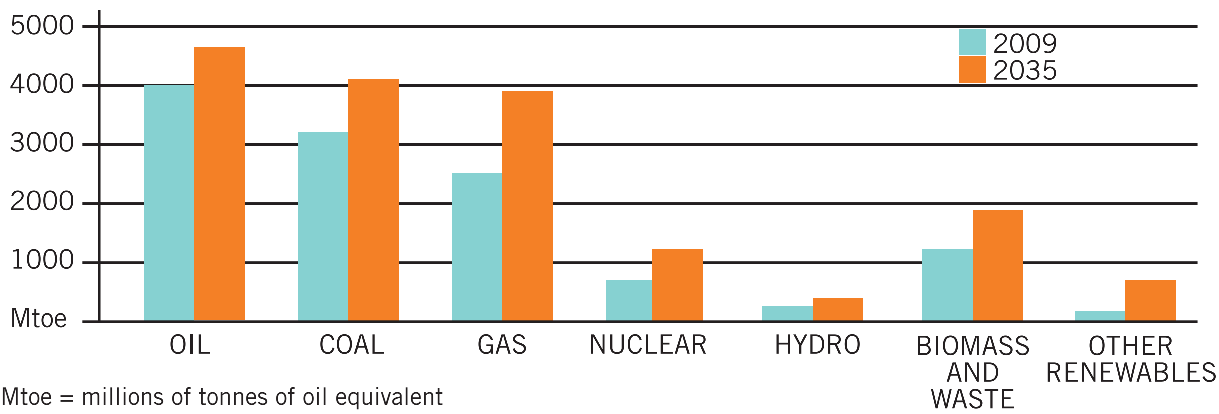
Pag. 170

Pag. 171

INTRODUCTION AND PURPOSE

Fossil fuels will continue to be an important part of the world's future energy and industrial production mix. CCS is the only technology available to significantly mitigate emissions from large-scale fossil fuel use. However, the rate at which CCS projects are progressing into construction and operation is slower than expected. Compounding the lack of progress is a relatively low profile and understanding of CCS by the wider community.

Figure 1: Global primary energy consumption is still underpinned by fossil fuels



Mtoe = millions of tonnes of oil equivalent

Source: International Energy Agency, World Energy Outlook 2011

The purpose of this draft Five-Year Plan is to outline the future mission of the Global CCS Institute in supporting its Members to accelerate the successful demonstration and deployment of CCS. As part of this, the Institute is developing a diversified funding model to meet Member requirements. An extensive period of consultation with Institute Members is underway, enabling Members to shape the Plan and the Institute's priorities.

The consultation process will provide the opportunity for all Institute Members to give specific feedback, including at the Institute's Members' Meeting in October 2012. The target is to finalise the Strategic Plan by the end of 2012. Implementing the Strategic Plan, especially those aspects related to building a sustainable, Member-driven organisation, will continue into 2013, again with extensive Member consultation.

Pag. 171

Pag. 172

OUR VISION OF SUCCESS: ENABLING THE DEMONSTRATION OF CCS

The Strategic Plan frames the Institute's activities around three Strategic Objectives designed to facilitate the acceleration of CCS demonstration and deployment globally:

- authoritative knowledge sharing – connecting people and networks;
- fact-based, influential advice and advocacy – global reach, regional focus; and
- strengthening the capacity for CCS implementation – improving full-chain readiness.

The success of these activities and the value associated with Institute Membership is based around two related components:

- the positioning of CCS as a key technology in the transition to a low-carbon economy, where the Institute's role is as an 'influencer' in advancing key policy, technology and market support frameworks for progressing CCS projects; and
- the Institute delivering value for Members and stakeholders based on its expertise, advocacy and knowledge sharing networks, thus becoming the core international resource on CCS.

Figure 2: Key success measures for the Five Year Strategic Plan

POSITIONING OF CCS IN THE MOVE TO A LOW-CARBON ECONOMY

CCS is included under international climate change agreements and associated support mechanisms, and international policy settings acknowledge and support CCS as a clean energy technology option.

Consistent with international climate change agreements, national policy settings are in place to establish a business environment conducive to CCS deployment (including appropriate price signals and support mechanisms to accelerate CCS projects) in all key CCS countries and evolving more broadly.

There is a high level of public understanding and acceptance of CCS as an important technology in reducing carbon dioxide emissions.

There is critical mass of operational projects by 2020 demonstrating at scale the integrated application of CCS technologies across the capture, transport and storage chain as well as a growing number of projects in the development pipeline.

DELIVERING VALUE FOR MEMBERS AND CCS STAKEHOLDERS

The Institute is engaged at senior levels of government and industry and is the pre-eminent body for linking industry, government and other stakeholders on CCS-related matters through:

- facilitating global-level dialogue among senior government, industry and NGO representatives;
- providing the key influential voice for CCS in climate and energy policy fora; and
- being the leading independent adviser on CCS matters including policies, markets, acceptance and project status.

The Institute is the internationally respected, first choice source of CCS information and knowledge, facilitating project and policy engagement networks across the globe.

The Institute is supported by an active, broad-based Membership engaged in setting priorities and direction through established processes.

The Institute's new business model is fully operational and the organisation is fit-for-purpose, being focused on efficiency, effectiveness and supporting its Members.

Pag. 172

Pag. 173

THE INSTITUTE AS THE GLOBAL CHAMPION FOR CCS

The Institute stands out as having the strongest organisational characteristics to perform these tasks and champion CCS on a global basis on behalf of and alongside the CCS community. Its independence and presence in all key regions make it ideally placed as the pre-eminent global institution to act as a value adding bridge between senior policy makers, project proponents and other key organisations. The Institute will seek to actively collaborate with other key international, regional and national organisations to undertake complementary activities and broaden Member value.

The successful demonstration and deployment of CCS, as part of a portfolio of cleaner energy solutions, is vital if the world is to achieve decarbonisation at least cost, while delivering more energy and growth.

To address the challenges impacting CCS, the Institute believes it is critical that:

- advocacy for CCS technologies and its vital role in reducing carbon dioxide emissions is maintained;
- progress of demonstration (and other) projects globally is closely monitored to inform and expedite decision making, and to support independent analysis and advice; and
- lessons learnt and best practices from these first-of-a-kind projects are shared as widely as possible among stakeholders.

There is no equivalent global CCS organisation that matches the Institute's combination of distinctive competencies, distinguishing features and track record of success.

Figure 3: The Global CCS Institute Value Proposition

DISTINCTIVE COMPETENCIES	KEY DISTINGUISHING FEATURES
• CCS is sole focus • Global reach and networks • Independent expertise • Extensive market knowledge • Professional capability – full chain • Extensive program and knowledge management experience • Focus on demonstration projects	• Champions the role of CCS in reducing carbon dioxide emissions • Keeps CCS central to the policy agenda • Natural go-between for CCS stakeholders • Global platform for showcasing project and policy developments • Independent, evidence-based, global advice and analysis • World's most comprehensive and up-to-date CCS projects database • Outputs tailored to suit the diverse range of Member organisations • Only global CCS organisation with broad-based Membership

Pag. 173

Institute expertise vital to progress

In the relatively short time since its establishment, the Institute has developed a set of distinctive competencies and distinguishing features enabling it to perform its mission through expertise, advocacy and knowledge sharing. These competencies centre on the Institute's global reach, its strong focus on CCS demonstration projects, its extensive market knowledge and professional capability across the CCS chain, its independence, and its extensive knowledge management capability.

The effectiveness of the Institute as an independent adviser, advocate, and knowledge sharing organisation for CCS benefits from its presence in all key areas: Australia, North America, Europe, Japan and with a China office to be established in 2012. The Institute's presence in these regions allows it to fully grasp regional differences that impact CCS development and to build these into its work program and knowledge sharing, advocacy and networking activities.

Institute's key distinguishing features

The Institute's distinctive competencies have allowed it to:

- keep CCS central to the global climate change and energy policy agendas;
- keep the business option for CCS open;
- provide independent, evidence-based advice and analysis on global trends in CCS and showcase global project and policy developments;
- bridge the gap between industry and government on CCS-related matters; and
- collaborate and customise work across a wide range of organisations and activities.

Building on a track record of success

This Strategic Plan builds on a strong track record of achievement by the Institute, including:

- key leadership roles in globally-significant policy and regulatory agendas such as the Clean Energy Ministerial, the Carbon Sequestration Leadership Forum (CSLF), the Asia-Pacific Economic Co-operation Expert Group on Clean Fossil Energy and the Alberta Regulatory Framework Assessment;
- an ongoing role since 2010 as a primary channel of influence on CCS-related matters in internationally significant climate change fora, including the recent recognition of CCS in the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism, including advocacy and provision of expert advice to Parties and the UNFCCC Secretariat on the development of the rules of inclusion;
- publication of the annual *Global Status of CCS* report, considered the world's most comprehensive reference source on the status of CCS projects and the impact of global policy, legal, regulatory and cost trends;
- managment of an international capacity development program spanning over 15 countries through participation in the governance of three CCS Capacity Building Trust Funds and the Institute's own efforts in undertaking scoping studies, capacity assessments and workshops in countries such as Malaysia, India, Mexico and Vietnam;

Pag. 175

- provision of services for other organisations, such as administering the CCS knowledge sharing network for the European CCS Demonstration Project Network, the Japanese Knowledge Sharing Network and delivery of knowledge sharing and capacity building initiatives in developing countries with grant funding of US$1,000,000 from the US Department of State; and
- the world's most visited public website dedicated to CCS with over 1,000 visitors each working day from most countries in the world, accessing a large range of reports, tool-kits and guidelines to assist the full range of stakeholders on different aspects of CCS demonstration.

THE STRATEGIC FRAMEWORK OF THE GLOBAL CCS INSTITUTE

The Institute remains committed to its mission of accelerating the demonstration and deployment of CCS. This mission targets the pivotal long-term, public good outcome of significantly reducing greenhouse gas emissions at least cost, and providing a diversity of low carbon-emitting fuel and feedstock choices through the use of CCS.

Figure 4: Strategic planning framework

SOCIETAL OUTCOMES FROM CCS	Significantly reduce greenhouse gas emissions through CCS Diversity of low carbon-emitting fuel and feedstock choices		
INSTITUTE MISSION	To accelerate the demonstration and deployment of CCS globally		
INSTITUTE STRATEGIC OBJECTIVES	Authoritative knowledge sharing	Fact-based, influential advice and advocacy	Strengthening the capacity for CCS implementation
INSTITUTE OUTCOMES	Increased public understanding and acceptance of CCS	Increased technical readiness of CCS and improved project economics	Increased government support for CCS, with widespread policy adoption

The value provided through Institute Membership must be linked to specific outcomes that accelerate the successful demonstration and deployment of CCS. The following outcomes will be the focus of Institute efforts:

- increased public understanding and acceptance of CCS;
- increased government support for the technology, with widespread policy adoption; and
- increased technical readiness and improved project economics.

The key activities to be undertaken under each of the Strategic Objectives are summarised on the following page.

Pag. 175

Strategic Objective 1

AUTHORITATIVE KNOWLEDGE SHARING

The Institute will generate, collect and share information, experiences and lessons learnt by connecting people and networks. This will enable government and industry to accelerate the uptake of the technology, improve public awareness, reduce costs and drive innovation.

Key strategies:

- implement new, cost-effective knowledge development processes and provide content of value to Institute Members and CCS stakeholders;
- improve analysis to boost the value-add provided from existing and prospective knowledge assets (importantly from active CCS projects);
- facilitate knowledge exchange globally through multiple channels and networks in an integrated and consistent fashion; and
- increase and leverage international presence, networks and linkages to maximise the timely sharing of best practice.

Benefits to Members

- providing knowledge and information relevant to Member needs and focused on the public good outcomes to be achieved by the Institute;
- improved efficiency and significantly reduced costs in accessing the most comprehensive, publicly-available, global repository of reputable and world-leading information and experiences on CCS; and
- the ability to participate in a range of digital and face-to-face events and networks to access the latest information on the demonstration of CCS, share experiences and resolve issues.

Strength in knowledge sharing underpins Institute activities

Since its inception, the Institute has made substantial achievements from its ability to share knowledge and provide independent, authoritative advice on CCS through:

- the most comprehensive and up-to-date global database, as well as status reporting and analysis of large-scale CCS projects and global policy, legal and regulatory trends;
- the dissemination of over 150 publicly-available reports, tool-kits and other ‘knowledge assets’ to assist the full range of CCS stakeholders;
- over 100 individuals providing personal insights through online media across all the key issues impacting on CCS; and
- Institute-sponsored Member and workshop events hosted in key CCS jurisdictions across the globe.

This has contributed to the Institute’s website being the most visited public website of all CCS knowledge sharing initiatives, with 20-30,000 visits per month.

Collaboration, customisation and cost effective processes

This Strategic Plan includes a focus on improving the essential knowledge sharing processes of planning, generation and distribution, through:

- greater collaboration with Members in planning and generating knowledge;
- customising outputs to better suit Member and stakeholder needs; and
- moving to a model where generating knowledge is more cost effective.

The international operation of the Institute, its independence and coverage of the CCS industry also places it as the pre-eminent global intermediary and facilitator.

Activities under this Strategic Objective will centre on making the Institute the first place for people to source reputable information on CCS, through:

- production of a wide range of targeted studies and reports based on both Member-defined knowledge needs and insightful research and analysis, and then sharing the results of this work among all stakeholders;
- provision of customised information to audiences not directly involved in CCS that want to access reliable information both on the role of CCS in reducing global carbon dioxide emissions and independent analysis of its status;
- acting as a 'bridge builder' to facilitate conversations and dialogue on CCS between policy makers, project proponents and other stakeholders at senior management and operational levels, including establishing and facilitating global networks focused on project and policy themes;
- making the Institute's digital platform the 'website of choice' for other organisations to disseminate knowledge on CCS to a global audience; and
- translation of key documents into other languages, where sufficient demand exists.

Strategic Objective 2

FACT-BASED, INFLUENTIAL ADVICE AND ADVOCACY IN SUPPORT OF THE DEMONSTRATION AND DEPLOYMENT OF CCS

A key reason for the Institute's formation was to create an organisation that could advise and advocate nationally and internationally for the vital role of CCS in the transition to a low-carbon economy. To this end, the Institute will work to inform and advise domestic and international audiences about CCS and low-carbon policies to advance understanding of the technologies as well as appropriate incentives, funding, financing and risk solutions.

Key strategies:

- work with stakeholders to build CCS understanding and information exchange;
- undertake CCS advocacy and messaging to build support for the demonstration and deployment of CCS technology; and
- work with other bodies active in the field of greenhouse gas mitigation to enhance knowledge sharing and collaboration to promote CCS technology and projects.

Benefits to Members

- having a global voice for CCS;
- a consistent and reliable source of basic information on CCS;
- access to up-to-date information on the global status of CCS; and
- efficiency gains through reducing duplication in activities that would otherwise be undertaken on local levels.

Thought leadership and information provision is an important service to Members, helping to leverage the Institute's reach and resources more widely. Measuring and monitoring the reach and impact of the media and communication campaigns to determine the degree of stakeholder and public understanding of CCS will be essential in tracking progress and allowing for any required modification in approach.

The need for CCS advocacy at a global level

CCS is considered a nascent technology in the early demonstration phase in the applications to which it must be deployed in quantity if it is to effectively help combat climate change. It is generally faced with very low levels of awareness, not only among the general public but also among many policymakers and other key influencers.

CCS faces strong opposition from some groups, often based on its linkage to fossil fuel production and concerns about the readiness and economic viability of the technology. Fossil fuels will continue to underpin the global economy well into the future and the emissions from their use need to be managed. As such, effective advocacy of the technology is essential. Prior to the formation of the Institute there was no other international organisation with a broad-based Membership focused on the full range of CCS activities.

Pre-eminent authority on the status of CCS

The Institute will continue to maintain the most comprehensive and up-to-date global database of CCS projects, and use the knowledge and insights gained from these projects to inform the preparation of the annual *Global Status of CCS* report. This report will remain the most authoritative source of information on developments in CCS, including not only technology and project developments but also policy, legal, regulatory, economic, financial and commercial issues in developed and developing countries.

Focus on building awareness and understanding

The Institute will develop an integrated media, marketing and communications approach to help build support for the adoption of CCS among influential stakeholder groups and the general community. This will involve collaboration with key organisations that share the goal of working towards large-scale adoption of CCS.

A collaborative approach based on expertise and advocacy

The Institute will work with a range of organisations that can help to further these goals. It has already developed strong working relationships with a number of key global bodies, including the International Energy Agency (IEA) and the CSLF. The work these bodies generate can be utilised by the Institute in its messaging and, as such, their activities are complementary to the Institute's. The Institute can also help these bodies in their broader roles by acting as a source of expert advice on CCS. The Institute is also working closely with internationally-recognised social researchers in developing teaching materials that explain the role of CCS along with other technologies in the transition to a low-carbon future.

Strategic Objective 3

STRENGTHENING THE CAPACITY FOR CCS IMPLEMENTATION

The Institute will strengthen the capacity for CCS implementation by addressing a range of complex challenges that have an impact on the demonstration of CCS. This includes appropriate policy and regulatory frameworks, establishing effective business cases, building capacity in developing countries and improving the readiness of CCS technologies.

Key strategies:

- engage with Member governments to support development and implementation of CCS policy and regulatory frameworks;
- inform understanding of financial and commercial issues and propositions to support the development of business cases for CCS projects;
- undertake capacity development activities to build the awareness, understanding, knowledge and skills required to progress CCS projects in developing countries; and
- draw upon Member expertise in supporting the activities to be undertaken by the Institute.

Benefits to Members

- influencing the development of international and national policy mechanisms to help realise the technology's global carbon dioxide emissions mitigation potential and assisting countries to deliver on their climate change commitments;
- improved understanding of approaches to building the business case for CCS, including up-to-date information on the readiness of key CCS technologies;
- access to high-calibre skills and advice that can practically support the development of demonstration projects by navigating barriers and developing solutions in a timely manner; and
- strengthening the capacity in developing nations so that a rapid uptake of CCS technology can occur as it is demonstrated, addressing a significant portion of future emissions.

Policy focus on CCS at international level

Central to the Institute's efforts in the policy arena is building upon its success in influencing the UNFCCC agenda on CCS. Building on established relationships, the Institute is well positioned to play a role to ensure that the international climate dialogue more generally, and UNFCCC negotiations specifically, retain a core CCS focus.

The Institute will continue to engage in key opportunities afforded to UNFCCC accredited observers to inform and shape the future implementation arrangements of the Climate Technology Center and Network under the Technology Mechanism, the Green Climate Fund under the Financial Mechanism and remedies to outstanding CCS issues in the CDM. This will be done through written submissions as well as senior Institute representation at key events and meetings.

The Institute will continue to provide evidence-based information to international and national bodies developing regulations and standards applicable to CCS. The Institute will also continue to facilitate the development and roll-out of best practice guidelines and toolkits.

Business case for CCS depends on continual improvement of best practice approaches

The Institute will further develop and publish its understanding of the business cases for CCS projects, including supportive approaches and needs for change and improvement. These efforts will be based on the experience of leading demonstration projects and on collaborative efforts with other organisations to inform a best practice approach.

The Institute will continue to conduct and facilitate analyses on cost trends (including key influencing factors such as technology developments) in low-carbon technologies, and implications for the commercial foundations of CCS.

Building capacity through projects and expertise

The Institute will continue to build capacity through a range of activities aimed at equipping individuals, organisations and governments with the required skills and knowledge to initiate, develop and implement CCS projects. The primary focus will be on developing countries. This will include in-country workshops on specific topics, training courses, study tours, and the application of toolkits to aid national and provincial governments and corporations.

Building on the knowledge and experience gained from its interactions with CCS projects and policy makers, the Institute will work closely with the CCS community to help ensure the right preconditions are present to support the demonstration of CCS.

The Institute is already engaged at a national level and globally in those areas where it has a professional capability. It will continue to develop related competencies with the objective of becoming a key advisory agency for governments, industry and communities that require information or advice on policy, regulatory, financial and capacity development issues associated with CCS.

A collaborative approach drawing upon Member expertise and involvement

The Institute will draw more heavily upon the expertise of Members to support its activities. This will involve not only inputting into the direction and priorities of the Institute but also active participation in various forums, task groups and networks addressing specific CCS issues.

BUILDING A GLOBAL MEMBER-DRIVEN ORGANISATION

The Institute was launched by the Australian Government in 2009. It was established as an independent, not-for-profit entity, owned by its Members and registered as a public company. The Institute now has 349 government, industry and general Members from over 40 countries. This achievement in itself highlights the significance of the Institute's mission to the global community.

The Australian Government provides almost the entire funding for the Institute, having committed a total of AU$305 million from inception through to 2017. The basis of this support was to provide sufficient funding to successfully launch the Institute as a global organisation to foster the demonstration and deployment of CCS. After this initial seed funding it was always planned that the Institute would ultimately become self-sustaining.

Pag. 181

The Institute has now reached the stage where it must begin transitioning towards that self-sustaining global organisation. Annual budget allocations to the Institute under its funding agreement with the Australian Government will reduce from 2012-13 and fall to AU$2.5 million in each of the final two years of the agreement (2015-16 and 2016-17).

The Institute is seeking to implement its new funding and business operations model well in advance of 2015 so that it can secure key resourcing and develop work programs, governance arrangements and organisational structures in line with the new business model.

An indicative annual budget of around AU$25 million is presently targeted for undertaking the activities outlined in this Strategic Plan. Key operational elements of this indicative budget include:

- high-calibre CCS professionals with coverage of the complete CCS chain;
- continued physical global presence in key CCS jurisdictions;
- ongoing maintenance (and development as required) of a state-of-the-art knowledge platform that acts as the global ‘go to place’ for CCS stakeholders;
- production of reports and analyses of value to Members and CCS stakeholders generally;
- ongoing capacity development efforts in developing countries;
- hosting and facilitating global and regional events and workshops at both senior management and technical professional levels; and
- ongoing administrative support and servicing for a broad Member-based organisation with global operations.

A range of options for broadening financial contributions to the Institute is under evaluation. The primary source of funding is expected to be Membership fees for work that remains very much focused on the public good. It is important for the Institute to maintain a broad and diversified Membership base and a range of fee setting principles is being evaluated to take into account the Institute’s diverse Membership that includes governments and many different industry sectors.

Additional contributions to support specific work activities where the Institute has a particular capability can supplement Membership fees. These contributions would align with the Institute’s mission and outcomes (and centre on work scopes that would be very much Member/contributor driven). For example, the Institute is the recipient of a US$500,000 grant from the US Department of State to undertake knowledge sharing and capacity building activities in developing countries.

Pag. 181

Figure 5: Potential sources of funding to the Institute

PRIMARY SOURCE OF FUNDS	OTHER SOURCES OF FUNDS
• Focused on public outcomes • Broad diversified Membership base with strong connectivity to the Institute • Range of possible fees structures and Membership arrangements under review • Fee setting principles being evaluated include capacity to pay, and the nature, size and CCS involvement of key actors	Additional contributions to support specific work activities: • Member driven focus • Public good outcome focus • Natural go-between for CCS stakeholders • Institute has capability across full CCS chain, including capacity development Opportunities for commercially-based activities consistent with Institute mission and Strategic Objectives.

The Institute has developed a strong professional capability across the CCS chain since its establishment. This presents the opportunity for the Institute to undertake commercially-based activities as they arise, consistent with its mission and Strategic Objectives. These activities are expected to be a relatively small proportion of total Institute funding during the period covered by this Strategic Plan.

The direction and priorities of the Institute will benefit from much stronger Member consultation than in the past and processes to facilitate this shift are under evaluation. This is just one aspect of the transition of the Institute to a fit-for-purpose organisation that is focused on efficiency, effectiveness and working in the broader interests of its Membership and stakeholders.

The appropriate organisational structure to support the operation of the new business model for the Institute will be developed once the key elements of the new model have been bedded down, particularly the work program that can be supported by available financial resources.

NEXT STEPS

The broad activities and outcomes of the Institute are set out in this Strategic Plan. The detailed work plans consistent with this Strategic Plan, including defining the specific outputs to be delivered and the setting and tracking of performance measures, will be described in the Annual Business Plan.

With the important exception of the work being undertaken in support of a sustainable, Member-driven global organisation, much of what has been described herein is evolutionary in nature and builds on the foundations put in place over the past three years.

Key milestones over the next 18 months focus on the process for finalising the Strategic Plan and for developing and testing the key principles and arrangements underpinning the new funding and business operations model.

Phase 1: Finalising the Strategic Plan

- release of the draft Plan to all Members in July 2012 for discussion and feedback;
- review with Members at the October 2012 Calgary Members' Meeting; and
- Strategic Plan finalised by end 2012 and circulated to Members.

Pag. 183

Phase 2: Implementation of the New Funding and Business Operations Model

- development and testing with Members of Membership fee principles and levels, processes for Member engagement and review of governance arrangements, commencing in the second half of 2012 and continuing into 2013;
- review of organisational structure and system requirements to take place in the first half of 2013; and
- steps to implement the new funding and business operations model completed by the October 2013 Members' Meeting, including approval of any Constitutional amendments.

The targeted milestones allow for a timeline of around 18 months from now to undertake the necessary Member consultations and implementation of organisational, corporate, legal and financial structures and systems to allow Membership fees and/or additional sources of revenue to be received by the Institute.

It is recognised that budgetary approval procedures for the payment of Membership fees and/or additional sources of funds to the Institute will vary across Member organisations – some may need longer than 18 months from now to incorporate these fees into their annual budgets.

To assure continued relevance in a very dynamic business and policy environment the Strategic Plan will be reviewed at its mid-point in 2015.

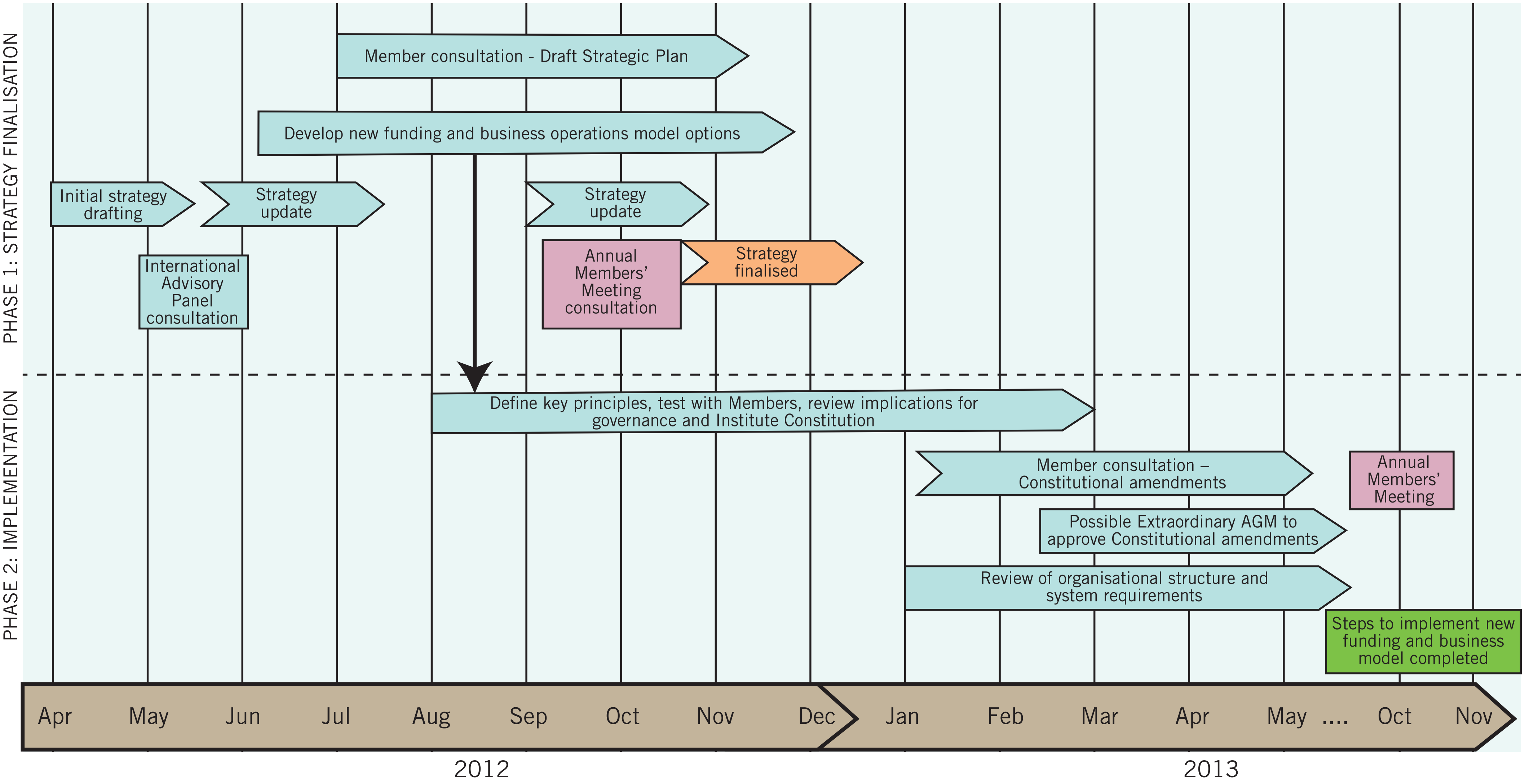
The timetable for Strategic Plan finalisation and key implementation milestones is on the following page.

For further information regarding the Member consultation and feedback process or to make enquiries regarding this document, please contact strategy@globalccsinstitute.com

Pag. 183

Pag. 184

Figure 6: Timetable for Strategic Plan finalisation and key implementation



Pag. 184

Pag. 185

Allegato 4.

Partecipazione alla Task Force Technology (TFT) della Piattaforma Zero Emission Fossil Fuel Power Plants (ZEP)

documento sui costi delle CCS

nota di ZEP sul documento sui costi delle CCS

Pag. 185

Pag. 186

Zero emissions platform

The Costs of CO_2 Capture, Transport and Storage

Post-demonstration CCS in the EU

European Technology Platform for Zero Emission Fossil Fuel Power Plants

Pag. 186

Introduction

Founded in 2005 on the initiative of the European Commission, the European Technology Platform for Zero Emission Fossil Fuel Power Plants (known as the Zero Emissions Platform, or ZEP) represents a unique coalition of stakeholders united in their support for CO_2 Capture and Storage (CCS) as a critical solution for combating climate change. Indeed, it is not possible to achieve EU or global CO_2 reduction targets cost-effectively *without* CCS, providing 20% of the global cuts required by 2050.[1] Members include European utilities, oil and gas companies, equipment suppliers, national geological surveys, academic institutions and environmental NGOs. The goal: to make CCS commercially available by 2020 and accelerate wide-scale deployment.

ZEP is an advisor to the EU on the research, demonstration and deployment of CCS. In 2006, it therefore launched its first Strategic Deployment Document (SDD) and Strategic Research Agenda (SRA).[2] The conclusion: an integrated network of CCS demonstration projects should be implemented urgently EU-wide. This was followed by an in-depth study[3] into how such a demonstration programme could work in practice, from every perspective – technological, operational, geographical, political, economic and commercial.

This approach was incorporated into the European Commission's policy framework and by 2009, two key objectives had been met: to establish funding for an EU CCS demonstration programme and a regulatory framework for CO_2 storage. An updated SDD followed in 2010.[4]

Now, ZEP's Taskforce Technology has undertaken a study into the costs of complete CCS value chains – i.e. the capture, transport and storage of CO_2 – estimated for new-build coal- and natural gas-fired power plants, located at a generic site in Northern Europe from the early 2020s. Utilising new, in-house data provided by ZEP member organisations, it establishes a reference point for the costs of CCS, based on a "snapshot" in time (all investment costs are referenced to the second quarter of 2009).

Three Working Groups were tasked with analysing the costs related to CO_2 capture, CO_2 transport and CO_2 storage respectively. The resulting integrated CCS value chains, based on these three individual reports,[5] are presented in this summary report. (For a complete picture of how the results were obtained, and all underlying assumptions, please refer to the three individual reports.)

ZEP acknowledges that the costs of CCS will be inherently uncertain until further projects come on stream. The study therefore does not provide a forecast of how costs will develop over time, but will be updated every two years in line with technological developments and the progress of the EU CCS demonstration programme. While this study focuses on power generation, future updates will also refer to co-firing with biomass, combined heat and power plants, and the role of industrial applications in greater detail.

1 International Energy Agency (IEA), World Energy Outlook, 2009
2 This included a first assessment of CO_2 capture costs, detailed in the underlying report, "The final report from Working Group 1 – Power Plant and Carbon Dioxide Capture", October 2006
3 www.zeroemissionsplatform.eu/library/publication/2-eu-demonstration-programme-co-2-capture-storage.html
4 www.zeroemissionsplatform.eu/library/publication/125-sdd.html
5 www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html; www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html; www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html

Key conclusions

- **Post 2020, CCS will be cost-competitive with other low-carbon energy technologies**
  The EU CCS demonstration programme will not only validate and prove the costs of CCS technologies, but form the basis for future cost reductions, enhanced by the introduction of second- and third-generation technologies. The results of the study therefore indicate that post-demonstration CCS will be cost-competitive with other low-carbon energy technologies as a reliable source of low-carbon power. CCS is on track to become one of the key technologies for combating climate change – within a portfolio of technologies, including greater energy efficiency and renewable energy.

- **CCS is applicable to both coal- and natural gas-fired power plants**
  CCS can technically be applied to both coal- and natural gas-fired power plants. Their relative economics depend on power plant cost levels, fuel prices and market positioning, whereas applicability is mainly determined by load regime.

- **All three CO_2 capture technologies could be competitive once successfully demonstrated**
  The study includes the three main capture technologies (post-combustion, pre-combustion and oxy-fuel), but excludes second-generation technologies (e.g. chemical looping, advanced gas turbine cycles). Using agreed assumptions and the Levelised Cost of Electricity as the main quantitative value, there is currently no clear difference between any of the capture technologies and all could be competitive in the future once successfully demonstrated. The main factors influencing total costs are fuel and investment costs.

- **Early strategic planning of large-scale CO_2 transport infrastructure is vital to reduce costs**
  Clustering plants to a transport network can achieve significant economies of scale – in both CO_2 transport *and* CO_2 storage in larger reservoirs, on- and offshore. Large-scale CCS therefore requires the development of a transport infrastructure on a scale matched only by that of the current hydrocarbon infrastructure. As this will lead to greatly reduced long-term costs, early strategic planning is vital – including the development of clusters and over-sized pipelines – with any cross-border restrictions removed.

- **A risk-reward mechanism is needed to realise the significant aquifer potential for CO_2 storage**
  Location and type of storage site, reservoir capacity and quality are the main determinants for the costs of CO_2 storage: onshore is cheaper than offshore; depleted oil and gas fields (DOGF) are cheaper than deep saline aquifers (SA); larger reservoirs are cheaper than smaller ones; high injectivity is cheaper than poor injectivity. Given the large variation in storage costs (up to a factor of 10) and the risk of investing in the exploration of SA that are ultimately found to be unsuitable, a risk-reward mechanism is needed to realise their significant potential and ensure sufficient storage capacity is available – in the time frame needed.

- **CCS requires a secure environment for long-term investment**
  Based on current trajectories, the price of Emission Unit Allowances (EUAs) under the EU Emissions Trading System will not, initially, be a sufficient driver for investment after the first generation of CCS demonstration projects is built (2015-2020). Enabling policies are therefore required in the intermediate period – after the technology is commercially proven, but before the EUA price has increased sufficiently to allow full commercial operation. The goal: to make new-build power generation with CCS more attractive to investors than without it.

Contents

Pag. 190

Executive summary

A complete analysis of CCS costs in the EU post 2020

Costs for different CO_2 capture, transport and storage options were first determined using data for the three main capture technologies (post-combustion, pre-combustion and oxy-fuel) applied to hard coal, lignite and natural gas-fired power plants; the two main transport options (pipelines and ships); and the two main storage options (depleted oil and gas fields, and deep saline aquifers), both on- and offshore.

The results were then combined in order to identify:

1. *Total costs for full-scale, commercial CCS projects in the EU post 2020*
2. *Key trends and issues for various deployment scenarios*
3. *The impact of fuel prices, economies of scale and other factors, e.g. economic.*

Utilising new, in-house data provided by ZEP member organisations

Publicly available cost data on CCS are scarce. In order to obtain a reliable base for the estimations, it was therefore decided to use new, in-house data provided exclusively by ZEP member organisations – 15 in total. This included five independent power companies and manufacturers of power plant equipment for CO_2 capture.

In order to access the data, all basic cost information was kept confidential, regarding both source and individual numbers. To this end, one person per area was assigned to collect the information, align it, create mean values and render it anonymous. However, all contributors to the study, including those who provided detailed economic data, are named in Annex II. (In future updates ZEP intends to improve the transparency of data provision, without breaching confidentiality.)

Power plants with CO_2 capture – from demonstration towards maturity

CO_2 capture comprises the majority of CCS costs. It is an emerging technology and historical experience with comparable processes shows that significant improvements are achievable – traditionally referred to as learning curves. While this study does not provide a forecast of how costs will develop over time, the following notations have been applied:

- A **base ("BASE") power plant** with CO_2 capture represents today's technology choices and full economic risk, margins, redundancies and proven components – as the very first units to be built following the demonstration phase. This constitutes a conservative cost level in the early 2020s.
- An **optimised ("OPTI") power plant** with CO_2 capture represents those units commissioned *after* the first full-size CCS plants have been in operation (~2025), including technology improvements, refined solutions, improved integration, but still using the three main capture technologies. These represent optimised cost estimations, based on first commercial experience.

In short, BASE and OPTI represent normal technology refinement and development following a successful demonstration (but not a mature technology, which will only be available in the longer term).

Pag. 190

Taking fuel cost variations into account

The fuel costs used in this study are the best estimation of a representative fuel cost in 2020. Due to the considerable uncertainty – especially in the case of natural gas, where there is a wide difference of opinion on the impact of shale gas on future prices – it was decided to use Low, Middle and High values for both natural gas and hard coal.

The ranges were selected during Q4 2010 and are consistent with detailed reviews such as the EC Second Strategic Energy Review of November 2008[6] for the year 2020 (assuming the Base Case of Average Oil Scenarios) and the UK Electricity Generation Cost Update, June 2010.[7]

For details of all major assumptions, see pages 10-14.

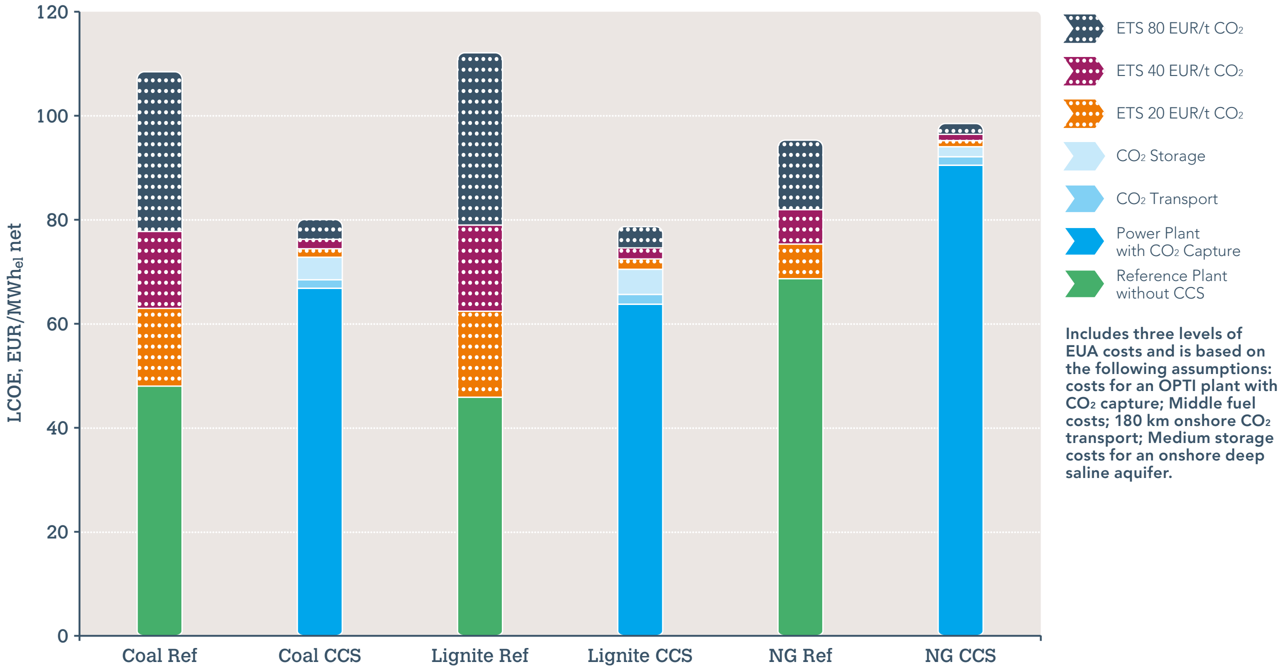
MAJOR RESULTS

a) Integrated CCS projects

As each part of the CCS value chain includes multiple variants, the results provide a probable (but not complete) set of combinations. This includes a single plant to a single "sink" (storage site) and a cluster of plants to a cluster of sinks, with a sensitivity analysis provided per combination. In order to calculate CO_2 capture and avoidance costs, reference power plants *without* CO_2 capture were also established:

- A **natural gas-fired** single-shaft F-class Combined Cycle Gas Turbine producing 420 MW_{el} net, at an efficiency of 58-60% (LHV) for BASE and OPTI plants respectively at €45-90/MWh depending on the fuel cost.
- For **hard coal**, a 736 MW_{el} net pulverised fuel (PF) ultra supercritical power plant at €40-50/MWh; for lignite, a PF-fired 989 MW_{el} net ultra supercritical plant and a lignite-fired 920 MW_{el} net PF ultra supercritical power plant with pre-drying of the lignite. All have steam conditions 280 bar 600/620°C live steam data.

Figure 1: The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)



[6] http://ec.europa.eu/energy/strategies/2008/2008_11_ser2_en.htm
[7] www.decc.gov.uk/assets/decc/statistics/projections/71-uk-electricity-generation-costs-update-.pdf

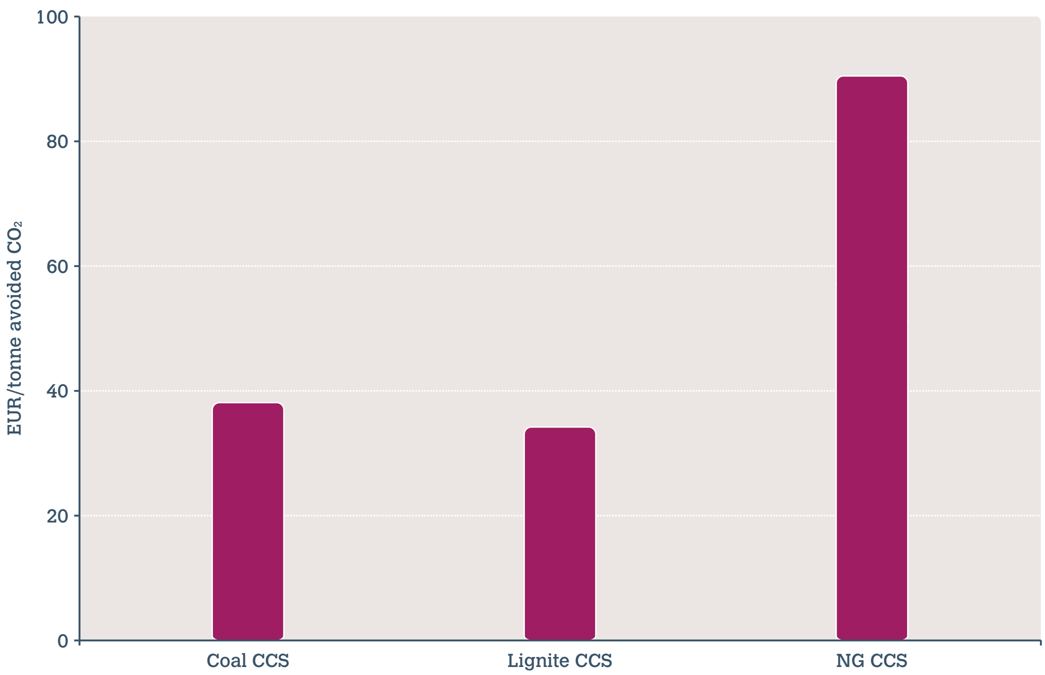
Pag. 192

- Following the demonstration phase, the application of CCS to fossil fuel power plants will result in higher electricity generating costs (e.g. increasing from ~€50/MWh up to ~€70/MWh for hard coal, excluding EUA costs). Corresponding CO_2 avoidance costs, compared to the reference plants with the same fuel, are shown in Figure 2 below.

- The two coal cases are similar in cost (~€70/MWh excluding EUA costs), while the gas case shows a higher cost (~€95/MWh excluding EUA costs). At lower EUA prices, the coal cases with CCS also come out more favourably than the gas case when compared to the reference plants. However, depending on different assumptions, the competitiveness of the technologies changes, with gas CCS becoming competitive at gas prices <€6/GJ. Gas CCS plants also produce less than half the amount of CO_2 to be captured per MWh than coal, resulting in lower transport and storage costs per MWh.

- The blue bars show that the combined cost of the power plant with capture comprises 80-90% of the total LCOE (~75% of the additional LCOE for CCS vs. the reference plants). However, CO_2 transport and storage to a large extent determine the location and decision to proceed with a project. Posing substantial development and scale-up challenges, costs are dominated by upfront investments, while any reward depends on volume streams, suitability of the storage site, utilisation and the development of an infrastructure (see below). While capture technology will be chosen based on a calculable economy, transport and storage costs therefore depend on the suitability of the chosen solution.

Figure 2: CO_2 avoidance costs for possible plants commissioned in the mid 2020s – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view (calculated on the same basis as Figure 1)



[8] This is in accordance with EU estimates of EUA prices for 2025: http://ec.europa.eu/clima/documentation/roadmap/docs/sec_2011_288_en.pdf

Pag. 192

- Figure 2 shows that the associated EUA break-even cost corresponds to a price of €37/tonne of CO_2 for hard coal; ~€34/tonne of CO_2 for lignite; and ~€90/tonne of CO_2 for gas. At an EUA price of €35/tonne of CO_2,[8] these full-size, coal-fired CCS power plants are therefore close to becoming commercially viable, while the gas case is not. However, unabated gas power plants remain a commercial option, as shown in Figure 1.

N.B. Costs for OPTI plants assume a completely successful demonstration of the technology and/or that the first full-size CCS plants (following the EU CCS demonstration programme) have already been in operation. All reported costs exclude the exceptional development and other costs associated with the demonstration programme itself.

Post 2020, CCS will be cost-competitive with other low-carbon energy technologies.

For detailed results on integrated CCS projects, see pages 15-26.

b) CO_2 Capture

Capture costs were determined for first-generation capture technologies which will probably be ready for deployment in the early 2020s: post-combustion, IGCC with pre-combustion and oxy-fuel. All three were applied to hard coal and lignite-fired power plants, while post-combustion was applied to natural gas.

- On an LCOE basis, there is no significant difference between the three capture technologies for coal (within the available accuracy): hard coal-fired power plants without capture have an LCOE of ~€48/MWh (excluding EUA costs), rising to €65-70/MWh[9] with capture for an OPTI plant. However, complexity differs considerably between the three options and none will become fully commercial until several large-scale plants have been operating following the demonstration phase. Achieving high plant availability is therefore key to keeping costs competitive.

- Natural gas-fired power plants without capture have an LCOE of ~€70/MWh, rising to ~€90/MWh with capture.[9] However, as they have a different cost structure to coal-fired CCS plants – with a lower capital cost and higher fuel costs – the LCOE is competitive with coal[9] if the gas price is low. At an EUA price of ~€35/tonne of CO_2, unabated gas (at €5/GJ) is also competitive with coal with CCS.[9]

- CO_2 avoidance costs against a reference plant with the same fuel *calculated at the fence of the plants* therefore give <€30/tonne of CO_2 avoided for lignite; just over €30/tonne for hard coal; and ~€80/tonne for natural gas. (All figures exclude transport and storage costs.)

- On a unit basis, small power plants are more expensive than large; BASE plants are more expensive than OPTI plants. As the less expensive option will always be chosen during the first 10 years of deployment, the lower figures in this study are the most likely to represent CCS plants commissioned in the early 2020s. During this period, the three main capture options will also develop considerably, in parallel with second- and third-generation technologies.

All three CO_2 capture technologies could be competitive once successfully demonstrated.

For detailed results on CO_2 capture, see pages 27-31 and the underlying report: www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html

[9] At Middle fuel prices

c) CO_2 Transport

The study presents detailed cost elements and key cost drivers for the two main methods of CO_2 transportation: pipelines and ships. These can be combined in a variety of ways – from a single source to a single sink, developing into qualified systems with several sources, networks and several storage sites over time. Several likely transport networks of varying distances are therefore presented, with total annual costs and a cost per tonne of CO_2 transported. The cost models operate with three legs of transport: feeders, spines and distribution, each of which may comprise on-/offshore pipelines or ships.

- The results show that pipeline costs are roughly proportional to distance, while shipping costs are fairly stable over distance, but have "step-in" costs, including (in this study) a stand-alone liquefaction unit potentially remote from the power plant. Pipelines also benefit significantly from scale, whereas the scale effects on ship transport costs are less significant.

- Typical costs for a short onshore pipeline (180 km) and a small volume of CO_2 (2.5 Mtpa) are just over €5/tonne of CO_2. This reduces to ~€1.5/tonne of CO_2 for a large system (20 Mtpa). Offshore pipelines are more expensive at ~€9.5 and €3.5/tonne of CO_2 respectively, for the same conditions. If length is increased to 500 km, an onshore pipeline costs €3.7/tonne of CO_2 and an offshore pipeline ~€6/tonne of CO_2.

- For ships, the cost is less dependent on distance: for a large transport volume of CO_2 (20 Mtpa) costs are ~€11/tonne for 180 km; €12/tonne for 500 km; and ~€16/tonne for very long distances (1,500 km), including liquefaction. For a smaller volume of CO_2 (2.5 Mtpa), costs for 500 km are just below €15/tonne, including liquefaction.

- For short to medium distances and large volumes, pipelines are therefore by far the most cost-effective solution, but require strong central coordination. Since high upfront costs, CAPEX and risk are barriers to rapid CCS deployment, combining ship and pipeline transport via the development of clusters could provide cost-effective solutions, especially for volume ramp-up scenarios. However, this entails the development of an infrastructure – including start-up costs, central planning and the removal of any cross-border restrictions. Technology and final costs therefore appear to be less of an issue than the development of a rational system for transport.

Early strategic planning of large-scale CO_2 transport infrastructure is vital to reduce costs.

For more detailed results on CO_2 transport, see pages 32-34 and the underlying report: www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html

d) CO_2 Storage

Publicly available data on CO_2 storage costs barely exists. A "bottom-up" approach was therefore taken, using cost components provided by ZEP members with an in-depth knowledge of closely linked activities and consolidated into a robust, consistent model. In order to cover the range of potential storage configurations and still provide reliable cost estimates, storage was divided into six main "typical" cases, according to major differentiating elements: depleted oil and gas fields (DOGF) vs. deep saline aquifers (SA); offshore vs. onshore; and whether existing ("legacy") wells were re-usable.

- The cost range is large – from €1 to €20/tonne of CO_2. On the assumption that the cheaper available storage sites will be developed first, and the more expensive when capacity is required, it could be argued that storage costs for the early commercial phase will be at the low/medium levels of the defined ranges for onshore SA at €2-12/tonne;

[10] In the commercial phase

onshore DOGF at €1-7/tonne; offshore SA (with the largest capacities) at €6-20/tonne; and offshore DOGF at €2-14/tonne. In other words:
– onshore is cheaper than offshore
– DOGF are cheaper than SA (particularly if they have re-usable legacy wells)
– offshore SA show the highest costs and the widest cost range
– sensitivity is dominated by field capacity, injection rate and depth.

- The availability and capacity of suitable storage sites developed into a key consideration. In terms of numbers, the majority of suitable sites are below the estimated capacity of 25-50 Mt, which corresponds to the need for more than five reservoirs to store 5 Mtpa[10] of CO_2 for 40 years; the majority of estimated capacity is found in very large DOGF and SA (>200 Mt capacity).

- In conclusion, CO_2 storage capacity is available in Europe. However, the best known storage sites are also the smallest and not sufficient for a larger system. Offshore – followed by onshore – SA have the largest potential, but also the highest costs. If the best options can be used, costs could be as low as a few €/tonne, rising to tens of €/tonne if the larger and more remote SA have to be used. Developers of these more efficient, but less known, storage sites must therefore be rewarded for taking on the risk and upfront costs required for their exploration and development.

Given the large variation in storage costs and the risk of investing in the exploration of deep saline aquifers that are ultimately found to be unsuitable, a risk-reward mechanism is needed to realise their significant potential.

For more detailed results on CO_2 storage, see pages 35-37 and the underlying report: www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html.

Sensitivities

A sensitivity analysis of the cost results was calculated for a supercritical OPTI hard coal-fired power plant, with post-combustion capture and storage in an onshore SA. This shows that fewer running hours result in a much higher cost (€19/MWh higher LCOE when plant load factor reduces from 7,500 to 5,000 hours per year). CAPEX and WACC also give relatively large variations, which is to be expected given that capital costs dominate for a coal-fired power plant: +/– 25% CAPEX leads to LCOE changes of +/– €8/MWh; +/–2% points from the 8% WACC leads to LCOE changes of +€6/–€5/MWh).

Plant life, however, shows a low sensitivity since the cost calculation is based on the net present value of the investment. Storage costs also make a small contribution to overall costs. Due to the relatively cheap fuel, the efficiency of the capture (absorption–desorption) process is also less important, while fuel costs as such have a larger impact. (Changing the Middle fuel cost from €2.4/GJ to a Low €2/GJ and a High €2.9/GJ leads to LCOE changes of –€4/+€5/MWh.)

Due to the cost structure for a natural gas-fired CCS power plant – with substantially lower investment costs, somewhat lower O&M costs and almost three times higher fuel costs – the total sensitivity is the reverse, i.e. much more influenced by fuel cost and less by capital.

Methodology

A complete analysis of CCS costs in the EU post 2020

The ZEP cost study presents best current estimates for full-scale commercial CCS in the power sector in Europe post 2020, based on new, in-house data provided by member organisations. The final results assume that all elements of the value chain have been successfully demonstrated in the EU CCS demonstration programme and other demonstration initiatives worldwide.

Three Working Groups within ZEP's Taskforce Technology first analysed the costs related to CO_2 capture, CO_2 transport and CO_2 storage respectively. The results of these three individual reports[11] were then combined to give total costs for integrated CCS projects

a) Utilising new, in-house data from ZEP member organisations

It is theoretically possible to obtain basic data on CCS technologies from several sources. However, most public reports have either used budget offers from manufacturers, quoted other studies, or calculated equipment costs from academic models. Several ZEP members have had difficulties obtaining relevant information for their specific situation and therefore undertaken a considerable amount of work themselves. Costs also differ significantly between different regions, such as the USA, Asia and Europe; and vary in time, as several public cost indices illustrate.

As reliable external cost data proved scarce, it was therefore decided to utilise the technical and economical knowledge of ZEP members who either manufacture, or have substantial research and experimental experience in CCS – 15 organisations in total. (This included five independent power companies and manufacturers of power plant equipment for CO_2 capture.) Indeed, many are already undertaking detailed engineering studies for CCS demonstration projects, encompassing the entire value chain. Power companies regularly cooperate with several manufacturers and are even now building plants of the kind described here (currently without CCS). The oil and gas industry also has decades of experience with natural gas analogues for the majority of the transport and storage chain.

Thanks to the diverse representation within ZEP, data covering all aspects of the costs and technology performance were therefore assembled, with important CAPEX figures (and appropriate contingencies) for the coal-fired CO_2 capture cases provided by the power companies and equipment suppliers from engineering studies completed to date.

In order to access the data, all basic cost information was kept confidential, regarding both source and individual numbers. To this end, one person per area (the co-author of the underlying report) was assigned to collect the information; compare and adjust it if large discrepancies were apparent; create mean values; and render it anonymous. However, all contributors to the study, including those who provided detailed economic data, are named in Annex II. In future updates, ZEP intends to improve the transparency of data provision, without breaching confidentiality.

N.B. Data for this report were collected in spring 2010, but in order to align them, all sources were recalculated by indices to the second quarter of 2009.

[11] www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html; www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html; www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html

b) Power plants with CO_2 capture – from demonstration towards maturity

Contributors of basic data were also asked if they could illustrate the development of both costs and technical solutions over time. Since the answers were not totally consistent – and included other considerations besides pure technology development – the results are not presented in the context of traditional learning curves. However, the following notations were applied:

- **A base ("BASE") power plant with CO_2 capture** represents today's technology choices – including full economic risk, margins, redundancies and proven components – as the very first units to be built following the demonstration phase. This constitutes a conservative cost level in the early 2020s.

- **An optimised ("OPTI") power plant with CO_2 capture** represents those units commissioned after the first full-size CCS plants have been in operation (~2025), including technology improvements, but not a completely new technology, e.g. improved steam data of the plant; improved energy utilisation in conventional equipment; higher level of plant integration; lower risk margins etc. In short, normal product development based on first commercial experience.

In short, BASE and OPTI represent normal technology refinement and development following a successful demonstration (but not a mature technology, which will only be available in the longer term).

See page 17 for a more detailed description of BASE and OPTI methodologies.

c) The application of CCS to carbon-intensive industrial sectors

This study focuses on CCS for power generation, but it could also potentially reduce CO_2 emissions from the steel, cement, refineries/petrochemical and other industries. Some of the applied processes in these industries have higher concentrations of CO_2 in some of their off-gases (natural gas processing, cement, steel, hydrogen manufacturing for refineries, ammonia production etc.) which could lead to comparable or lower capture costs than those for coal.

However, the variety, uniqueness and scale of industrial production processes will lead to a wide range of capture costs and less generic solutions which are not easy to compare. ZEP will therefore seek cooperation with relevant industries in order to reference the costs of industrial CCS applications – including biomass-based applications – in future updates of the ZEP cost report.

d) Major assumptions

For consistency, a number of common assumptions were established and applied across all three Working Groups. These are presented below in order to allow full transparency and comparisons with specific projects. The sensitivity of changes to these basic assumptions were also analysed and the results are given below.

Economic assumptions
Volatility in plant and equipment costs, short- and long-term costs and currency developments have been addressed by indexing all estimates to one specific period – the second quarter of 2009. Any user of the cost data in this report is therefore advised to estimate and adjust for developments after this period. The cost basis is European and all reported costs are in euros; currency exchange rates representative of the actual date of original studies have been used.

A real (without inflation) cost of capital for investments, here designated as WACC (Weighted

Pag. 198

Average Cost of Capital), is assumed to be 8% (with sensitivity evaluated for 6% and 10%). The chosen real WACC reflects required return on equity and interest rates on loans and it is assumed that the inflation rate is equal for all costs and incomes during the project life. The required CAPEX has been annualised and discounted back to the present using the WACC.

The fuel costs used in this study are the best estimation of a representative fuel cost in 2020. Owing to the considerable uncertainty – especially in the case of natural gas, where there is a wide difference of opinion on the impact of shale gas on future prices – it was decided to use Low, Middle and High values for both natural gas and hard coal. The ranges were selected during Q4 2010 and are consistent with detailed reviews such as the EC Second Strategic Energy Review of November 2008[12] for the year 2020 (assuming the Base Case of Average Oil Scenarios), and the current UK Electricity Generation Cost Update.[13]

The following fuel costs were selected for the study:

Fuel Costs	Low	Middle	High
Hard coal - €/GJ	2.0	2.4	2.9
Lignite - €/GJ	1.4	1.4	1.4
Natural gas - €/GJ	4.5	8.0	11.0

For electricity consumptions for CO_2 transport and storage operations (beyond the power plants), an electricity purchase price of €0.11/kWh was found to be representative. The agreed CCS project lifetime is 40 years for commercial hard coal-based and lignite-based projects; 25 years for natural gas turbine-based projects.

Technical assumptions

Due to the inherently high investments for thermal power plants with CO_2 capture, it is assumed that all power plants will operate in base load, operating for 7,500 hours equivalent full load each year. This is also consistent with the fact that a CCS plant, if realised, will have a lower variable operations cost than a corresponding plant without CCS (when including the EUA price) and thus always be dispatched before any other fossil fuel power plant, including gas. The only reason why a CCS plant would not work in base load mode is either because there is more prioritised power (e.g. Wind) available than is needed, or if the technical availability is lower.

Power plant concepts with CO_2 capture

The technologies studied are first-generation capture technologies: post-combustion CO_2 capture; IGCC with pre-combustion capture; and oxy-fuel, adapted to hard coal, lignite and natural gas, as applicable. For each technology, a range of costs was developed for BASE and OPTI power plants (see above).

For hard coal-fired and lignite-fired power plants, the following power plant concepts were used:

- PF ultra supercritical (280 bar 600/620°C steam cycle) power plant with post-combustion capture based on advanced amines.

- Oxygen-blown IGCC with full quench design, sour shift and CO_2 capture with F-class Gas Turbine (diffusion burners with syngas saturation and dilution).

- Oxy-fired PF power plant with ultra supercritical steam conditions (280 bar 600/620°C steam cycle).

For the integrated CCS projects, average expected values have been used for OPTI plants with capture, since the costs for the plant concepts are similar. For hard coal-fired power plants, average sizes and quantities of captured CO_2 for one power plant block are:

- Net electric capacity: ~700 MW_{el}
- Captured CO_2: 0.85 t/MWh_{el} net, ~4.5 Mt/year.

[12] http://ec.europa.eu/energy/strategies/2008/2008_11_ser2_en.htm
[13] www.decc.gov.uk/assets/decc/statistics/projections/71-uk-electricity-generation-costs-update-.pdf

Pag. 198

For lignite-fired power plants, average sizes and quantities of captured CO_2 for one power plant block are:
- Net electric capacity: ~800 MW_{el}
- Captured CO_2: 0.95 t/MWh_{el} net, ~5.5 Mt /year.

For natural gas-fired Combined Cycle Gas Turbines (CCGT) power plants for the integrated CCS projects with OPTI post-combustion CO_2 capture (based on an advanced amine), the sizes and quantities of captured CO_2 for one power block (consisting of one single-shaft F-class CCGT) are:
- Net electric capacity: ~350 MW_{el}
- Captured CO_2: 0.33 t/MWh_{el} net, ~1 Mt/year.

Reference power plants concepts without CO_2 capture

The corresponding reference power plants without CO_2 capture used in this study are:

- Natural gas-fired single-shaft F-class Combined Cycle Gas Turbine producing 420 MW_{el} net at an efficiency of 58% (LHV and BASE) or 60% (LHV and OPTI).

- Hard coal 736 MW_{el} net pulverised fuel (PF) ultra supercritical (280 bar 600/620°C steam cycle) power plant.

- Lignite-fired 989 MW_{el} net PF ultra supercritical (280 bar 600/620°C steam cycle) power plant and a lignite-fired 920 MW_{el} net PF ultra supercritical (280 bar 600/620°C steam cycle) power plant with pre-drying of the lignite.

A key assumption for the design of the entire CCS chain concerns production volumes and profiles. Based on the power plant concepts with CO_2 capture, three different annual CO_2 volumes have been considered:

- 2.5 million tonnes per annum (Mtpa) representing a commercial natural gas-fired plant with CCS (a plant with two power blocks), or a coal-based demonstration project.

- 10 Mtpa representing a full-scale commercial coal-fired power plant with CCS (a plant with two power blocks).

- 20 Mtpa representing a typical full-scale, mature CCS cluster.

The production profile is assumed to be linear, with equal hourly production rates of 333, 1,330 and 2,660 tonnes CO_2/hour respectively during the 7,500 hours per year. In reality, a wide variety of volumes will be present, but the three categories illustrate the possible modus operandi for the systems.

Boundary conditions

Boundaries between the three elements of capture, transport and storage have been defined as follows:

- *Compression/liquefying/processing of the captured CO_2 to meet the requirements of the initial transport process* are included in the design and cost of the power plants with CO_2 capture. The assumed delivery conditions for CO_2 from the capture plant are:
  - 110 bar and ambient temperature (max. 30°C) for *pipeline as initial transport*, with CO_2 quality requirements that should permit the use of cost-effective carbon steel materials in CO_2 pipelines and meet health and safety requirements.
  - 7 bar and -55°C for *ship as initial transport*, with CO_2 quality as above for pipelines, but with a water content low enough to allow carbon steel for the logistic system.

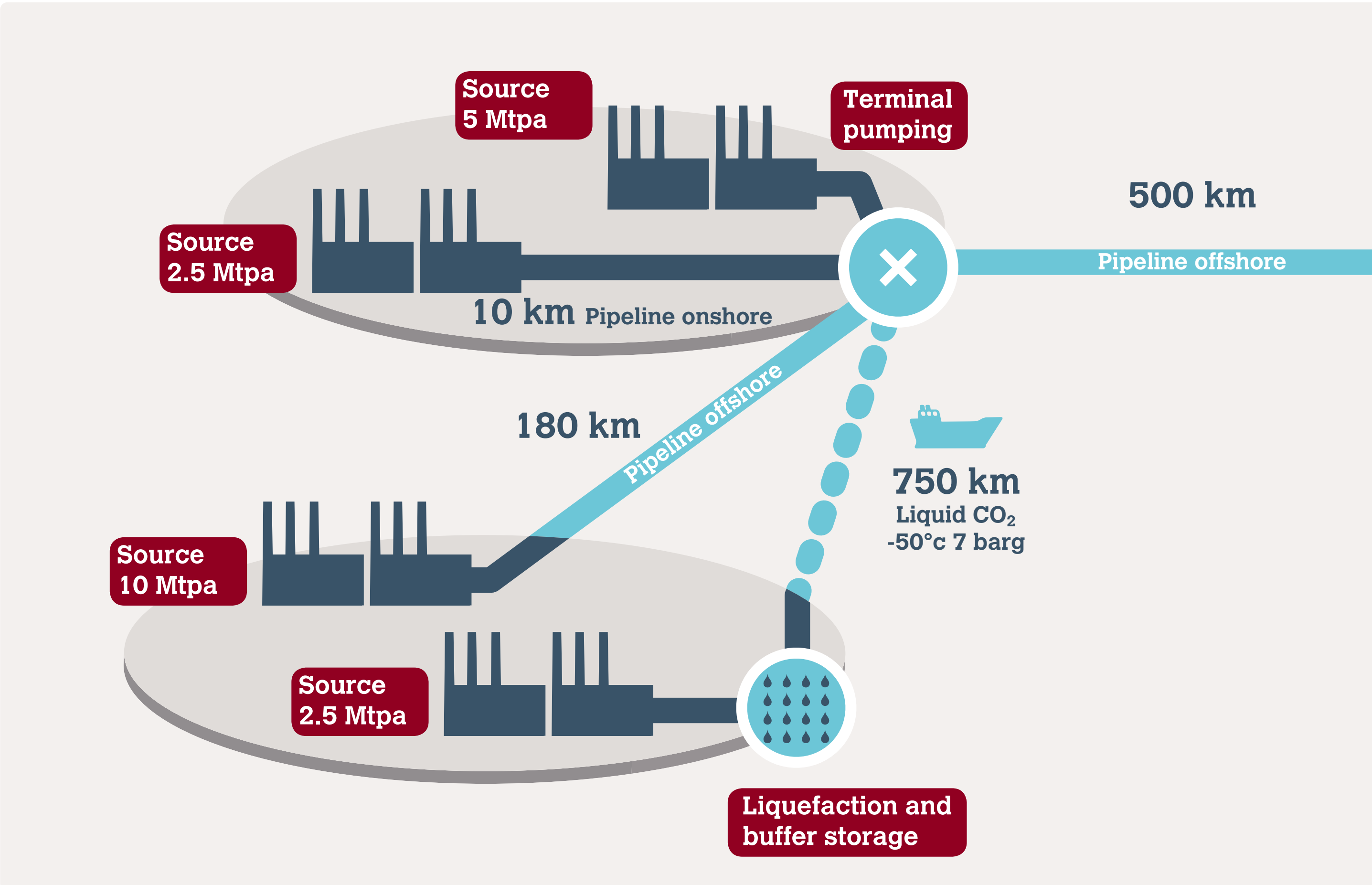
- The *transport process is assumed to deliver the CO_2 to the storage process at the well-head* in the following condition:
  - Temperature offshore: ambient seawater temperature, from 4°C to 15°C
  - Temperature onshore: ambient ground temperature ~10°C
  - Pressure: minimum 60 bar
  - Cost estimates for onshore pipelines assume that the pipeline terminates in a valve and a metering station, which constitute the interface to the storage process onshore.
  - Both offshore pipeline and ship transport cost estimates include the cost of a sub-sea well-head template, whereas manifold costs are assumed to be included in storage costs with the drilling of injection wells. The boundary towards storage is therefore at the sea bottom surface, below this template. For ship transport,

this implies conditioning (pumping and heating to the required condition) onboard for "slow" discharge directly to the well(s) without the use of intermediate buffer storage. A resulting assumption is that both the wells and storage reservoir are capable of receiving injection interrupted by shorter or longer periods, while waiting for the subsequent ship.

Several assumptions are also used in the reports in order to simplify the process and the calculations.

For further details, see individual reports on CO_2 capture, transport and storage.[14]

Figure 3: An offshore 20 Mtpa CO_2 transport network with an offshore pipeline spine of 500 km (used in this report)



[14] www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html;
www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html;
www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html

The results

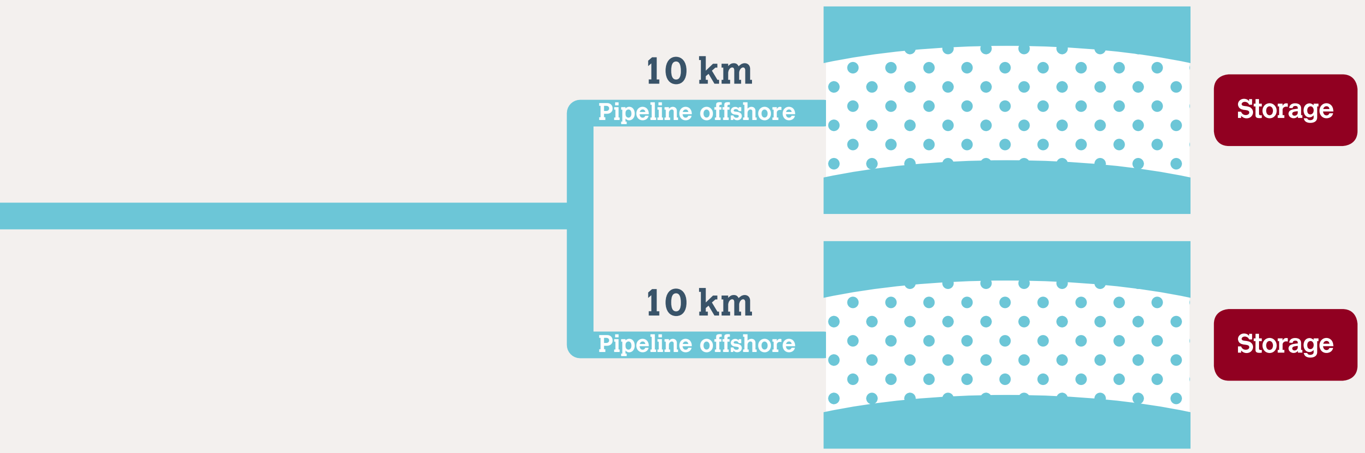
Integrated CCS projects

Costs for different CO_2 capture, transport and storage options were first determined, then combined in order to identify:

- *Total costs for full-scale commercial CCS projects in the EU post 2020.*
- *Key trends and issues for various deployment scenarios in the early commercial phase.*
- *The impact of fuel prices, economies of scale and other factors, e.g. economic.*

As each part of the CCS value chain includes multiple variants, the results provide a probable – but not complete – set of combinations.

N.B. Detailed data for the underlying cases for power plants and CO_2 capture, transport and storage are given in Table 6 in Annex I.



a) Single plant to a single "sink"

Early commercial power plants with CCS in Europe may be fired with coal or natural gas in the following scenarios:

- **Commercial hard coal-fired plants with CCS**. This case consists of 2 x 700 MW_{el} power plant blocks with CO_2 capture, together producing ~10 Mt CO_2 per year and a moderately favourable transport scenario, comprising a 10 km feeder + 180 km main pipeline to a deep saline aquifer (SA) onshore storage site.

- **Commercial natural gas-fired plants with CCS**. This case consists of 2 x 350 MW_{el} power plant blocks with CO_2 capture, together producing ~2 Mt CO_2 per year, which is reasonably close to the calculated costs for transporting 2.5 Mtpa used in the study. It also has a favourable transport scenario, comprising a 180 km onshore pipeline to an onshore SA storage site.

As large natural gas-fired CCGT plants can emit quantities of CO_2 comparable to CCS demonstration projects firing coal and lignite, they will therefore have similar transport and storage costs per tonne of CO_2.

b) Clusters of plants and sinks achieve economies of scale for CO_2 transport and storage

Wide-scale CCS deployment may well require the use of storage sites located further away from the power plant and the use of both on- *and* offshore storage sites. While costs for pipeline transport of CO_2 over long distances from a single plant to a single sink increase proportionally to the distance, clustering power plants to a local transport network results in economies of scale in both CO_2 transport and CO_2 storage in larger storage sites.

This is illustrated by calculating costs for a cluster arrangement consisting of natural gas and hard coal-fired power plants, utilising a common 500 km pipeline and a cluster of storage sites offshore:

- Two natural gas-fired plants – each with 2 x 350 MW_{el} power plant blocks with CO_2 capture – together producing ~2 Mt CO_2 per year per plant.

- One hard coal-fired plant – with 1 x 700 MW_{el} power plant block with CO_2 capture – producing ~5 Mt CO_2 per year.

- One hard coal-fired plant – with 2 x 700 MW_{el} power plant blocks with CO_2 capture – together producing ~10 Mt CO_2 per year.

The offshore 20 Mt/year CO_2 transport network[15] comprises (see Figure 3 above):

- A 5 Mt point source at the collecting point (one hard coal-fired plant, with 1 x power plant block with CO_2 capture).

- 2.5 Mt (from one natural gas-fired plant, with 2 x power plant blocks with CO_2 capture), transported to the collecting point via a 10 km onshore pipeline.

- Another 2.5 Mt CO_2 (from the other natural gas-fired plant, also with 2 x power plant blocks with CO_2 capture), transported 750 km by ship to the hub.

- A final 10 Mt CO_2 (from one hard coal-fired plant, with two power plant blocks with CO_2 capture), transported 180 km offshore by pipeline.

From the hub, 20 Mt CO_2 is transported in an offshore pipeline (500 km) and finally distributed to the storage sites – SA or DOGF – via two 10 km pipelines, each carrying 10 Mt CO_2.

[15] Further described in the CO_2 Transport Cost Report, as Network # 8b

c) The costs of CCS for various deployment scenarios

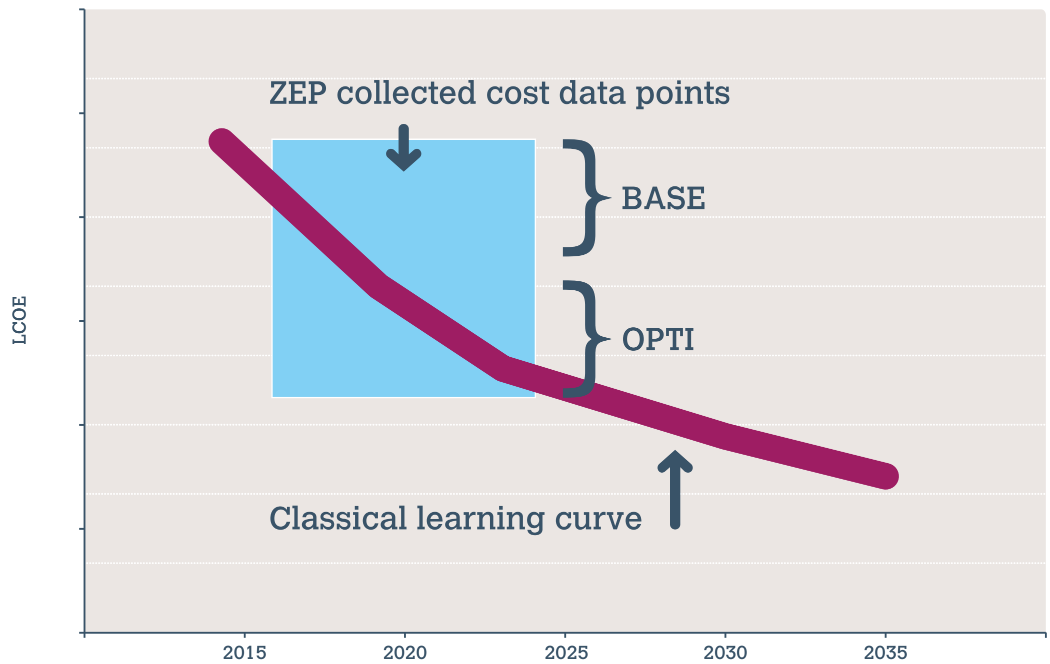
For each capture technology, two sets of costs were developed for new-build power plants with CO_2 capture: a base plant (BASE) represents an early, more conservative plant design with higher costs; an optimised plant (OPTI) represents a design based on first commercial experience – including technology improvements, refined solutions and improved integration – but still using the three main capture technologies (see also page 11).

No precise date can be attached to the raw data points collected from ZEP contributors. As illustrated in Figure 4, they are representative of costs estimated in 2009/2010 for a commercial plant whose Final Investment Decision is taken between 2015 and 2025. The data were normalised through a common cost calculation template, ensuring that the resulting numbers would be grounded into a defined set of assumptions. The highest cost numbers correspond to the BASE plant definition and have been normalised and averaged, while the lowest numbers correspond to OPTI plants, based on first commercial experience.

This approach is not based on a classical industrial learning curve approach, but constructed from the anonymous collection of the various contributions from ZEP members, each with their own views on the learning curve. However, ZEP believes that the cost boundaries between BASE and OPTI represent the most accurate view to date on the expected cost span for first commercial plants to be commissioned post 2020. (Several studies exist describing the potential of cost reduction for CCS as a result of the learning process, such as from Edward Rubin at Carnegie Mellon University.[16])

For the integrated CCS cases described below, average expected costs for OPTI plants have been used, since it is considered that the majority of commercial CCS projects will be based on OPTI plant designs, rather than the more expensive BASE designs. Low, Medium/Base and High cost assumptions are used for CO_2 storage. For detailed data for power plant concepts with CO_2 capture and CO_2 storage cost assumptions, see Table 6 in Annex 1.

Figure 4: An illustration of ZEP data collected for base (BASE) and optimised (OPTI) power plants with CO_2 capture (post-combustion, IGCC with pre-combustion and oxy-fuel)



[16] www.cmu.edu/epp/iecm/IECM_Publications/2007a%20Rubin%20et%20al,%20Intl%20Jour%20of%20GHG%20(Feb).pdf

Pag. 204

Figure 5: Total LCOE for integrated CCS projects vs. reference plants without CCS (including various assumed costs for EUAs under the EU ETS and using Middle fuel costs)

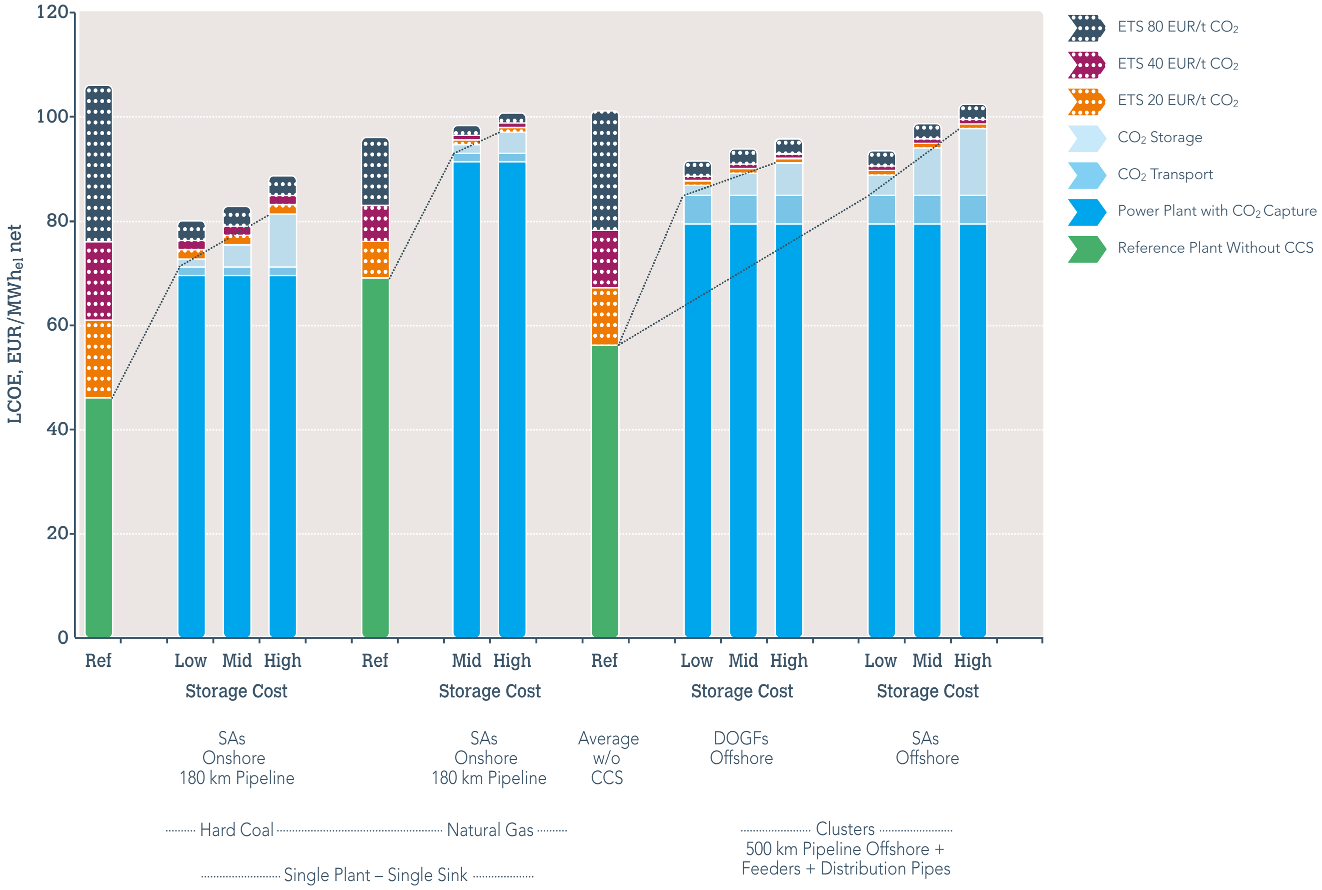


Figure 5 shows the calculated LCOE for various cases, with the green bars representing the reference plants for each case. The blue bars represent the Single Plant hard coal and natural gas CCS power plants to the left and a Cluster of plants to the right. On top of each bar, transport and storage costs are added, while the striped colours show EUA costs for different price levels. The dotted lines highlight the LCOE for each CCS case (excluding any costs for EUAs) vs. reference cases without CCS.

- The combined cost of the power plant with capture accounts for the majority of total costs.
- Based on study assumptions, coal-fired power plants will primarily be fitted with CCS, since they are more competitive if EUA costs are high enough.

While Figure 5 shows total LCOE for integrated CCS projects vs. reference plants without CCS (including various assumed costs for EUAs) using *Middle fuel* costs, Table 4 (page 40) and Figure 11 (page 23) show the *ranges* of LCOE for power plants with CCS resulting from uncertainties and variations in CO_2 capture, transport and storage costs.

Other calculations may also be made from Figure 5, such as the CO_2 avoidance costs and the additional cost of CCS for generated electricity. This is illustrated in Figures 6-10.

Pag. 204

Pag. 205

Figure 6 shows costs per tonne of CO_2 captured for integrated CCS projects (hard coal and natural gas) calculated with Low, Middle and High Fuel Costs. Transport and Storage costs are also added (Single Source – Single Sink).

From Figure 6 we can conclude that:

- CO_2 capture costs per tonne for the natural gas-fired Single Plant case are much higher than for the hard coal-fired Single Plant case, due to the higher fuel price and the lower CO_2 concentrations in gas turbine exhaust gases than in boiler flue gases (requiring larger absorbers for the same quantities of CO_2).

- The impact of the fuel price on the total cost per tonne of CO_2 captured is higher for gas than for coal.

- When calculated on a *per tonne basis*, the CO_2 transport and storage is more expensive for gas than for coal, since smaller quantities give higher specific costs. Total cost per kWh, on the other hand, is lower for gas, since it produces less than half the amount of CO_2 (see also Figure 7).

Figure 7 shows additional LCOE for integrated CCS projects (hard coal and natural gas) vs. reference plants without CCS (Single Plant – Single Sink). Calculations are made for Low, Middle and High fuel costs (excluding any saved costs for EUAs).

From Figure 7 we can conclude that:

- Total additional LCOE is higher for the hard coal case than for the natural gas case for all fuel cost scenarios.

- The additional LCOE for CO_2 capture is mildly dependent on fuel price. The LCOE for natural gas compared to hard coal is around the same for the Middle fuel cost; lower for the Low fuel cost; and higher for the High fuel cost.

- The additional LCOE for CO_2 transport and storage is lower for the natural gas case than for the hard coal case.

If only transport and storage costs are calculated, Figures 8 and 9 can be created, where Clusters are also included. These give cost elements for the different cases and show that:

- Single Source – Single Sink cases do not give high transport costs because shorter distances are assumed than for a larger Cluster.

- SA are always more expensive than DOGF.

- Storage costs are higher for coal than for gas when calculated as LCOE, but lower per tonne of CO_2.

Pag. 205

Figure 6: Costs per tonne of CO_2 captured for integrated CCS projects (hard coal and natural gas) calculated with Low, Middle and High Fuel costs. Transport and Storage costs are also added (Single Source – Single Sink)

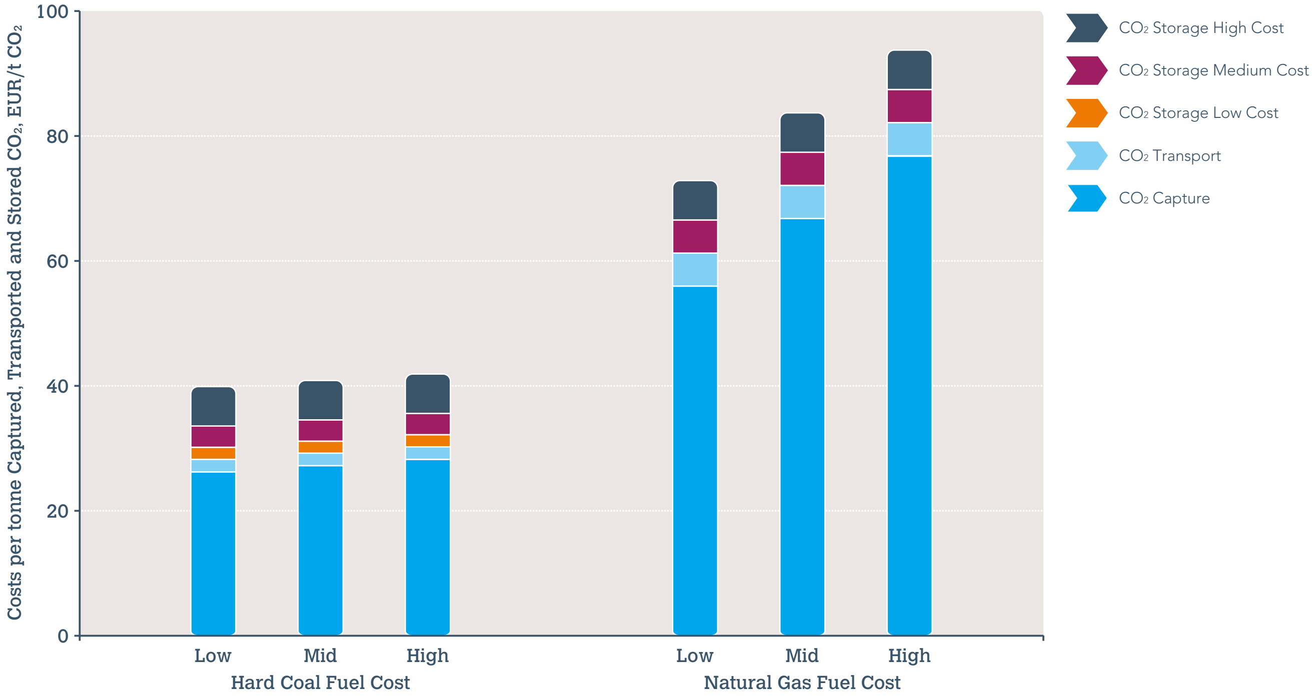


Figure 7: Additional LCOE for integrated CCS projects (hard coal and natural gas) vs. reference plants without CCS (Single Plant – Single Sink). Calculations are made for Low, Middle and High fuel costs (excluding any saved costs for EUAs)

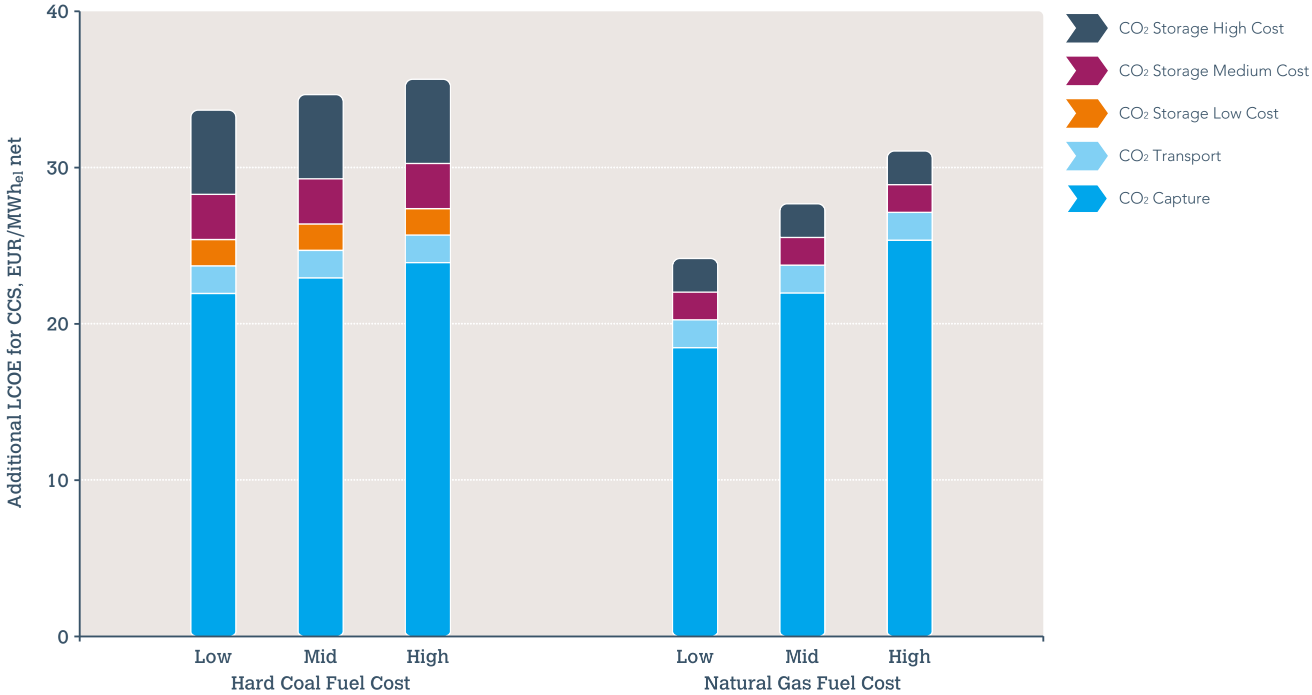


Figure 8: Calculated costs per tonne of CO_2 captured for transport and storage for integrated projects. For the Clusters, the use of SA and DOGF are highlighted

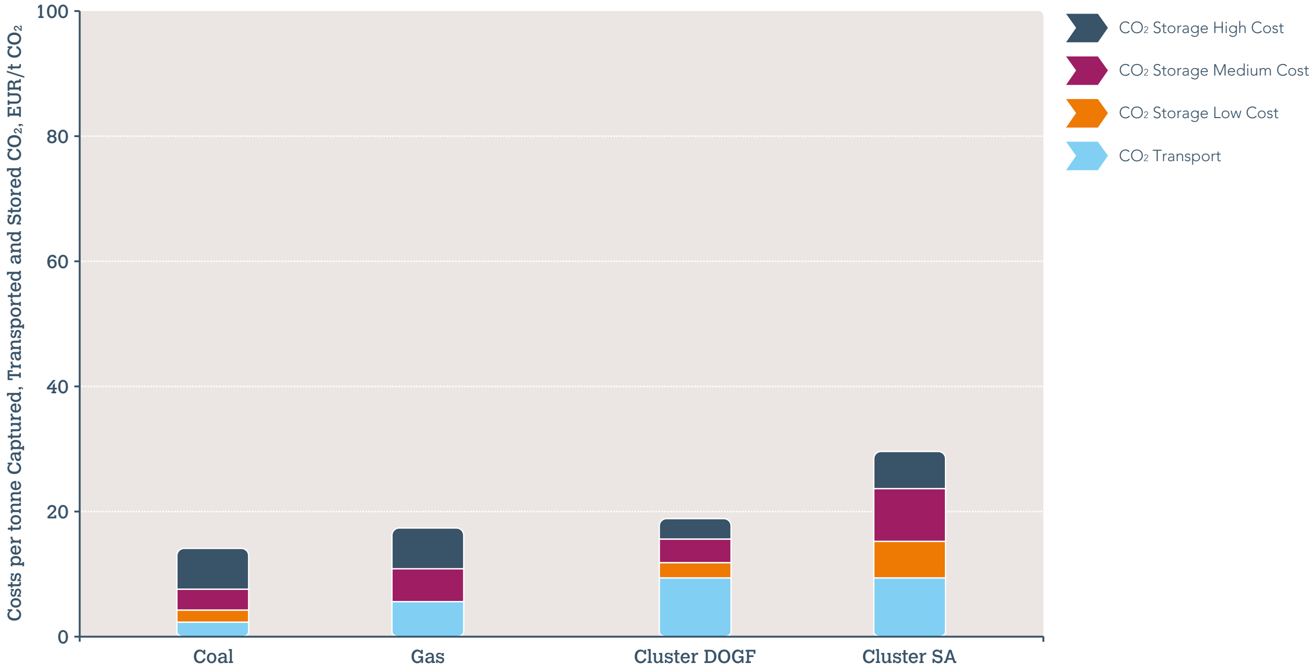


Figure 9: Calculated costs as LCOE for transport and storage for integrated projects. For the Clusters, the use of SA and DOGF are highlighted.

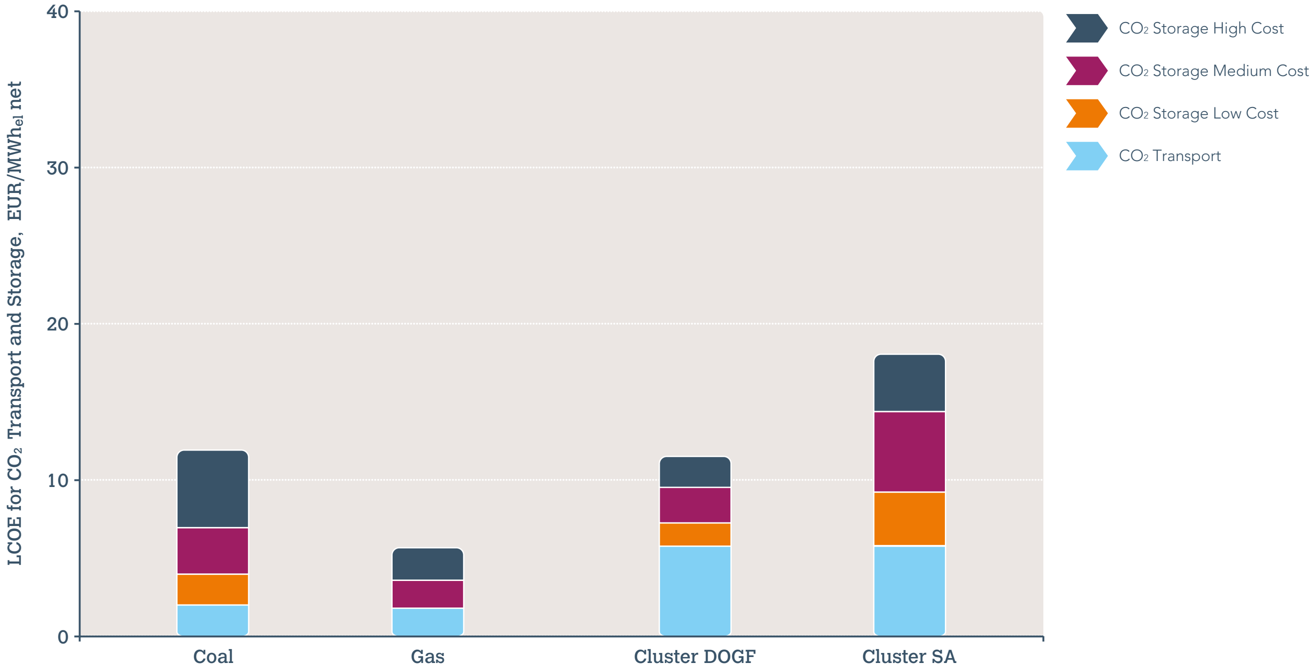


Figure 10: Total CO_2 avoidance costs for integrated CCS projects – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view.

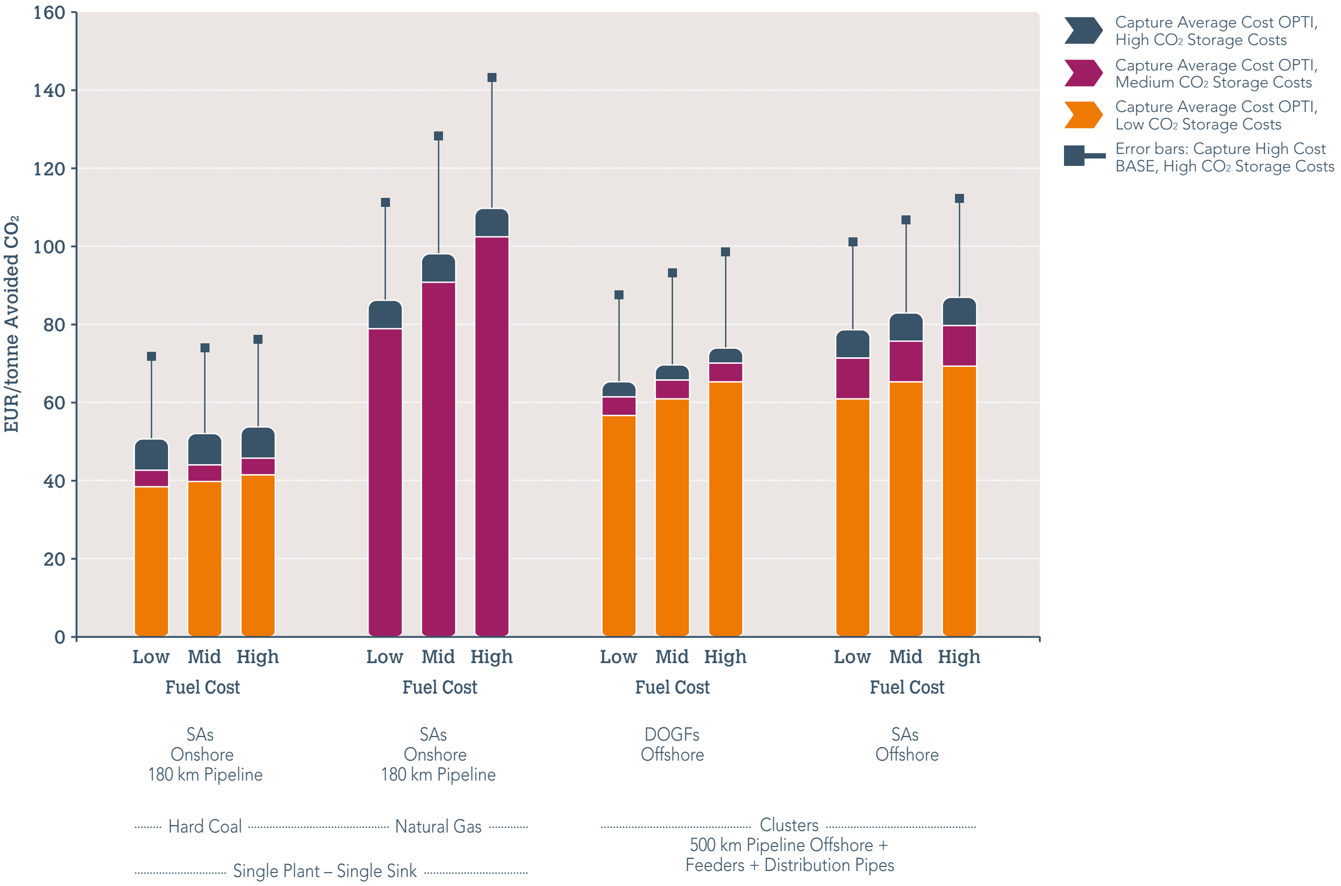


Figure 10 shows CO_2 avoidance costs for the integrated cases. This mirrors the EUA price and shows how high it must rise before it is more feasible to build a power plant with CCS than a corresponding reference plant without. If the higher cost for a BASE plant with CO_2 capture is also combined with the high CO_2 storage cost assumptions, the resulting total avoidance cost rise is illustrated by the error bars.

- For the hard coal Single Plant – Single Sink case, CO_2 avoidance costs are €40-50/t CO_2 (mainly dependent on the level of CO_2 storage costs), while those for natural gas are much higher and strongly dependent on fuel prices. It will therefore be cheaper to build natural gas-fired plants without CCS and pay for EUAs, than to build them with CCS for EUA prices lower than €80-110/t CO_2.

- For the Cluster with storage in offshore DOGF, CO_2 avoidance costs are €55-70/t CO_2 due to its mix of natural gas- and coal-fired plants. The difference between using a Low and High fuel cost equates to a range of ~€10/t CO_2. For storage in offshore SA, CO_2 avoidance costs increase by €5-15/t CO_2 over the DOGF case.

- If the same transport network and storage system (DOGF) is applied to a Cluster consisting only of hard coal-fired plants, CO_2 avoidance costs are €45-60/t CO_2.

Pag. 209

d) Impact of fuel prices on costs

As fuel price is one factor which will influence the deployment of CCS considerably, it is important to disseminate the results for varying prices (Figure 11).

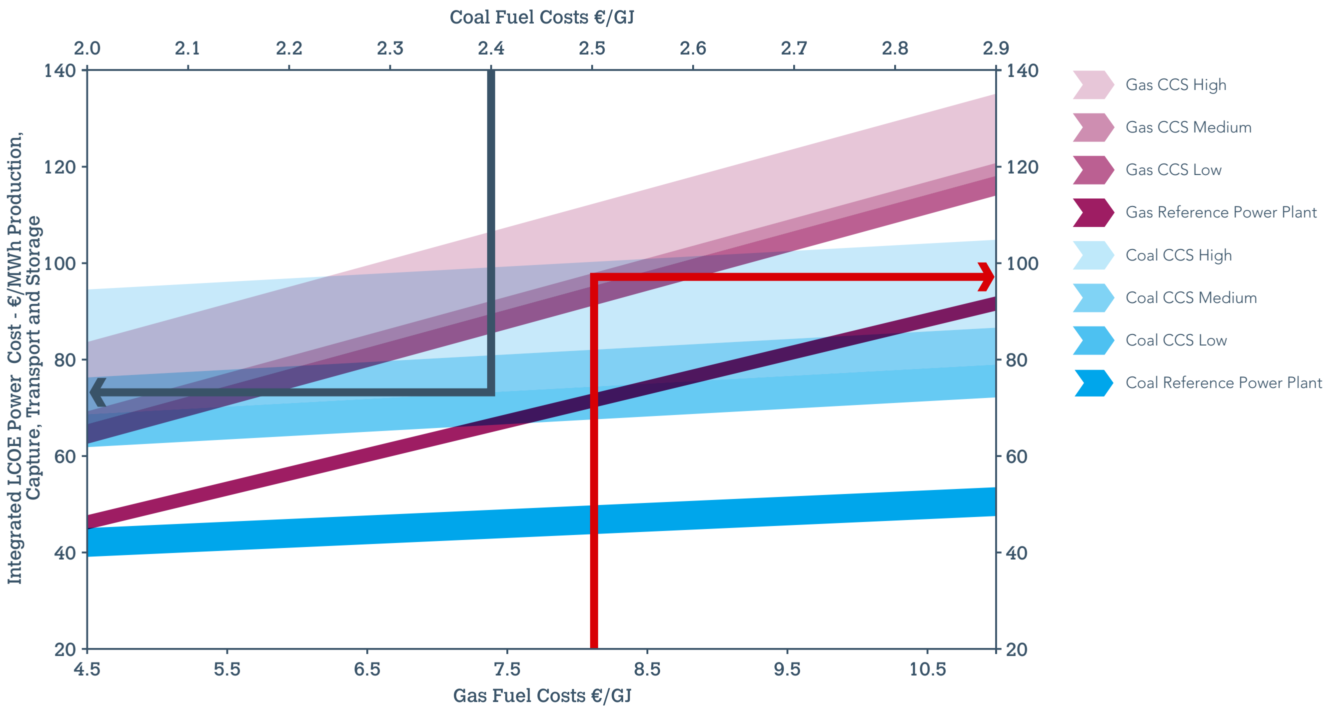
N.B. Figure 16 on page 29 shows the impact of fuel prices on CO_2 capture costs; Figure 11 below includes the entire CCS value chain.

Figure 11 describes the LCOE for the reference plants (lower curves) and the CCS plants as a function of fuel prices. The figure actually contains two diagrams: the upper horizontal axis shows the coal prices, while the lower axis shows the gas prices with the fuel price ranges used in this study.

N.B. These two prices do not have a fixed relation to each other, as may be the impression given by the diagram.

In this study, the Middle fuel cost for coal is €2.4/GJ; €8.0/GJ for gas. These two assumptions are illustrated as solid blue (for coal) and red (for gas) lines in the diagram.

Figure 11: LCOE ranges for Single Plant – Single Sink cases vs. reference plants without CCS, using the fuel cost ranges used in the study (excluding any EUA costs).



The LCOEs cover the ranges from Low OPTI CO_2 capture costs combined with Low CO_2 storage cost assumptions, up to High BASE CO_2 capture costs combined with High CO_2 storage cost assumptions. Natural gas LCOEs are strongly dependent on the fuel costs. As no low OPTI data were provided for natural gas, they have been estimated to be €5/MWh lower than for the reported OPTI data.

- For the hard coal-fired, Single Plant – Single Sink case, CCS increases the LCOE from €40-50/MWh (excluding any EUA costs) to €70-90/MWh. (This does depend somewhat on the fuel cost (here €2-3/GJ) and cost levels for CO_2 storage).
- For the natural gas CCGT power plant with CCS, the final result is heavily dependent on the fuel cost (here €4.5-11/GJ). For natural gas prices lower than ~€6/GJ, the LCOE is competitive with the hard coal Middle fuel cost-based cases. This is a little higher than when only the capture cost was calculated (Figure 16).

For clarity, two tables with basic data for the integrated CCS projects are included in Annex 1: Table 4 shows all data for the LCOE calculations, while the amount of investment that will have to be made is illustrated by the CAPEX shown in Table 5.

Pag. 209

e) CCS: a cost-effective source of low-carbon power

This study has assumed that all power plants will operate in base load since:

a) A CCS power plant will be dispatched before any unabated fossil fuelled power plant as the variable costs will be considerably lower (taking EUA prices into account).

b) A CCS power plant investment will need forecasted base-load utilisation as LCOE costs have a high dependency on plant load factor – especially for coal.

Figure 12: The LCOE of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)

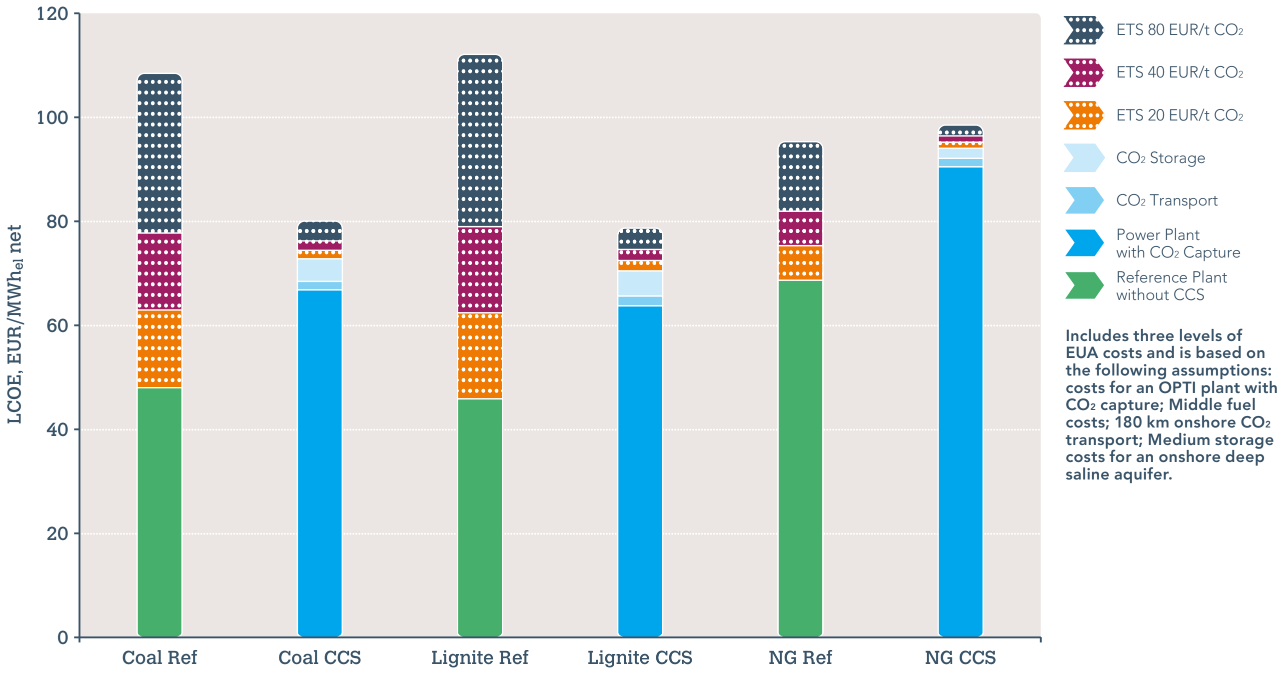
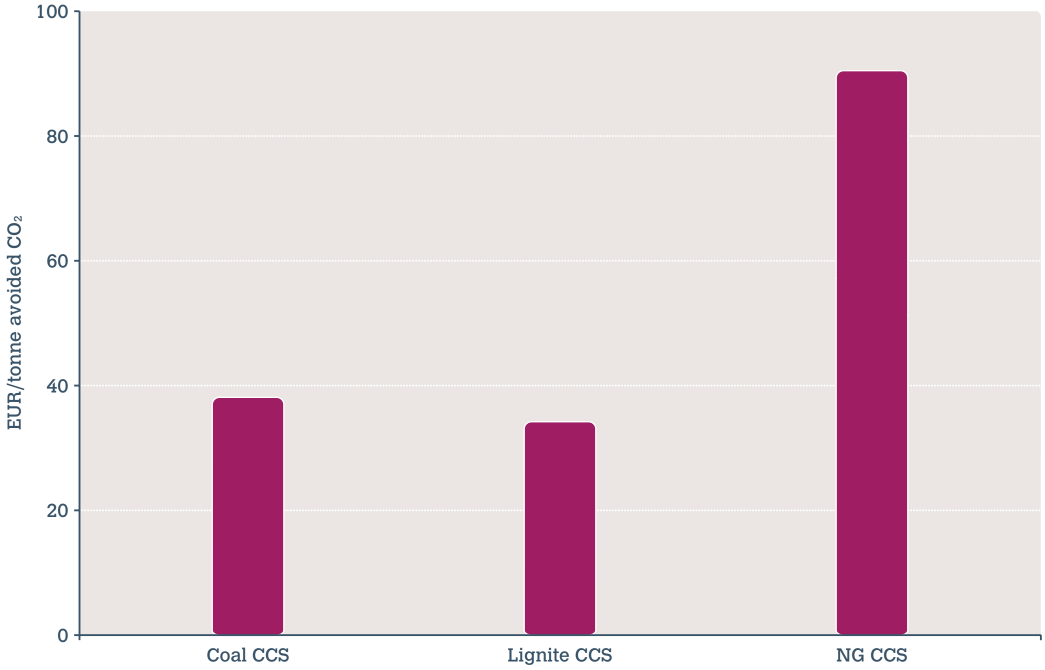


Figure 12 shows estimated LCOE for an OPTI power plant with CCS, including three levels of EUA costs, and is based on the following assumptions:

- *Costs for a OPTI power plant with CO_2 capture*
- *Middle fuel costs*
- *180 km onshore CO_2 transport*
- *Medium storage costs for an onshore SA.*

- The two coal cases are similar in cost, while the gas case shows a higher cost. At lower EUA prices, the coal cases with CCS also come out more favourably than the gas case when compared to the reference plants.
- The blue bars show that the combined cost of the power plant with capture comprises 80-90% of the total LCOE (~75% of the additional LCOE for CCS vs. the reference plants). However, transport and storage are a vital part of the CCS value chain and to a large extent determine the location and decision to proceed with a project. The need to obtain permits and public support must also be taken into account.
- The corresponding avoidance costs for CCS, compared to the reference plants with the same fuel, are shown in Figure 13 below.

Figure 13: CO_2 avoidance costs for possible plants commissioned in the mid 2020s – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view (calculated on the same basis as Figure 12)



- The associated EUA break-even cost would correspond to a price of ~€37/tonne of CO_2 for hard coal; ~€34/tonne of CO_2 for lignite; ~€90/ tonne of CO_2 for gas.

- At an EUA price of €35/tonne[17] of CO_2, these full-size, coal-fired CCS power plants are therefore close to becoming commercial and competitive with coal-fired power plants without CCS, while the gas case is not. However, unabated gas power plants remain a commercial option with the assumptions made, as can be seen in Figure 12.

N.B. Costs for OPTI plants assume a completely successful demonstration of the technology and/or that the first full-size CCS plants (following the EU CCS demonstration programme) have already been in operation. All reported costs exclude the exceptional development and other costs associated with the demonstration programme itself.

There is a small but noticeable difference between Figures 5-10 and Figures 12 and 13. While the latter use lowest-cost capture technology, Figures 5-10 use a mean value for the three different technologies. When we compare selected cases, primarily the best capture technology will be chosen in each case. Figures 5-10 also do not include any lignite cases as this would complicate the figures significantly. However, as Figures 12 and 13 do not include any variations for storage, fuel or transport costs, lignite can be included.

[17] This is in accordance with EU estimates of EUA prices for 2025: http://ec.europa.eu/clima/documentation/roadmap/docs/sec_2011_288_en.pdf

Pag. 212

f) Co-firing with biomass

Biomass is a more expensive fuel than coal (calculated per energy unit), and at current EUA prices and without support regimes, increases the price of CCS if it is used for co-combustion.

Under the ETS Directive, biomass combustion has a zero emission factor. In order to incentivise biomass combustion for CCS, a negative emission factor for such use of biomass is therefore necessary in order to create a level playing field between renewable and fossil fuel-based CCS. This can be achieved through project-specific applications to the European Commission, which has signalled that it would welcome such requests from Member States.

The break-even point for the commercial viability of CCS and biomass co-combustion would then be an EUA price of ~€50/tonne of CO_2, at today's relative fuel costs for coal and biomass in Northern Europe. This evaluation is not addressed in this study, but will be covered in future updates.

Pag. 212

Pag. 213

CO_2 Capture

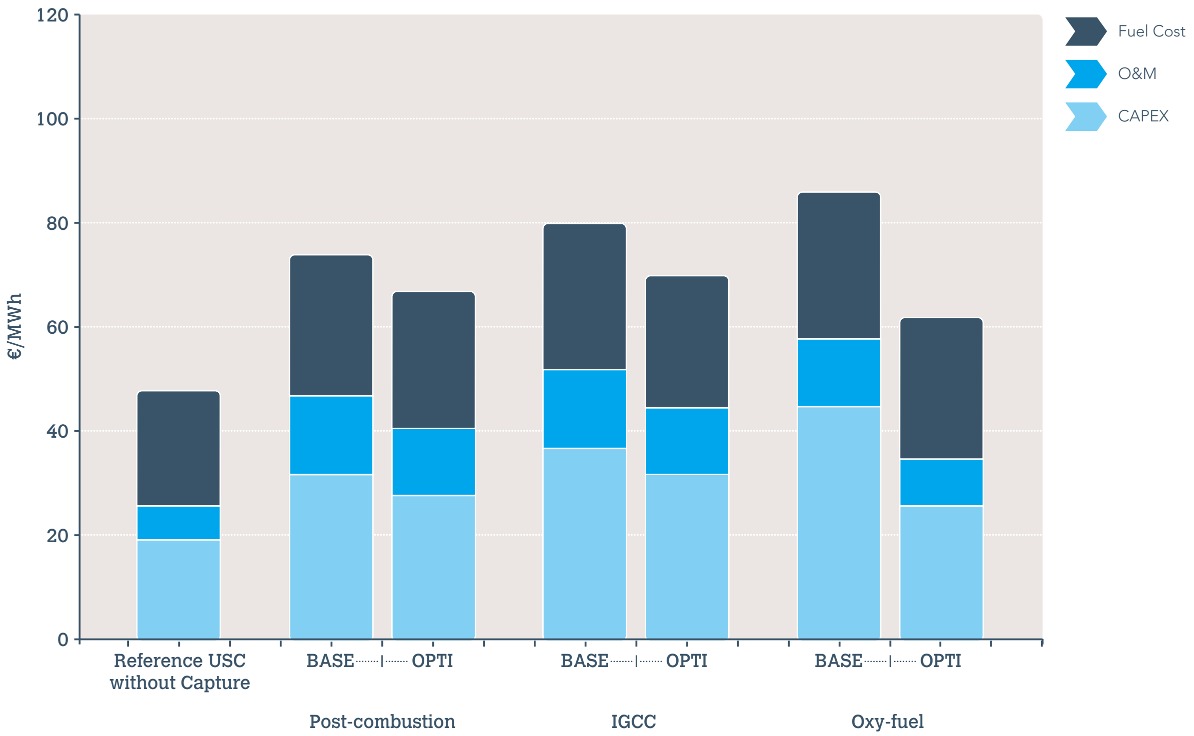
ZEP has calculated the LCOE and CO_2 avoidance costs for power plants commissioned in the early 2020s, located at a generic greenfield site in Northern Europe. The aim: to establish the perceived "real" investment, O&M costs for the first, state-of-the-art commercial power plants with CO_2 capture in Europe. Costs for CO_2 capture include the capture process, plus the conditioning and compression/liquefaction of the captured CO_2 required for transport.

N.B. Cost estimates do not include any additional site-specific investments. Costs for power plants with first-generation CO_2 capture technologies are calculated for High, Middle and Low fuel costs respectively. See page 17 for a description of BASE and OPTI power plants with capture.

Figure 14 shows that for hard coal-fired power plants based on second-quarter 2009 equipment cost levels, a fuel cost of €2.4/GJ and 7,500 equivalent full-load operating hours, the addition of CO_2 capture and the processing of the CO_2 for transport is estimated to increase the LCOE from ~€48/MWh to €60-70/MWh, depending on the capture technology for a new-build OPTI power plant design. (Costs for the first (BASE) plants are higher, as anticipated.)

Corresponding CO_2 avoidance costs range from €30-35/t CO_2, as shown in Figure 15 below.

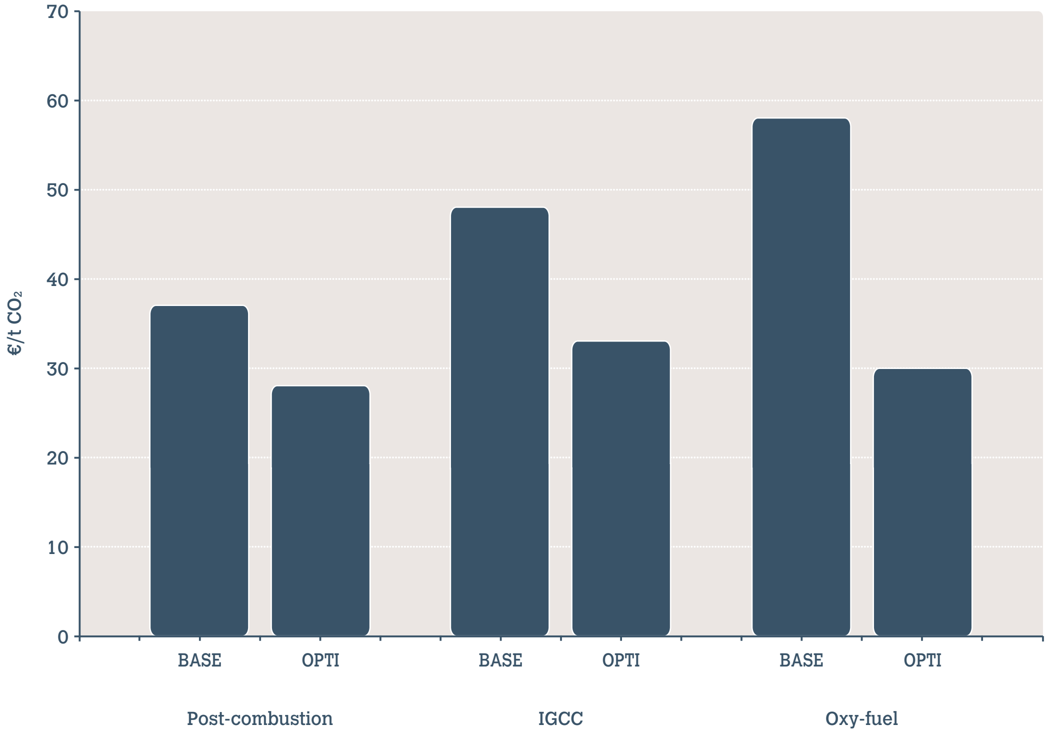
Figure 14: The LCOE for hard coal-fired power plants with CO_2 capture (using Middle fuel costs)



Pag. 213

Pag. 214

Figure 15: CO_2 avoidance costs for hard coal-fired power plants with CO_2 capture



Studies have also been undertaken for lignite-fired power plants with CO_2 capture that imply that a CO_2 avoidance cost in the range of €30/t CO_2 is possible for an OPTI advanced power plant with CO_2 capture and pre-drying of the lignite.

As anticipated, an analysis of *natural gas* CCGT power plants with post-combustion capture shows a heavy dependence of fuel costs on the final result, as can be observed in Figure 16 for an OPTI power plant.

At the lower end of the cost range of natural gas, CO_2 avoidance costs are still more than double those of a hard coal-fired power plant, but due in part to the lower quantities of CO_2 to be captured, the LCOE is competitive with other fuel sources, being ~€65/MWh for a natural gas price slightly under €5/GJ (see Figure 16).

Availability may slightly differ for the different capture technologies and the development of renewable power may also limit the plant's operational time in the future. However, the achievement of high plant availability must be a key objective of the EU CCS demonstration programme so that costs remain competitive. This is especially important for pre-combustion capture, as the IGCC power plant design contains a considerably larger number of components and is not a common technology within the power industry.

Nevertheless, a CCS plant will always be dispatched before any other fossil-fuelled power plant, due to the lower variable operating costs (when EUA prices are taken into account). An unabated plant, on the other hand, will suffer from the cost of EUAs.

In order to illustrate the impact of availability for hard coal-fired power plants with CO_2 capture, a calculation of the generation costs has been made as a function of equivalent operating hours (Figure 17, pages 29-30).

Pag. 214

Figure 16: LCOE and CO_2 avoidance costs for natural gas-fired power plants with CO_2 capture are heavily dependent on the fuel cost. The vertical blue lines for €4.5, €8 and €11/GJ represent the Low, Middle and High cases used for gas fuel cost.

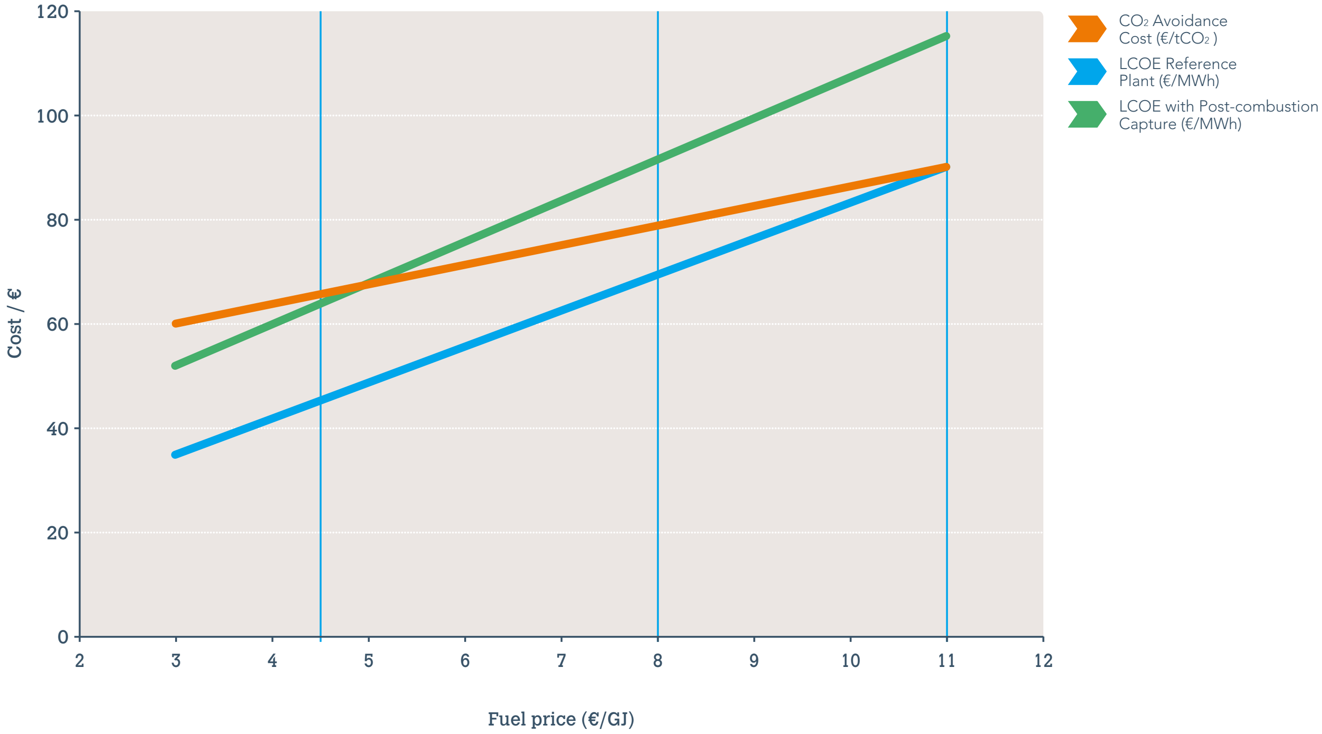
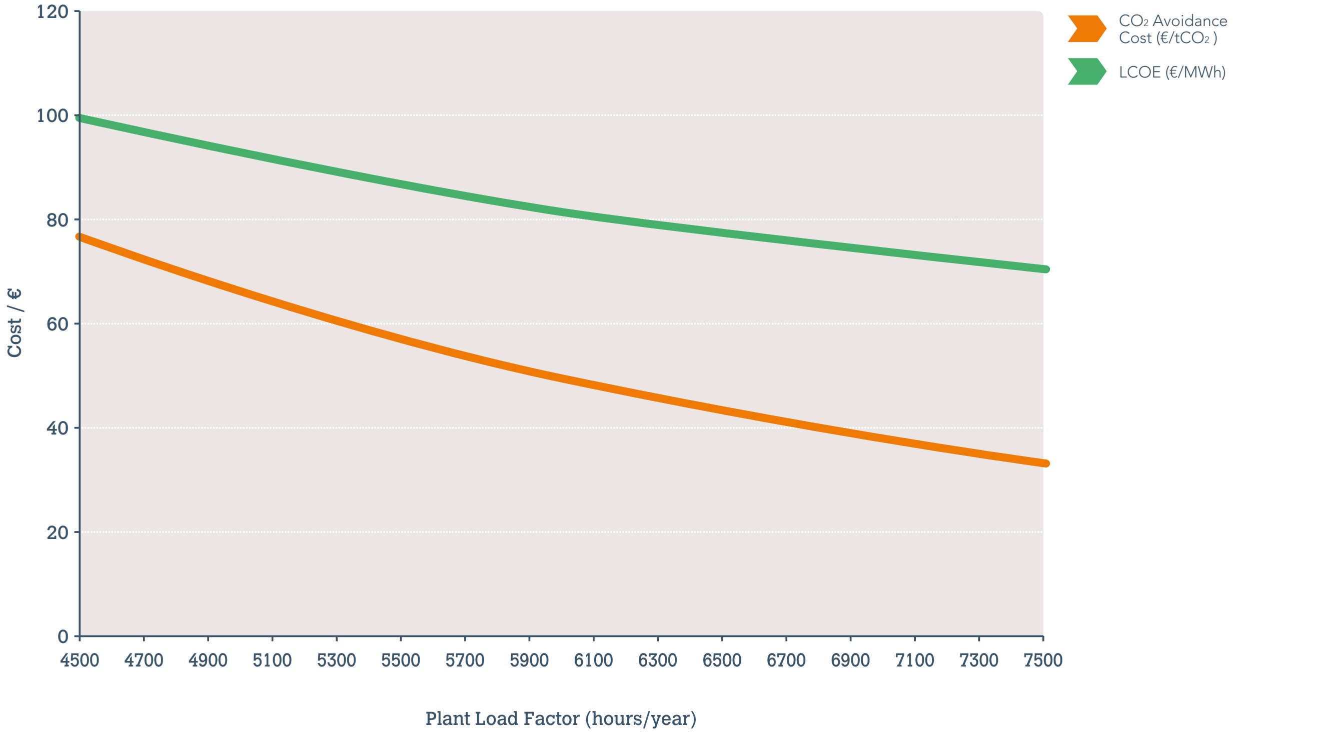
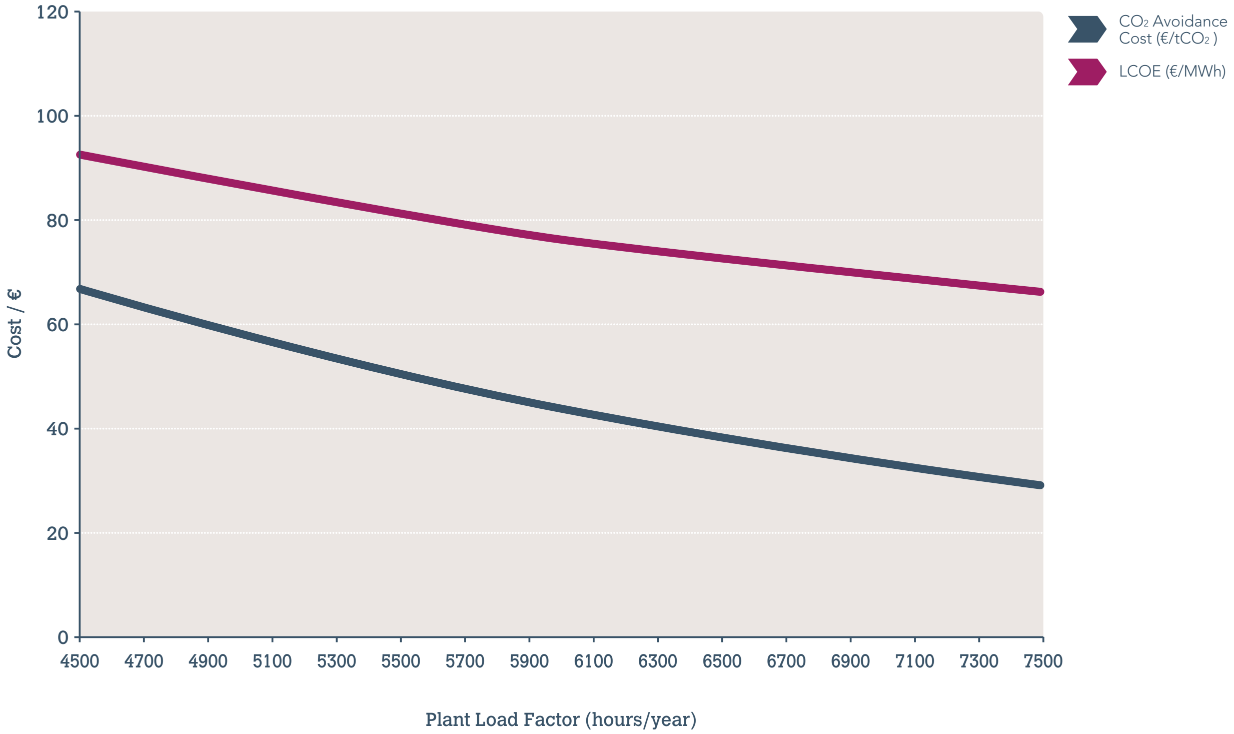


Figure 17: Dependence on Plant Load Factor for all three coal technologies, based on OPTI plants. Reference power plant load is kept at 7,500 hours per year for the calculation of CO_2 avoidance costs. Achieving high plant availability is key to keeping costs competitive.

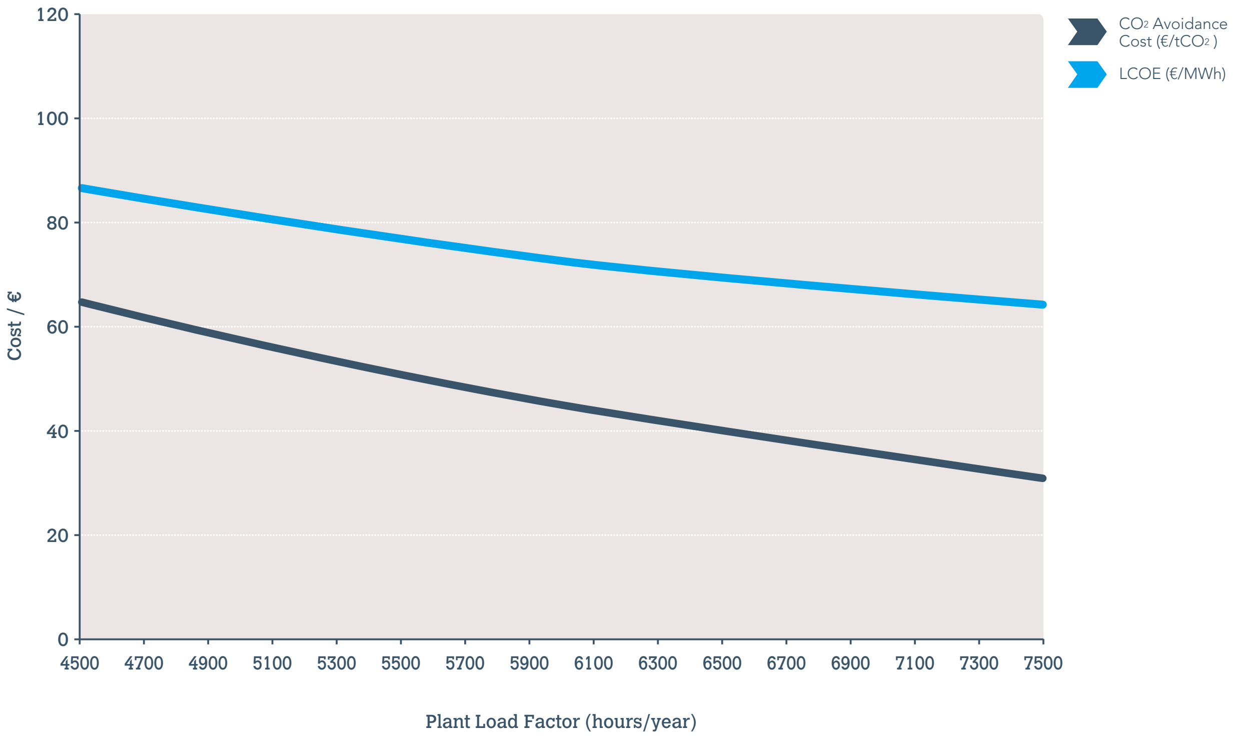


Hard coal IGCC power plants with pre-combustion capture

Pag. 216



Hard coal-fired power plants with post-combustion capture



Hard coal-fired power plants with oxy-fuel

Pag. 216

Analysis of other CO_2 capture cost studies

The costs obtained in this study cannot directly be compared to other previously published studies as the boundary conditions tend to be different, which impacts on the final result. However, a simple comparison has been made by extracting the technical and economic data from other studies and recalculating the costs with the boundary conditions of this study. This shows that as CO_2 avoidance costs are higher for less efficient sub-critical steam power plants, state-of-the-art ultra supercritical steam conditions need to be considered as standard for new-build European power plants (which may in the future be retrofitted with CCS, as well as built directly with CCS).

The LCOE and CO_2 avoidance costs calculated in this study are also higher than those of previous European cost studies[18] due to a better current understanding of the capture processes. However, they tend to be slightly lower than the majority of other recent international studies.[19]

For full details of underlying assumptions and cost calculations, see the individual report on CO_2 capture: www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html.

[18] E.g. "EU Demonstration Programme for CO_2 Capture and Storage (CCS): ZEP's Proposal", November 2008; ENCAP: "Power systems evaluation and benchmarking. Public Version", February 2009
[19] E.g. Global CCS Institute: "Strategic Analysis of the Global Status of Carbon Capture and Storage: Report 2 Economic Assessment of Carbon Capture and Storage Technologies", 2009; NETL: "Cost and Performance Baseline for Fossil Energy Plants", DOE/NETL-2007/1281, August 2007

Pag. 218

CO_2 Transport

This study describes the two major methods of transportation – pipelines (on- and offshore) and ships (including utilities) – and for each of these presents detailed cost elements and key cost drivers. These may be combined in a variety of ways – from a single source to a single sink, developing into qualified systems with several sources, networks and several storage sites over time.

Several likely transport networks of varying distances are therefore presented, including total annual costs and a cost per tonne of CO_2 transported. The cost models operate with three legs of transport: feeders, spines and distribution, each of which may comprise on- or offshore pipelines or ships. For some pipeline cases, CAPEX per tonne per km is also presented, providing a tool for comparison.

Table 1: Cost estimates (in €/t CO_2) for commercial natural gas-fired power plants with CCS or coal-based CCS demonstration projects with a transported volume of 2.5 Mtpa

Distance km	180	500	750	1500
Onshore pipeline	5.4	n. a.	n. a.	n. a.
Offshore pipeline	9.3	20.4	28.7	51.7
Ship	8.2	9.5	10.6	14.5
Liquefaction (for ship transport)	5.3	5.3	5.3	5.3

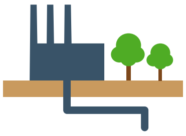
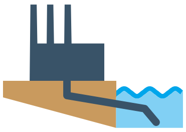
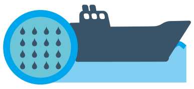
For commercial natural gas-fired power plants with CCS, or coal-based CCS demonstration projects, a typical capacity of 2.5 Mtpa and "point-to-point" connections are assumed. Table 1 shows the unit transportation cost (€/tonne) for such projects, depending on transport method and distance:

- Pipeline costs are roughly proportional to distance, while shipping costs are only marginally influenced by distance. Pipeline costs consist mainly (normally over 90%) of CAPEX, while for shipping, CAPEX is normally under 50% of total annual costs.
- If the technical and commercial risks are also considered, the construction of a "point-to-point" offshore pipeline for a single demonstration project is obviously less attractive than ship transportation for distances also below 500 km. (Pipeline costs here exclude any compression costs at the capture site, while the liquefaction cost required for ship transportation is specified.)

Pag. 218

Pag. 219

Table 2: Cost estimates for large-scale networks of 20 Mtpa (€/tonne CO_2). In addition to the spine distance, networks also include 10 km-long feeders (2*10 Mtpa) and distribution pipelines (2*10 Mtpa)

Spine Distance km	180	500	750	1500
 Onshore pipeline	1.5	3.7	5.3	n. a.
 Offshore pipeline	3.4	6.0	8.2	16.3
 Ship (including liquefaction)	11.1	12.2	13.2	16.1

Once CCS is a commercially driven reality, it is assumed that typical volumes are in the range of 10 Mtpa serving one full-scale coal-fired power plant, or 20 Mtpa serving a cluster of CO_2 sources. The unit transportation cost for such a network with double feeders and double distribution pipelines is estimated in Table 2.

- Pipelines benefit significantly from scale when comparing costs with the 2.5 Mtpa point-to-point solutions in Table 1, whereas the scale effects on ship transport costs are less significant. (Shipping costs here include the costs for a stand-alone liquefaction unit, i.e. remote from the power plant.)
- Ship investments are further assumed to have a residual value for hydrocarbon transportation, as well as being able to serve other CO_2 projects, which will be considered in any evaluation of project risks. All cost estimates are based on custom design and new investment, i.e. no re-use of existing pipelines or existing semi-refrigerated LPG tonnage.

These figures assume full capacity utilisation from day one, which will probably be unrealistic for a cluster scenario. If, for example, volumes are assumed to be linearly ramped up over the first 10 years, this increases the unit cost of pipeline networks by 35-50% depending on maximum flows. For ships, ramp-up is achieved by adding ships and utilities when required, resulting in only marginal unit cost increases. To illustrate this, a calculation of the sensitivity of four key factors on pipeline transport was performed (Figure 18).

Pag. 219

Figure 18: Sensitivity of four key factors on offshore pipeline costs, 10 Mtpa and 500 km when calculated as €/tonne CO_2 (see ZEP report on the Costs of CO_2 Transport)

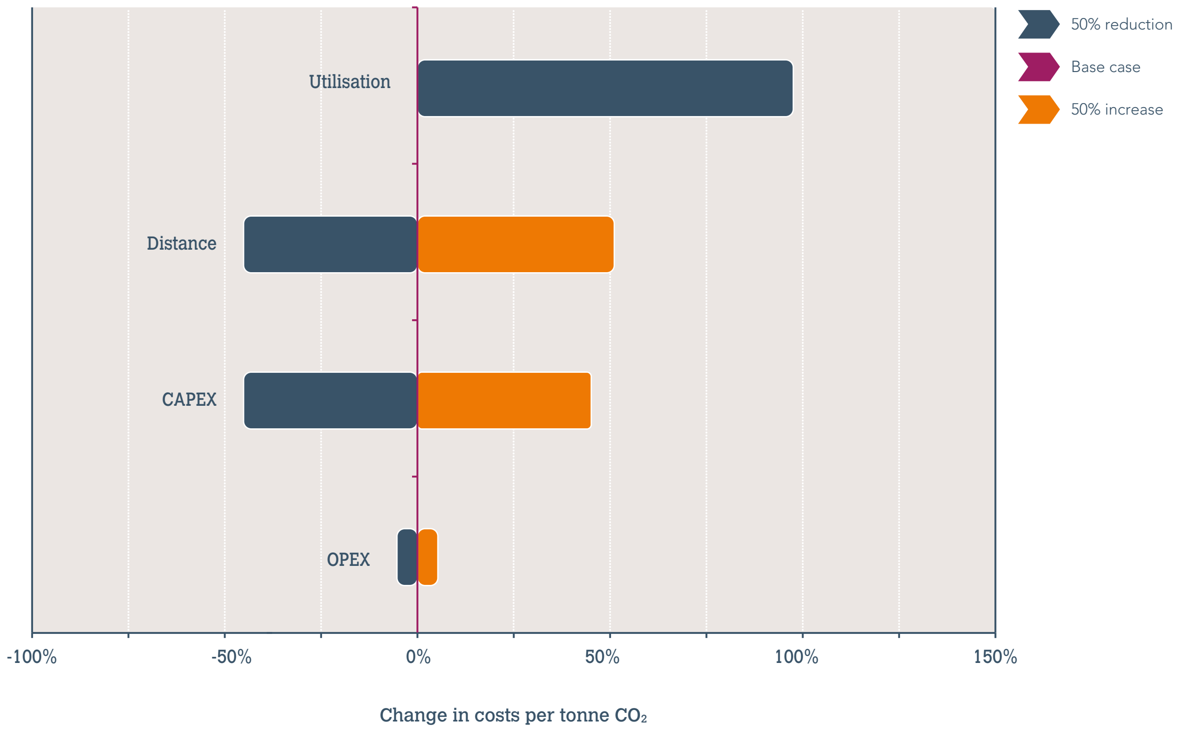


Figure 18 shows that utilisation, distance and CAPEX almost linearly influence the cost, since this is dominated by capital costs, which are almost linear to length of the pipe.

In conclusion, the main aim of this report is to provide cost estimates for large-scale CCS, rather than recommend generic modes of transport. However, assuming that high CAPEX and high risk are obstacles to rapid CCS deployment, combining ship and pipe transport in the development of clusters could provide cost-effective solutions – especially for volume ramp-up scenarios. For short to medium distances and large volumes, on the other hand, pipelines are by far the most cost-effective solution, but require strong central coordination.

For full details of underlying assumptions and cost calculations, see the individual report on CO_2 transport: www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html

Pag. 221

CO_2 Storage

Publicly available data on CO_2 storage costs barely exists. As the development of a generic model was not possible from a time and resources perspective, the study utilised the technical and economical knowledge of ZEP members who have substantial research and experimental experience in the area of CO_2 storage and associated costs. As the IEA Greenhouse Gas R&D Programme[20] was also planning a similar project, the work was carried out as joint venture: a "bottom-up" approach was taken, based on potentially relevant cost components, and data consolidated into a robust and consistent model.

The availability and capacity of suitable storage sites developed into a key consideration. Data were made available from the EU GeoCapacity Project[21] database, comprising 991 potential storage sites in deep saline aquifers (SA) and 1,388 depleted oil and gas fields (DOGF) in Europe.

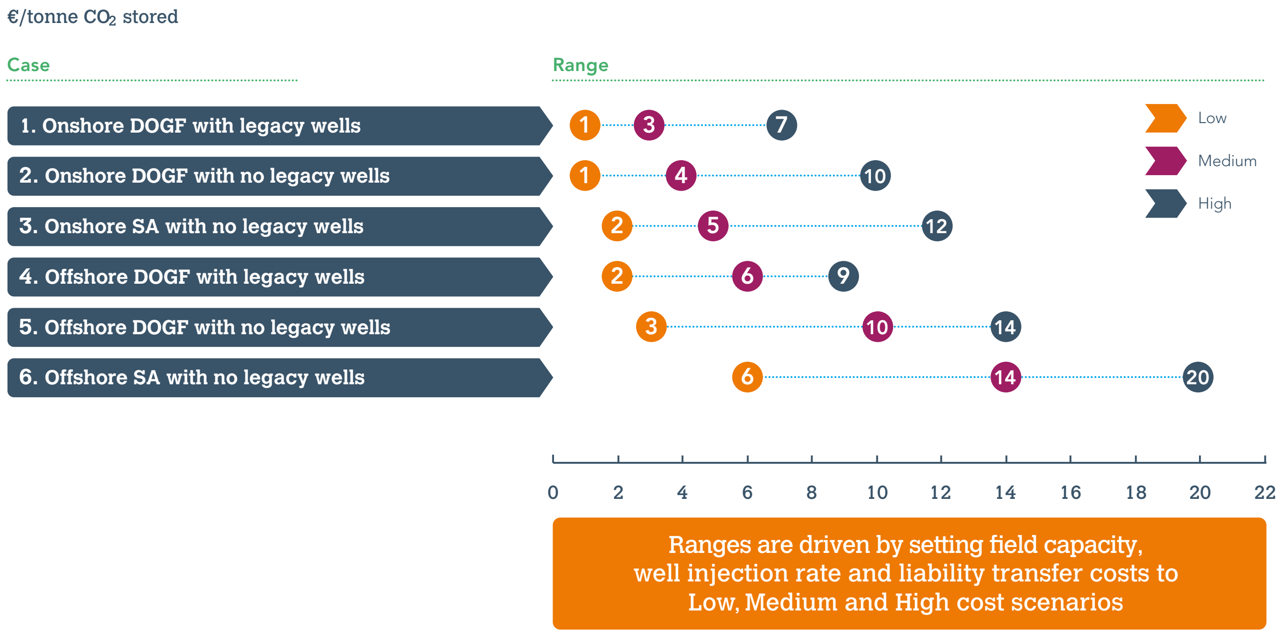
In terms of *numbers*, the majority are below an estimated capacity of 25-50 Mt, which corresponds to the need for more than five reservoirs to store the 5 Mtpa[22] reference single stream of CO_2 for 40 years and is assumed to be uneconomical. However, the majority of estimated capacity is found in very large DOGF and SA (>200 Mt capacity). In the commercial phase, exploration activities should therefore focus on large reservoirs which are capable of storing CO_2 from both single *and* multiple sources.

In order to cover the range of potential storage configurations and still provide reliable cost estimates, storage was divided in six main "typical" cases according to major differentiating elements:
- DOGF vs. SA; offshore vs. onshore.
- Whether there is the possibility of re-using existing ("legacy") wells.

For each of the six cases, three scenarios (Low, Medium and High) were defined to give a cost range estimate for each case (Figure 19).

N.B. The decision was made to restrict this costing exercise to reservoirs with a depth of 1,000 to 3,000 m.

Figure 19: Storage cost per case, with uncertainty ranges; purple dots correspond to base assumptions



[20] www.ieagreen.org.uk
[21] www.geology.cz/geocapacity
[22] In the commercial phase

Pag. 221

Pag. 222

Figure 19 shows that:

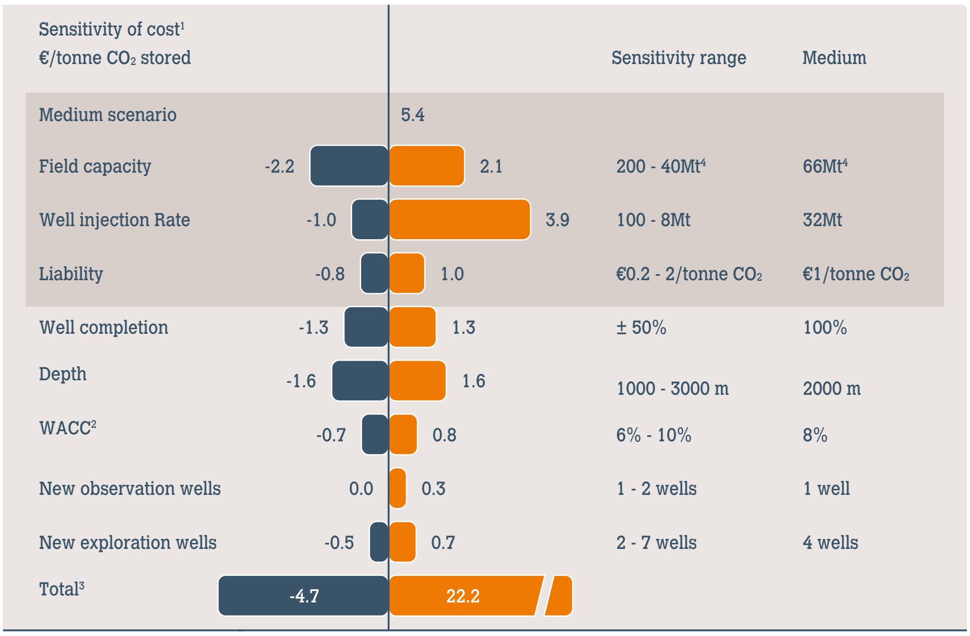
- There is a wide cost range within each case, the High cost scenario being up to 10 times more expensive than the Low cost scenario. This is mainly due to natural variability between storage reservoirs (i.e. field capacity and well injectivity) and only to a lesser degree to uncertainty in cost parameters. Despite this, the following trends stand out:
  – onshore is cheaper than offshore
  – DOGF are cheaper than SA (even more so if they have re-usable legacy wells)
  – the highest costs, as well as the widest cost range, occur for offshore SA.

- The capacity of storage reservoirs in Europe, according to current understanding, exhibits a mirror image of these cost trends: there is more storage capacity offshore than onshore (especially for DOGF) and more in SA than in DOGF. In short, the cheapest storage reservoirs also contribute the least to total available capacity.

Sensitivity analyses were also carried out to determine which of 26 considered cost elements carried the most weight in terms of the variability of the final cost. To allow a transparent comparison between cost figures for the various cases, a 1:3 source-to-sink ratio was assumed as the base setting in all cases. (This may represent a slightly conservative assumption for SA.)

This is quantified in the sensitivity analysis illustrated below for one of the cases, showing the effect of eight major cost drivers: field capacity, well capacity (injectivity times the lifetime of the well), cost of liability, well completion, depth, WACC, number of new observation wells and number of new exploration wells. (The impact of the remaining 18 cost elements was found not to be significant enough to be taken into account).

Figure 20: Illustration of sensitivities in the storage cost calculations for one storage case



¹ The sensitivity denotes the individual effect of ranging a parameter on the total cost in Medium scenario
² Weighted Average Cost of Capital
³ Parts do not add to total. Combined effect of variables is larger due to independencies
⁴ High scenario is 1 emitter to 1 field; Medium scenario is 1 emitter to 3 fields; Low scenario is 1 emitter to 5 fields

Pag. 222

Pag. 223

Figure 20 shows that:

- Field capacity has either the largest or second largest effect in all cases – the selection of storage reservoirs with respect to their capacity is therefore a key element in reducing the cost of CO_2 storage.

- Well capacity is also an important factor in cost variations. Storage reservoir selection and the design and placement of wells are therefore of key importance for onshore storage. For offshore cases, well completion cost is the second contributor to variations in cost, reflecting the specificities of that environment.

For full details of underlying assumptions and cost calculations, see the individual report on CO_2 storage: www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html

Sensitivity analysis for the integrated CCS cases

In order to analyse the robustness of the cost calculations for the CCS integrated projects, the variation of the results for some ingoing factors has been examined for a supercritical OPTI hard coal-fired power plant, with post-combustion capture and storage in an onshore SA (Table 3 and Figure 21 below).

- As anticipated, the capital cost dominates, in the sense that reduced running hours result in much higher cost; CAPEX and WACC also give relatively large variations. It is noted that plant life has a low sensitivity, since the cost calculation is based on the net present value of the investment and that which happens far in the future has little influence on the present situation. Storage costs also make a small contribution to overall costs, as does the efficiency of the capture (absorption–desorption) process due to the relatively cheap fuel.

Table 3: Sensitivity parameters and ingoing factors for a supercritical OPTI hard coal-fired power plant, with post-combustion capture; short (180 km) point-to-point transport; and storage in an onshore SA

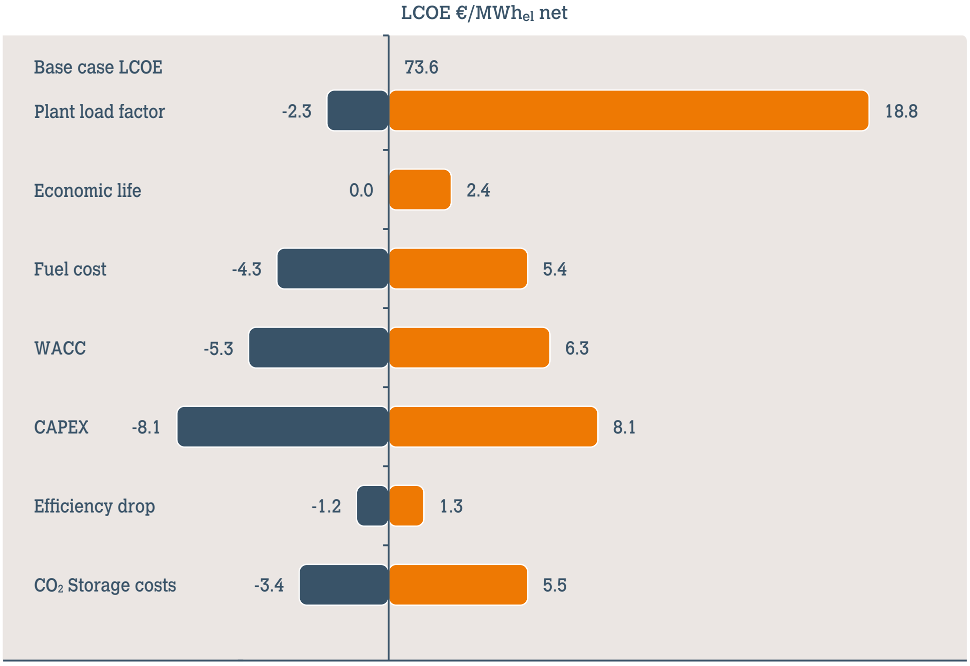
		Sensitivity parameters		
Ingoing factors		**Low LCOE**	**Medium LCOE***	**High LCOE**
Plant load factor	Hours/year	8,000	7,500	5,000
Economic life	Years	-	40	25
Fuel cost	€/GJ LHV	2	2.4	2.9
WACC	%	6%	8%	10%
CAPEX		–25%	-	25%
Reboiler duty; efficiency drop vs. Reference USC w/o capture	% points	5.5%	7.0%	8.5%

* Base case

CO_2 storage costs		**Low**	**Medium**	**High**
– CO_2 stored (capacity one field)	Mt	200	66	40
– CO_2 store rate (one field)	Mtpa	5.00	1.65	1.00
– CAPEX storage (one field)	M€	69.5	69.5	89.1
– CAPEX storage (one field)	M€ per (Mtpa)	13.9	42.1	89.1
– OPEX storage (one field)	M€ pa	2	3.1	4.2
– OPEX storage (one field)	€/tonne	0.40	1.88	4.20

Pag. 223

Figure 21: Sensitivities of the calculated cost results for a hard coal-fired, supercritical OPTI power plant with post-combustion capture; short (180 km) point-to-point transport; and Medium storage costs for an onshore SA. The nominal cost for this case is €73.6/MWh



Glossary

CAPEX	Capital expenditure or investment
CCGT	Combined Cycle Gas Turbine
CCS	CO_2 Capture and Storage
CO_2	Carbon dioxide
DOGF	Depleted oil and gas fields
EU	European Union
EUA	Emission Unit Allowance
EUR	Euro
BASE	Base power plant with CO_2 capture
GJ	Gigajoule
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
Km	Kilometre
kWh	Kilowatt hour
LCOE	Levelised Cost of Electricity
Leg	Re-usable Legacy Wells
LPG	Liquefied Petroleum Gas
M	Metre (metric)
M€	Millions of euros
Mt	Million tonnes
Mtpa	Million tonnes per annum
MWh	Megawatt hour
MW_{el}	Megawatt of electricity
OPTI	Optimised power plant with CO_2 capture
n.a.	Not applicable
NG	Natural gas
NPV	Net Present Value
NoLeg	Non Re-usable Legacy Wells
NGO	Non-governmental organisation
Offs	Offshore
Ons	Onshore
O&M	Operation and Maintenance
Pa	Per annum
PF	Pulverised Fuel
R&D	Research and Development
SA	Deep saline aquifer(s)
t	Tonne
TFT	ZEP Taskforce Technology
USC	Ultra supercritical
WACC	Weighted Average Cost of Capital
ZEP	European Technology Platform for Zero Emission Fossil Fuel Power Plants, known as the Zero Emissions Platform

Annexes

Annex 1: Basic data for integrated CCS projects

Table 4: Total LCOE for integrated CCS projects vs. reference plants without CCS (including various assumed costs for EUAs) using Low and High Fuel costs

	Single Plant - Single Sink Hard Coal				Single Plant - Single Sink Natural Gas		
	Ref	With CCS			Ref	With CCS	
Power Plant and CO_2 Capture							
• Power production (MWh$_{el}$ net)	2 x 736	2 x 700			2 x 420	2 x 360	
• LCOE (€/MWh$_{el}$ net) (Averages for OPTI plants) for Low - High fuel prices	43 - 51	65 - 75			46 - 90	64 - 115	
• LCOE Average All Plants (€/MWh$_{el}$ net) for Low - High fuel prices	43 - 51	65 - 75			46 - 90	64 - 115	
CO_2 Transport							
• CO_2 volumes (Mtpa)	-	10			-	2.5	
• Distance (km)	-	180 + Feeder			-	180	
• LCOE (€/MWh$_{el}$ net)	-	1.8			-	1.8	
CO_2 Storage							
• Type of storage		SAs Onshore				SAs Onshore	
• Cost scenario	-	Low	Mid	High	-	Mid	High
• CO_2 stored over 40 years (Number of reservoirs)x(Mt per reservoir)	-	2x200	6x66	10x40	-	1.5x66	2.5x40
• LCOE (€/MWh$_{el}$ net)	-	1.7	4.6	9.9	-	1.8	3.9
TOTAL LCOE (€/MWh$_{el}$ net) (Excluding Emission Unit Allowances) for Low - High fuel prices	**43-51**	**69-79**	**72-82**	**77-87**	**46-90**	**68-119**	**70-121**
Emission Unit Allowances within EU ETS Contribution to LCOE (€/MWh$_{el}$ net)							
• For ETS 20 €/tonne CO_2	15	2			7	1	
• For ETS 40 €/tonne CO_2	30	4			13	2	
• For ETS 80 €/tonne CO_2	61	7			27	4	

Cluster			
Ref		With CCS	
Hard Coal	Nat Gas	Hard Coal	Nat Gas
3 x 736	2 x 420	3 x 700	2 x 360
43 - 51	46 - 90	65 - 75	64 - 115
	44 - 69		64 - 94

-	20
-	500 + Feeders + Distribution Pipelines
-	5.8

	DOGFs Offshore		
-	Low	Mid	High
-	4x200	12x66	20x40
-	1.5	3.8	5.7

44-69	**71-101**	**74-104**	**75-105**

11	2
23	3
45	6

Cluster			
Ref		With CCS	
Hard Coal	Nat Gas	Hard Coal	Nat Gas
3 x 736	2 x 420	3 x 700	2 x 360
43 - 51	46 - 90	65 - 75	64 - 115
	44 - 69		64 - 94

-	20
-	500 + Feeders + Distribution Pipelines
-	5.8

	SAs Offshore		
-	Low	Mid	High
-	4x200	12x66	20x40
-	3.5	8.7	12.4

44-69	**73-103**	**78-108**	**82-112**

11	2
23	3
45	6

Pag. 228

Table 5: CAPEX for integrated CCS projects vs. reference plants without CCS

	Single Plant - Single Sink Hard Coal: Ref	Single Plant - Single Sink Hard Coal: With CCS			Single Plant - Single Sink Natural Gas: Ref	Single Plant - Single Sink Natural Gas: With CCS	
Power Plant and CO_2 Capture							
• Power production (MWh_{el} net)	2 x 736	2 x 700			2 x 420	2 x 360	
• CAPEX (€/KW_{el} net) (Averages for OPTI plants)	1600	2660			786	1511	
• CAPEX (M€)	2355	3916			660	1100	
• CAPEX All Plants (M€)	2355	3916			660	1100	
CO_2 Transport							
• CO_2 volumes (Mtpa)	-	10			-	2.5	
• Distance (km)	-	180 + Feeder			-	180	
• CAPEX (M€)	-	240			-	150	
CO_2 Storage							
• Type of storage		SAs Onshore				SAs Onshore	
• Cost scenario	-	Low	Mid	High	-	Mid	High
• CO_2 stored over 40 years (Number of reservoirs)x(Mt per reservoir)	-	2x200	6x66	10x40	-	1.5x66	2.5x40
• CAPEX (M€ per reservoir)	-	69.5	69.5	89.1	-	69.5	89.1
• CAPEX (M€)	-	139	417	891	-	104	223
TOTAL CAPEX (M€)	**2355**	**4295**	**4573**	**5047**	**660**	**1354**	**1473**

- Table 5 shows that the capital intensity of fossil power plants will increase significantly with the addition of CCS. The overall CAPEX for gas power with CCS remains lower than for coal.

- As long as electricity market prices match the LCOEs (shown in Figure 5 for the Middle fuel costs), annual incomes will be sufficient to cover the annual costs for fuels, EUAs, O&M costs, as well as return the CAPEX (at the required interest rate) during the project lifetime. (For detailed data on annual costs for fuels, O&M and CAPEX, see the individual cost reports for CO_2 capture, transport and storage.)

Pag. 228

Pag. 229

Cluster			
Ref		With CCS	
Hard Coal	Nat Gas	Hard Coal	Nat Gas
3 x 736	2 x 420	3 x 700	2 x 360
1600	786	2660	1511
3533	660	5873	1100
	4193		6973

Ref	With CCS
-	20
-	500 + Feeders + Distribution Pipelines
-	1710

Ref	DOGFs Offshore		
-	Low	Mid	High
-	4x200	12x66	20x40
-	55.5	47.8	44.1
-	222	574	882
4193	**8905**	**9257**	**9565**

Cluster			
Ref		With CCS	
Hard Coal	Nat Gas	Hard Coal	Nat Gas
3 x 736	2 x 420	3 x 700	2 x 360
1600	786	2660	1511
3533	660	5873	1100
	4193		6973

Ref	With CCS
-	20
-	500 + Feeders + Distribution Pipelines
-	1710

Ref	SAs Offshore		
-	Low	Mid	High
-	4x200	12x66	20x40
-	237.6	198.6	169.3
-	950	2383	3386
4193	**9634**	**11066**	**12069**

Pag. 229

The Costs of CO_2 Capture, Transport and Storage

The Costs of CO_2 Capture, Transport and Storage

Table 6: Overview of data for Integrated CCS cases – costs for power plants and CO_2 capture calculated for Middle fuel costs

Power Plants with Capture and CO_2 Compression/Conditioning | **Transportation**

Commercial hard coal

	Reference plant: Power Cost without Capture (EUR/MWh$_{el}$ net)	Capacity: One Block with Capture (MWh$_{el}$ net)	Additional: Power Cost for Capture (EUR/MWh$_{el}$)	Captured CO_2 (t/MWh$_{el}$)	Captured CO_2 (Mt CO_2 pa)	Captured CO_2 Cost (EUR/t)	Avoided CO_2 (t/MWh$_{el}$)	Avoided CO_2 Cost (EUR/t)	Blocks: Nr of
Hard coal-fired plant	46	~ 700	23	0.85	~ 4.5	27	0.67	34	2

Similar costs for the capture technologies.
Average values for OPTI plants with capture according to ZEP CO_2 capture cost report.

Single Plant - Single Sink cases
Demonstration and commercial CCS projects

Short transport distance onshore

	Network	Volume (Mtpa)	Source/s/ (#*Mtpa)	Transport: Feeder/s/ (km)	Feeder/s/ Type	Spine (km)	Spine Type	Distribution (km)	Distribution Type	Store/s/ (#)	Cost (EUR/t)	Cost EUR/MWh$_{el}$	Accumulated Mt CO_2 (40 years)
Hard coal-fired plant	1 a	10	1*10	10	Onshore	180	Onshore	0	–	1	2.1	1.8	400

Commercial natural gas. In terms of CO_2 quantity, also demonstration hard coal/lignite with the same transport and storage costs per tonne CO_2.

	Reference plant: Power Cost without Capture (EUR/MWh$_{el}$ net)	Capacity: One Block with Capture (MWh$_{el}$ net)	Additional: Power Cost for Capture (EUR/MWh$_{el}$)	Captured CO_2 (t/MWh$_{el}$)	Captured CO_2 (Mt CO_2 pa)	Captured CO_2 Cost (EUR/t)	Avoided CO_2 (t/MWh$_{el}$)	Avoided CO_2 Cost (EUR/t)	Blocks: Nr of
Natural gas combined cycle	69	~ 350	22	0.33	~ 1	67	0.28	79	~ 2

1 gas turbine as in ZEP capture cost report. However, many other studies assume 2 gas turbines.
Post-combustion capture, OPTI, according to ZEP CO_2 capture cost report.

Short transport distance onshore

	Network	Volume (Mtpa)	Source/s/ (#*Mtpa)	Transport: Feeder/s/ (km)	Feeder/s/ Type	Spine (km)	Spine Type	Distribution (km)	Distribution Type	Store/s/ (#)	Cost (EUR/t)	Cost EUR/MWh$_{el}$	Accumulated Mt CO_2 (40 years)
Natural gas combined cycle		2.5	1*2.5			180	Onshore			1	5.4	1.8	100

Clusters to benefit from large-scale infrastructure
Could be developed if/when many commercial CCS projects are realised

	Reference plant: Power Cost without Capture (EUR/MWh$_{el}$ net)	Capacity: One Block with Capture (MWh$_{el}$ net)	Additional: Power Cost for Capture (EUR/MWh$_{el}$)	Captured CO_2 (t/MWh$_{el}$)	Captured CO_2 (Mt CO_2 pa)	Captured CO_2 Cost (EUR/t)	Avoided CO_2 (t/MWh$_{el}$)	Avoided CO_2 Cost (EUR/t)	Blocks: Nr of
Natural gas combined cycle	69	~ 350	22	0.33	~ 1	67	0.28	79	~ 2
Natural gas combined cycle	69	~ 350	22	0.33	~ 1	67	0.28	79	~ 2
Hard coal-fired plant	46	~ 700	23	0.85	~ 4.5	27	0.67	34	2
Hard coal-fired plant	46	~ 700	23	0.85	~ 4.5	27	0.67	34	2*2
Weighted average:	57		23	0.61		37	0.49	46	

Offshore

	Network	Volume (Mtpa)	Source/s/ (#*Mtpa)	Transport: Feeder/s/ (km)	Feeder/s/ Type	Spine (km)	Spine Type	Distribution (km)	Distribution Type	Store/s/ (#)	Cost (EUR/t)	Cost EUR/MWh$_{el}$	Accumulated Mt CO_2 (40 years)
Natural gas combined cycle	8 b	20	2.5	10	Onshore	500	Offshore	2*10	Offshore	2	9.5	5.8	800
Natural gas combined cycle			2.5	750	Ship								
Hard coal-fired plant			5	–	–								
Hard coal-fired plant			10	180	Offshore								

Table 6: Overview of data for Integrated CCS cases – costs for power plants and CO_2 capture calculated for Middle fuel costs

	Storage																INTEGRATED CCS CASE COSTS					
	Location	Type	Data quality	Legacy	Low Cost Scenario				Medium Cost Scenario				High Cost Scenario				Low Storage Cost Scenario		Medium Storage Cost Scenario		High Storage Cost Scenario	
					Field capacity	Fields	Cost		Field capacity	Fields	Cost		Field capacity	Fields	Cost			For CCS		For CCS		For CCS
				Wells	Mt CO_2	Nr of	€/t CO_2	€/MWh_{el}	Mt CO_2	Nr of	€/t CO_2	€/MWh_{el}	Mt CO_2	Nr of	€/t CO_2	€/MWh_{el}	€/t CO_2	€/MWh_{el}	€/t CO_2	€/MWh_{el}	€/t CO_2	€/MWh_{el}
Single Plant - Single Sink																						
Hard coal-fired plant	Onshore	Aquifer	Data-Poor	No	200	2.0	2.0	1.7	66	6.1	5.4	4.6	40	10	11.7	9.9	~ 31.2	~ 27	~ 34.6	~ 29	~ 40.9	~ 35
Natural gas combined cycle	Onshore	Aquifer	Data-Poor	No					66	1.5	5.4	1.8	40	2.5	11.7	3.9			~ 77	~ 26	~ 84	~ 28
Clusters																						
Natural gas combined cycle																						
Natural gas combined cycle	Offshore	DOGF	Data-Rich	Yes	200	4.0	2.4	1.5	66	12.1	6.2	3.8	40	20	9.4	5.7	~ 49	~ 30	~ 53	~ 32	~ 56	~ 34
Hard coal-fired plant	Offshore	Aquifer	Data-Rich	No	200	4.0	5.8	3.5	66	12.1	14.3	8.7	40	20	20.3	12.4	~ 52	~ 32	~ 61	~ 37	~ 67	~ 41
Hard coal-fired plant																						
Weighted average:																						

Pag. 232

Annex II: Participants in the ZEP CCS cost study

Surname	Name	Organisation	Remark
Antilla	Miko	Metso Power Oy	
Apeland	Sigve	Gassco	
Bassano	Claudia	ENEA	
Bauduin	Guy	GE Energy	
Berg Cortesi	Hanne	Bellona	
Bergmann	Heinz	RWE, ZEP Coordination Group Chair	
Buddenberg	Torsten	Hitachi Power Europe	
Buttinelli	Mauro	INGV	
Chamberlain	John	Gas Natural Fenosa	Co-author, Capture
Christensen	Niels Peter	Vattenfall	Co-chair, TFT
Chiesa	Paolo	Politecnico di Milano	
Corbisiero	Biagina	Tirreno Power	
Curcio	Stefano	Rezia Energia	
Dale	Henning M	Gassco	
Decarre	Sandrine	IFP Energies nouvelles	
Deiana	Paolo	ENEA	
Demofonti	Giuseppe	Centro Sviluppo Materiali SpA	
Dernjatin	Pauli	Fortum	
Desideri	Umberto	Università di Perugia	
Desroches	Jean	Schlumberger Carbon Services	Co-author, Storage
Dodero	Giorgio	IPG Srl	
Doukelis	Aggelos	National Technical University of Athens	
Dupont	Maike	E.ON Gas Storage	
Ehinger	Andreas	IFP Energies nouvelles	
Ekström	Clas	Vattenfall	Editor and co-author
Eldrup	Nils	GassTek	
Enas	Carlo	EON Italia	
Fabbri	Antonin	BRGM	
Girardi	Guiseppe	ENEA	
Folke	Christian	E.ON	
Girardi	Guiseppe	ENEA	
Goldschmidt	Dirk	Siemens	Co-chair, TFT
Graziadio	Mario	ENEL	
Hansen	Hans Richard	Teekay Shipping Norway AS	
Holland Lloyd	Peter	Doosan Babcock	
Hoth	Peer	DE Federal Ministry BMWI	
Hunt	Matthew	Doosan Babcock	
Irons	Robin	E.ON	
Jagger	Martin	Shell	
Jammes	Laurent	Schlumberger	
Jordan Escalona	Natividad	RWE Power AG	
Kokko	Ari	Metso Power Oy	
Kuivalainen	Reijo	Foster Wheeler Energia Oy	
Lewis	Deirdre	SLR Consulting	
Lupion	Monica	CIUDEN	
Manzolini	Giampaolo	Politecnico di Milano	

Pag. 232

Surname	Name	Organisation	Remark
Marion	Pierre	IFP Energies nouvelles	
Maas	Wilfried	Shell	Co-author, Storage
Melien	Torgeir	Statoil	
Mezzadri	Diego	Rezia Energia	
Modder	Hans	ZEP Secretariat	
Neades	Samantha	IEAGHG	
Nijveld	Erik	Shell	
Nilsson	Jenny-Ann	Vattenfall	
Nilsson	Per Arne	Panaware ab	Co-author, Transport
Persoglia	Sergio	OGS	
Picard	Guillemette	Schlumberger	
Quattrocchi	Fedora	INGV	
Rennie	Alastair	Amec	
Rosso	Pasquale	ARA-Milan	
Sala	Luca	Ansaldo	
Santarcangelo	Lara	ENEL I&I	
Schreurs	Harry	Agentschap NL	Co-author, Storage
Schwendig	Frank	RWE Power AG	
Serbutoviez	Sylvain	IFP Energies nouvelles	
Skagestad	Ragnhild	Tel-tek	
Snippe	Jeroen	Shell	
Sorgenti	Rinaldo	Assocarboni	
Stangeland	Aage	The Research Council of Norway	
Strömberg	Lars	Vattenfall	Co-chair, TFT and Co-author
Tarvis	Tiina	Vattenfall	Co-editor
Teruel Munoz	Juan Enrique	Gas Natural Fenosa	Co-author, Capture
Tjetland	Goeril	Bellona	
Torp	Tore	Statoil	
Tortello	Enzo	Ansaldo Energia	
Tranier	Jean-Pierre	Airliquide	
Unterberger	Sven	EnBW	
Valenti	Giampiero	ENEL	
Van der Kuip	Muriel	TNO	
Weckes	Patrick	Hitachi-Power Europe	
Wendt	Tobias	E.ON Ruhrgas	
Wiedermann	Alexander	MAN Diesel & Turbo SE	
Wildgust	Neil	IEAGHG	
Wolf	Markus	Alstom Power	
Zanin	Egidio	Centro Sviluppo Materiali SpA	

Pag. 234

European Technology Platform for Zero Emission Fossil Fuel Power Plants

Pag. 234

Pag. 235

info@zero-emissionplatform.eu
www.zeroemissionsplatform.eu

July 2011

Pag. 235

Post 2020, CCS will be cost-competitive with other low-carbon energy technologies

The companies, scientists, academics and environmental NGOs that together make up the Zero Emissions Platform (ZEP) have undertaken a ground-breaking study into the costs of CO_2 Capture and Storage (CCS) based on new data provided exclusively by ZEP member organisations on existing pilot and planned demonstration projects. The conclusion: following the European Union's CCS demonstration programme, CCS will be cost-competitive with other sources of low-carbon power, including on-/offshore wind, solar power and nuclear.

As publicly available cost data is scarce, ZEP members provided their own in-house data in order to establish a reference point for the costs of CCS based on a "snapshot" in time (all investment costs are referenced to the second quarter of 2009). The aim: to estimate the costs of complete CCS value chains – i.e. the capture, transport and storage of CO_2 – for new-build coal- and gas-fired power plants, located at a generic site in Northern Europe from the early 2020s. This is described in three reports[1] on CO_2 capture, CO_2 transport and CO_2 storage respectively, with resulting integrated CCS value chains presented in a summary report[2].

N.B. As the costs of CCS will be inherently uncertain until further projects come on stream, the ZEP CCS cost study will be updated every two years in line with technological developments and the progress of the EU CCS demonstration programme.

KEY CONCLUSIONS

CCS is on track to become one of the key technologies for combating climate change

In order to keep global warming below 2°C – cost-effectively – CCS must provide 20% of the global cuts required by 2050, according to the International Energy Agency (IEA); the costs of doing so *without* CCS will be over 70% higher. In turn, CCS will enable Europe to enjoy a surge in economic growth – creating new jobs, boosting industry and promoting technology leadership.

ZEP's study indicates that the EU CCS demonstration programme will not only prove the costs of CCS, but provide the basis for future cost reductions, enhanced by the introduction of second- and third-generation technologies. CCS is therefore on track to become one of the key technologies for combating climate change – within a portfolio of technologies, including greater energy efficiency and renewable energy.

Indeed, the future electricity system will look very different from today's, requiring flexible solutions to accommodate increasing quantities of intermittent power sources. Energy storage (e.g. via pumped storage, or new forms such as electric car batteries) is likely to spread and combine with demand-side management, supported by smart grids. Base-load demand will probably fall and the need for balancing power increase in order to complement intermittent power sources. The additional need for energy storage capacity and balancing power, as well as the operation of thermal power plants at lower utilisation, is likely to increase the cost of electricity.

ZEP will therefore undertake a complementary study on the costs of CCS in the context of other low-carbon energy technologies. However, recent reports such as the IEA's "Projected Costs of Generating Electricity - 2010"[3] indicate that the costs of post-demonstration CCS with coal (€70-90/MWh) and gas (€70-120/MWh), as presented in ZEP's study, will be cost-competitive with other low-carbon power options – including on-/offshore wind, solar power and nuclear.

In short, a broad mix of low-carbon energy technologies is necessary, not only to meet CO_2 reduction targets, but ensure a reliable energy supply – cost-effectively.

[1] www.zeroemissionsplatform.eu/library/publication/166-zep-cost-report-capture.html; www.zeroemissionsplatform.eu/library/publication/167-zep-cost-report-transport.html; www.zeroemissionsplatform.eu/library/publication/168-zep-cost-report-storage.html
[2] www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html
[3] www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2207

CCS is applicable to both coal- and gas-fired power plants

CCS can technically be applied to both coal- and gas-fired power plants. Their relative economics depend on power plant cost levels, fuel prices and market positioning, whereas applicability is mainly determined by load regime. While co-firing with biomass is not covered in the study, it will be in future updates as it provides significant abatement potential when combining CCS with sustainably-produced biomass feedstock.

All three CO_2 capture technologies could be competitive once successfully demonstrated

The study covers first-generation capture technologies only (post-combustion, pre-combustion and oxy-fuel). Using agreed assumptions and the Levelised Cost of Electricity as the main quantitative value, there is currently no clear difference between any of these and all could be competitive in the future once successfully demonstrated. The main factors influencing total costs are fuel and investment costs.

Early strategic planning of large-scale CO_2 transport infrastructure is vital to reduce costs

Clustering plants to a transport network can achieve significant economies of scale – in both CO_2 transport and CO_2 storage in larger reservoirs, on- and offshore. Large-scale CCS therefore requires the development of a transport infrastructure on a scale matched only by that of the current hydrocarbon infrastructure. As this will lead to greatly reduced long-term costs, early strategic planning is vital – including the development of clusters and over-sized pipelines – with any cross-border restrictions removed.

While the study focuses on power generation, the application of CCS to heavy industry and fuel transformation could abate ~15% of all global man-made CO_2 emissions by 2050 (IEA). Indeed, in steel and cement production, for example, it is the only means of achieving deep emission cuts. If different CO_2 sources – power, industry and fuel transformation – are located in close proximity, they can therefore share CO_2 transport and storage infrastructure, and should be included in all National CCS Master Plans.

A risk-reward mechanism is needed to realise the significant aquifer potential for CO_2 storage

Location and type of storage site, reservoir capacity and quality are the main determinants for the costs of CO_2 storage: onshore is cheaper than offshore; depleted oil and gas fields are cheaper than deep saline aquifers; larger reservoirs are cheaper than smaller ones; high injectivity is cheaper than poor injectivity. Given the large variation in storage costs (up to a factor of 10) and the risk of investing in the exploration of deep saline aquifers that are ultimately found to be unsuitable, a risk-reward mechanism is needed to realise their significant potential and ensure sufficient storage capacity is available – in the time frame needed.

Creating a secure environment for long-term investment in Europe

The current main incentive for the EU-wide deployment of CCS is the price of Emission Unit Allowances (EUAs) under the EU Emissions Trading System (ETS). However, based on current trajectories, this will not be a sufficient driver for investment after the first generation of demonstration projects is built (2015 - 2020). Enabling policies are therefore required in the intermediate period – after the technology is commercially proven, but before the EUA price has increased sufficiently to allow full commercial operation. **The goal: to make new-build power generation *with* CCS more attractive to investors than without it.**

Until a support system for biomass is in place, co-firing with CCS will not be commercially viable. A negative emission factor for such use of biomass under the ETS Directive is therefore necessary in order to create a level playing field between renewable energy and fossil fuel-based CCS. This can be achieved through project-specific applications to the European Commission, which has signalled that it would welcome such requests from Member States.

Incentives for CCS in heavy industry and fuel transformation are also urgently required: to date, only the "NER 300" mechanism provides any significant amount of funding for such applications.

Finally, there is an urgent need to drive down costs via new well-targeted R&D into next-generation technologies, as defined by ZEP in its 2010 report: "Recommendations for Research to Support the Deployment of CCS in Europe beyond 2020."[4] This identifies key areas for improvement, together with the main strands for R&D to 2030 and beyond.

[4] www.zeroemissionsplatform.eu/library/publication/95-zep-report-on-long-term-ccs-rad.html

Allegato 5.

Partecipazione a CCS EII Team (Iniziativa industriale Europea sulle CCS) del SET Plan (Strategic Energy Technologies)

agenda riunione di Otobre 2011

conferenza del SET Plan, Varsavia Novembre 2011

decisione sui Key Performance Indicators (KPI) per i progetti sulle CCS

presentazione delle attività in Italia

Pag. 239

European Strategic Energy Technology Plan (SET-Plan)

European Industrial Initiative CCS
EII Team meeting 5 October 2011

Rue Demot 24, 1040 Brussels
Room 03/47

DRAFT AGENDA

10.00 – 10:15	**Welcome & Approval of draft Agenda** **Adoption of minutes of last meeting**
10:15 – 11:30	**Update on the SET Plan** – Mapping exercise & follow-up to KPIs (EC) – Reporting on Financing Workshop (EC) – SET-Plan Materials Roadmapping exercise
11:30 – 12:00	**Next SET Plan Conference under the PL presidency**
12:00 – 13:00	**R&D funding needs for 2012-2020**
13:00	**Lunch**
14:00 – 15:30	**R&D priorities and FP7 calls** - currently open call and next FP7 call (EC) - discussion
15:30 –	**Governance –** Member States delegates
– 16:00	**Any Other Business** **-** FP7 CO_2 Europipe **& concluding remarks**

Pag. 239

Pag. 240

SEVENTH FRAMEWORK PROGRAMME

SET Plan Conference
under the Polish Presidency

Andrzej Siemaszko
Katarzyna Sobótka

Krajowy Punkt Kontaktowy Programów Badawczych UE
Instytut Podstawowych Problemów Techniki Polskiej Akademii Nauk

www.kpk.gov.pl

Pag. 240

Pag. 241

SEVENTH FRAMEWORK PROGRAMME

SAVE THE DATE

28-29 November 2011
Warsaw, Poland

www.kpk.gov.pl

Pag. 241

Pag. 242

SEVENTH FRAMEWORK PROGRAMME

SET PLAN CONFERENCE, WARSAW

Strategic topics for the conference:

- SET Plan Financing:
- Smart Cities
- EIIs
- EERA

Pag. 242

Pag. 243

SEVENTH FRAMEWORK PROGRAMME

SET PLAN CONFERENCE, WARSAW

- **SET Plan Financing:**
- The outcome from the conference will be a strong political resolution on financing of technologies which are under the Strategic Energy Technology Plan for the next financial framework (2013-2020).
- Following topics will be raised: complementing FP7 grants with loans and equity financing, EU Instruments and continuation of FP7, the role of European Investment Bank in SET-Plan, financial contribution of Member States and industry, the role of the financial sector.

Pag. 243

Pag. 244

SEVENTH FRAMEWORK PROGRAMME

SET PLAN CONFERENCE, WARSAW

- **Smart Cities:**
- The conference will bring the commitment of stakeholders to develop holistic solutions to urban energy and transport problems in some selected 'model cities',

Pag. 244

Pag. 245

SEVENTH FRAMEWORK PROGRAMME

SET PLAN CONFERENCE, WARSAW

❑ European Industrial Initiatives

❑ What have been achieved by now (results) and what are the plans for future:

- ❑ European Industrial Bioenergy Initiative
- ❑ European Sustainable Nuclear Industrial Initiative
- ❑ European Wind Initiative
- ❑ Solar Europe Initiative
- ❑ European CO2 Capture, Transport and Storage Initiative
- ❑ European Electricity Grid Initiative

www.kpk.gov.pl

Pag. 245

Pag. 246

SEVENTH FRAMEWORK PROGRAMME

SET PLAN CONFERENCE, WARSAW

❑ EERA Joint Programmes

❑ What have been achieved by now (results) and what are the plans for future:

- ❑ Wind Energy
- ❑ Photovoltaics
- ❑ Smart Grids
- ❑ Geothermal
- ❑ Carbon Capture and Storage
- ❑ New Materials for Nuclear
- ❑ Bioenergy

www.kpk.gov.pl

Pag. 246

Pag. 247

CONFERENCE SCHEME

SEVENTH FRAMEWORK PROGRAMME

MO, 28 NOV

10:00

POLITICAL PLENARY SESSION

LUNCH

AFTERNOON PLENARY SESSION

SN ETP meeting

GALA DINNER

Pag. 247

Pag. 248

SEVENTH FRAMEWORK PROGRAMME

CONFERENCE SCHEME

TU, 29 NOV

MORNING PLENARY SESSION

LUNCH

SN ETP meeting

Pag. 248

Pag. 249

SEVENTH FRAMEWORK PROGRAMME

SOON MORE INFORMATION

www.setplan2011.pl

www.kpk.gov.pl

Pag. 249

EUROPEAN COMMISSION

PROVIDING INFORMATION FOR DECISION-MAKING

Mapping of Projects relevant to the CCS-EII

Vangelis TZIMAS

EUROPEAN COMMISSION

SET-Plan Project Mapping
Responses

Projects on Carbon Capture & Storage (CCS)

Country	*Number of projects*	*Budget (MEuro)*
EU	8	48.03
CZ	1	2.00
DE	6	105.80
ES	5	28.24
PL	1	4.23
PT	1	3.03
CH	1	4.20
UK	9	58.20
TOTAL	32	253.73

*** 3 projects (all from Spain) out of the total 32 are combined CCS & bioenergy.**

Pag. 251

EUROPEAN COMMISSION

SETIS PROVIDING INFORMATION FOR DECISION-MAKING

Definition and Quantification of the KPIs for the CCS EII

Vangelis TZIMAS

EUROPEAN COMMISSION

Background

- KPIs represent an essential toolkit for monitoring and reviewing EII progress
- KPIs are instrumental for planning future RDD activities
  - Projects should demonstrate their link with the CCS-EII IP
- KPIs, incorporated in the IP, have now been further refined ahead of the Steering Group meeting, to form the **first generation of the CCS-EII KPIs** focusing on ongoing and future RDD activities.
  - Constitution of the First Monitoring and Review Framework for the CCS-EII

Pag. 251

Pag. 252

EUROPEAN COMMISSION

Modalities

- The first generation KPIs is the result of **joint efforts** between the Industry (ZEP ETP) and the Commission/SETIS.
- Starting point was the KPIs of the IP.
- Based on the work by ZEP ETP (cost reports) and the CCS Project Network.
- Dedicated meetings and teleconferences between ZEP and Commission/SETIS.
- Work (description and quantification of KPIs) is nearly completed.
- Data gathering and analysis procedures will be defined at a later stage.

EUROPEAN COMMISSION

General Principles

- Simplicity for ease of measurement and interpretation
- 2 overarching KPIs to measure the progress of the EII towards meeting its strategic objective (competitiveness)
- 12 second-tier KPIs to measure progress at project level
- Definition and quantification of KPIs based on the PN info & experience gathering form and ZEP cost reports

Pag. 252

Pag. 253

EUROPEAN COMMISSION

Boundary Conditions

- Calculations for the overarching KPIs based on commercial large scale plant that starts operating in mid 2020s after successful demonstration, with optimised technology based on first commercial experience but still not mature (OPTI).
- CCS plants operate in baseload mode (7500 h/y)
- Transport and storage costs are excluded
- Reference systems
  - Coal: 736 MW, ultra supercritical, η=46%
  - NG: 420 MW, single shaft, F class combined cycle, η=60%
- Reference fuel
  - Hard coal from world market
  - NG on European market
- **Economic** assumptions
  - WACC: 8%
  - Project life: Coal: 40y, NG: 25y

EUROPEAN COMMISSION

Overarching KPIs (1)

1. **Levelised Cost of Electricity (LCoE) for power generation (€/MWh)**
   - **LCoP (LCO Product) for industrial applications (€/t)**

- Measured for reference (PF and NG) plants and CCS plants (average values for different capture technologies)
- Calculation based on 2nd tier KPIs:
  - Specific capital investment
  - O&M costs
  - Availability
  - Efficiency
- … and other assumptions:
  - Discount rate, lifetime
  - Load factor
  - Fuel costs (assuming coal and NG prices)
  - Carbon costs (assuming CO2 prices)

Pag. 253

Pag. 254

EUROPEAN COMMISSION

Overarching KPIs (2)

2. CO2 avoidance cost (€/t_{CO2})

$$AC = \frac{LCoE_{CCS} - LCoE_{ref}}{SCE_{ref} - SCE_{CCS}}$$

- Calculation based on LCoE and specific CO2 emissions (SCE) of reference and CCS plants

EUROPEAN COMMISSION

2^{nd} tier KPIs (1)

- **Progress in the demonstration programme**
  - Cumulative number of FIDs
  - Gross installed cumulative CCS capacity
  - Number of projects in the PN
- **Cost effectiveness**
  - Additional capital costs
  - Additional O&M costs
  - Availability
  - Plant efficiency
  - Capture rate

Pag. 254

Pag. 255

EUROPEAN COMMISSION

2nd tier KPIs (2)

- **Environmental effectiveness and safety**
  - Annual average CO2 avoided
  - Cumulative CO2 stored
  - Number of instances of CO2 movement out of designated containment volume
  - Quantity of CO2 moved out of designated containment volume
- **Public awareness of CO2 storage**
  - Number of permits for storage projects
  - Eurobarometer pole rating

EUROPEAN COMMISSION

Quantification of Baseline and targets

- Baseline values for the overarching KPIs are calculated based on today's technology plant concepts (BASE)
- Target values for the overarching KPIs are calculated for optimised plant concepts based on first commercial experience and still not mature (OPTI)

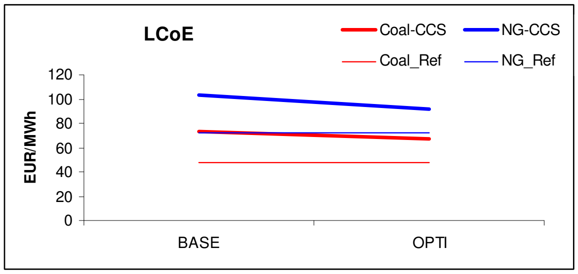
	BASE		OPTI	
	Coal	Gas	Coal	Gas
SCI (EUR/kW)	2860	1828	2530	1511
OM (EUR/MWh)	14,5	12,6	13,1	9,8
Efficiency (%)	37	48	39	52

Pag. 255

Pag. 256

EUROPEAN COMMISSION

Evolution of Overarching KPIs



ΔLCoE:

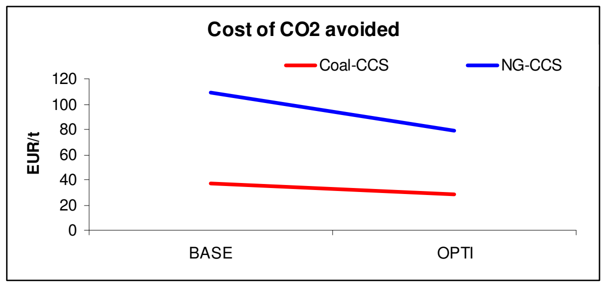
Coal: -8%

NG: -12%

ΔAC:

Coal: -24%

NG: -28%



Pag. 256

ITALY

Rev.2

European Strategic Plan for Energy Technologies - SET Plan -

Short summary of Italian Contribution to the "European Initiative for the Capture, Transport and Storage of CO_2"

Giuseppe Girardi
italian government representative
for the EII Team of the CCS Initiative

TOPICS:

Bruxelles, May 20th, 2010

1. BACKGROUND

The need to update energy policies worldwide in order to deal with climate change effectively is now unanimously considered a priority by the scientific and political communities as well as by people. It is also unanimously believed that what is needed is an approach integrating energy usage and energy production. Such an approach requires that we speed up the transition towards an economy not any longer based on fossil fuels, but instead on an increased demand / supply efficiency and on renewable sources, while aiming at clean technologies and emissions closer and closer to zero wherever fossil fuels are used.

Therefore the energy and research policy in this field must take the following factors into account:

- fossil fuel demand will stay very high in the coming decades, above all in the Countries with an Emerging Economy
- the development and widespread commercial deployment of intrinsically zero emission technologies at a competitive cost will take longer
- it is necessary to act immediately to reduce the emissions into the atmosphere that fossil fuel usage will still bring about.

In Italy this vision is widely agreed, and several measures have been taken in order to achieve the desired goals.
The Italian Energy policy foresees, in the medium-short term: diversify the energy suppliers, diversify routes and the related infrastructures, support the international dialogue between producers and consumers, increase energy efficiency both in electricity generation and in end-uses, diversify energy sources; while, in the medium-long term: emphasize energy diversification while coping with environmental concerns, continue the process of liberalization of the electricity market towards retail market, increase security of energy supply, reduce energy prices and tariffs, streamline the authorization procedures.

In this context we are now adopting three technological carbon management options:

- reduce carbon intensity, increasing renewables and fuel swithing;
- improve efficiency, acting on demand side and supply side
- sequester carbon, mainly applying CCS technologies and enhancing natural sinks

2. CCS TECHNOLOGY OUTLOOK: OUR VIEW IN ITALY

The usage of renewable energy, of advanced transport systems including hydrogen and fuel cells, the re-launch of nuclear power with new design and, above all, energy efficiency stay the main aims of policies dealing with greenhouse gas emission.

However, it is widely believed by now that resorting to CCS is one of the options available today to be used if we are to contribute significantly to emission reduction in the short and medium term.

Italy reckons that CCS techniques have to be adopted in order to contribute to reduce emissions by about 20% by the year 2050 in a scenario for the year 2050 where emissions are 50% lower than today's levels.

Our view is that the technologies needed for CO2 capture, transport and storage are mostly known and some of that have been used for decades with a different purpose of a merely commercial nature (as in Enhanced Oil Recovery), although they were never related to the aim of reducing CO2 emissions.

On the other hand, a strong demonstration programme on a commercial scale, also in Italy, is needed which verify its effectiveness and safety, as well as lot of medium-long term R&D work for lowering the costs and increase global efficiency.

However, some important questions have not been answered; these regard the scenario of regulations and authorizations, above all concerning the phases of CO2 transport and geological storage, and the problem of social acceptability of the entire CCS process.

As far as **capturing CO2** is concerned, the consensus is unanimous: we can point out neither the best nor the most promising capture technology available today.
Therefore, we must act upon a double temporal horizon: on one hand is the need to implement *demonstrative installations* by the year 2020 so that we can verify the possibility of a quick transition to the

commercial stage. On the other hand is the need to pursue *research activities* leading to further developments after the year 2020, aiming at significant cost reductions (especially for the capture) and at the increase of the overall efficiency.

Looking at **CO2 transport** via pressurized pipelines, technologies are mostly those used for the transport of natural gas, also regarding the pressure levels (around 80 bar). In such conditions CO2, unlike natural gas, is generally in its state of supercritical fluid. In the USA, where CO2 transport is typically intended for EOR use and it happens in areas with little population, this part is substantially considered fully developed. In the European context, and in Italy too, which may involve densely populated areas and a fluid with chemical characteristics (with regard to its content of water and impurities) which are variable depending on the separation and conditioning processes that follow, higher design costs may be required.

With regard to **CO2 storage**, from the technological and scientific viewpoint, we know most of the elements needed in the CCS geological sequestration.
Many types of formations are suitable for CO2 storage for very long time. CO2 can be injected in its supercritical condition (which happens at about 800 m below the surface) into porous formations containing fluids (deep saline aquifers) or into reservoirs where hydrocarbons are running out. The third trapping option regards those coal seams which are otherwise unmineable by the classic mining methods. When CO2 is injected in them, it binds itself to the carbon better than methane: if the latter is present it is then released.

The evaluations of the sedimentary basins and of the known fields of hydrocarbons are not well known in Italy, even if a lot of data have been collected during the time by ENI, a crucial work has been done in this field during last years by several organizations, and several experimental activities have been started.

Furthermore, other methods other than geological ones have been started to be studied, specially that related to the usage of CO2.

Regarding the **regulatory aspects**, many positive steps have been made to include CCS techniques into international protocols. The regulatory framework is destined to evolve rapidly, above all thanks to the recent European Directive 2009/31/EC of 23 April 2009 on CO2 Geological Storage, which binds the member states, inter alia, to report on the implementation state of the Directive on the national level in June 2011.

In Italy the transposition of that directive has been started and will be realized through a base law followed by various administrative acts; a draft text of a base law is ready for consultation with stakeholders. There are two key issues to be addressed, scope of consultation with regions and geological database. The process should be completed by the end of 2010.

As for **public acceptance**, recent research indicates that more than 90% of the population is considering greenhouse effect mitigation an important factor to pursue with determination because of its implications on climate change. However most of the people who were interviewed on the subject did not know or were not fully aware of the potential of CCS for greenhouse effect mitigation. The lack of awareness of the population regarding CCS makes it imperative that correct information from reliable sources is made available to the public.

A communication strategy addressing a wide and varied group of people to whom CCS is a concern is essential to prevent positions which are extremely anti-CCS, irrational or effectively opposing the objective from monopolizing the debate: in Italy several initiatives have been launched to this end.

3. MAIN FINALIZED R&D ACTIVITIES

Italian research centres and universities have started specific studies and programmes regarding various aspects of CCS over 10 years ago. Such initiatives have been financed thanks to European (FP5, FP6, FP7) and national funding, essentially from the Ministry of University and Research and from the Ministry of Economic Development. The latter in particular, has financed a vast programme based on a strong synergy between national stakeholders and intended to increase the competitiveness of our industrial system, also via to the Italian participation to international initiatives like the *Carbon Sequestration Leadership Forum* (CSLF) and the European Technological Platform for *Zero Emission Fossil Fuel Power Plants* (ZEP).

Here is a synthetic list of the main projects under way in our country.

3.1 PROGRAMMES FINANCED BY THE ITALIAN GOVERNMENT

INITIATIVES CO-FUNDED BY THE MINISTRY OF UNIVERSITY AND RESEARCH

SOTACARBO "COHYGEN project – pre-combustion technology"
The research program focuses on the production of hydrogen and clean fuel gas (high temperature desulfurization) from coal and CO2 capture from "syngas" using solvents. A pre-combustion test platform has been constructed; it consists of two main installations: a 5 MWt gasification pilot installation equipped with a gas treatment system, and a smaller one (400 kWt) for hydrogen and electricity generation. Furthermore, research infrastructures and dedicated laboratories became available as a result.

ENEA "ZECOMIX project – pre-combustion technology"
The research program focuses on the study of coal gasification, syngas treatment, CO2 capture with solid sorbents, H2 production and burning for power generation by means of a high efficiency gas turbine cycle; the ZECOMIX pilot installation will start by September 2010, operating at a coal feeding rate of 50 kg/h.

ENEA "CARBOMICROGEN project - distributed generation based on hydrogen rich syngas"
The main goal is the study and development of small power generation systems based on syngas generated by coal and/or biomass; these generation systems are also based on the hydrogen obtained from CO2 capture and the resulting syngas.

INITIATIVES CO-FUNDED BY THE MINISTRY OF ECONOMIC DEVELOPMENT: "CERSE PROGRAM" FOR R&D ON ELECTRICITY SYSTEM

ENEA "Coal fired power plants for electricity and hydrogen combined production project"
The main goals are the following: a) research on pre-combustion capture technologies and CO2 storage (with ECBM and also CO2 injection in deep saline aquifers); b) testing on pilot installations; c) to support the national Industry and research system with the aim of increasing their cooperation with a view to their playing a stronger role at the international level; d) to define the Italian national path on CCS; e) to stimulate the cooperation among national stakeholders in order to increase public acceptance.

ENEA "Oxy-combustion for coal fired power installations"
This project, that will be followed by a demonstrative program managed by ENEL, focuses on the development and testing of an innovative combustion system fed with coal slurry, operating at 5 bar with exhaust gas recirculation and utilizing the so-called "flameless combustion"; the main activities are:

- advanced modelling and "LES" simulation code (named HeaRT-MPh) validation;
- combustion system testing with advanced diagnostics;
- development of an advanced pumping system for coal slurry;
- feasibility study for a demonstrative plant fed with Italian (Sulcis) low quality coal.

ENEA/ SOTACARBO "Coal gasification with CO2 capture and storage"
The main goals are: a) to carry out experimental activities on two main test rigs. The first one consists of a coal gasification and CO2/H2 separation system operating with a 30 kg/h coal feeding. The second one is a 6 MWt coal gasifier. Their aim are:

- to qualify advanced gas cleaning and CO2 separation processes, as well as gasification processes using mainly CO2;
- to study real installations equipped with CO2 capture systems, with a view to constructing a demonstrative power installation in Sardinia;
- to study the feasibility of CO2 storage in the Sulcis coal basin

ERSE "Characterization of CO_2 storage sites"
The project has the objectives of pinpointing areas potentially suitable to CO_2 geological storage, creating a Geographic Information System for the National Inventory of Potential Storage Sites, refining calculation systems and tuning up instrumentation. The project involves also the monitoring of marine sites and activities favouring communication and outreach of the CCS technology.

ERSE "Development of membranes for the separation of hydrogen from syngas"
The main goal is to develop new membranes by chemical deposition of palladium and its alloys on porous media for use in separating hydrogen from syngas. A specially valuable application is the Membrane Shift Reactor, already successfully demonstrated at the laboratory scale.

ERSE "Degradation of a turbogas running on hydrogen rich syngas"
Analyses and modelling are carried out concerning the mechanisms that damage the critical materials (due to heat) in aggressive environments from the thermal, chemical and erosion points of view. Amongst the results obtained, we can mention the modelling to predict the materials life and various non-destructive methods to estimate of the wear condition of materials.

ERSE "Sorbent solids suitable for the capture from combustion fumes"
A capture system just upstream of the chimneys of existing installations is being studied. At present this can be put into practice using absorption processes in amine solutions. To ERSE is due the concept design and development of an original solution based on solid sorbents able to penalize efficiency significantly less.

CNR "Innovative technologies for the improvement of the environmental performance of powdered coal power plants"
The activity of this research programme consists of two strains: a) the development of advanced diagnostic techniques for the monitoring of the pollutants typically associated with coal combustion and for studying the impact of the coal type utilized; b) the development and/or implementation of technologies for the reduction of the pollutant load upstream and downstream of the combustion system, including: the characterization of the process of de-volatilization and combustion of the particles as a function of the characteristic of the coal, the pre-treatment of the coal powder and the treatment of flue streams for the reduction of pollutants.

INITIATIVES CO-FUNDED BY THE MINISTRY OF ECONOMIC DEVELOPMENT: "INDUSTRY 2015 PROGRAM"

ENEL/ENEA "MILD combustion project"
The main goal is to develop and test MILD combustion in different industrial sectors, because of its higher efficiency, strong reduction of NOx and particulate emission; it involves several industrial operators (mainly power generation and steel industry) as well as research organizations working on heating furnaces, gas turbines, boilers, and oxygen fired coal power installations. An experimental program on a 6 MWt pilot installation coal oxyfiring with CO_2 capture is ongoing.

3.2 INTERNATIONAL PROGRAMMES WITH THE PARTICIPATION OF ITALIAN PARTNERS

Weyburn (Weyburn CO_2 monitoring project) (*completed: INGV, Sapienza Università di Roma)*
A project which aims at refining the injection and monitoring techniques for the CO_2 utilized for Enhanced Oil Recovery (EOR) at the Weyburn oil field. The CO_2 originates in a coal gasification plant and is transported up to its storage site via a pipeline having a length of 330 km

NASCENT (Natural analogues for the geological storage of CO_2) *completed; GA.I.A. Srl, OGS)*
It is thematic network, which aims at helping companies, industry and research agencies working on the development, evaluation, and spreading of CO_2 capture and storage techniques as acceptable tools for climate change mitigation. Twenty-nine organizations from nine European countries adhered to it.

CASTOR (CO_2: from cCApture to STORage) *completed; EniTecnologie S.p.A., GSV S.p.A., OGS)*
Project for the optimization of post-combustion CO_2 capture techniques using low concentrations, low pressures and high volumes. As for the storage, 4 potential sites with different characteristics have been analyzed, both on land and at sea (Casablanca, Snohvit, K12B e Atzbach-Schwanenstadt).

INCA-CO2 (INternational Co-operation Actions on CO2 capture and storage) ***completed; OGS)***
The goal is to support European stakeholders in their international initiatives, and to provide European politicians and decision-makers with a coherent view of international initiatives.

GeoCapacity (Assessing European capacity for geological storage of CO2) ***(completed; ENI, OGS)***
The aim of the project is to identify and evaluate the major CO2 emission sites in Europe, existing infrastructure for its transportation via pipelines and suitable storage sites in geological formations: saline aquifers, depleted hydrocarbon fields and deep coal seams. A first collaboration has been started with China. An estimate has been made of the "actual" CO2 storage capacity in all the countries examined.

DYNAMIS (Towards H2 and electricity production with CO2 capture and storage) ***(completed; ENEL)***
The project aims at analyzing effective pathways to construct large hydrogen production installations, with consequent storage of the CO2 produced in the process. It is part of the European initiative HYPOGEN involving, as an intermediate step, the construction of test infrastructures for the joint production of electricity and hydrogen from fossil fuels, with permanent CO2 storage.

CO2GeoNet (European Network of eExcellence on the geological storage of CO2) (completed, carries on as an Association; OGS, Sapienza Università di Roma)
It links 13 research institutions of 7 European nations and employing over 250 researchers to do studies about CO2 geological storage. Its main aim is to foster a gradual and lasting integration among its partners until a "virtual institutie" comes to life, competitive at the world level with similar foreign institutions. In 2008 the members founded the Association CO2GeoNet. OGS manages its General Secretariat

CO2ReMoVe (CO2 geological storage: Research Into Monitoring And Verification technology)
underway; OGS, Sapienza Università di Roma)
The project aims at improving the techniques for: monitoring of storage sites and of leakages at the surface and through the wells; predicting the long- term behaviour of the stored CO2; evaluating the risks for various sites and at different temporal scales; preparing guidelines for the industry and central and local authorities.

MovECBMm (Monitoring and verification of ECBM) ***(underway; Carbosulcis, OGS, Rome University)***
The project aims at monitoring and checking the CO2 storage capacity in a deep coal seam. Its components are: the study of the processes of adsorption in the coal matrix; the development of models to optimize methane production; the improvement to the best possible degree of the techniques for monitoring CO2 and methane while they migrate in a reservoir.

CCP and CCP2 (CO2 Capture Project) ***(underway; ENI S.p.A.)***
It is an initiative of 8 major oil companies and three government organizations who promote and carry out study and research to: reduce marginal uncertainty of CCS, both technical and economical; reduce capture costs by 20-30%; identify and tackle the critical aspects of geological storage; create operational standards; develop modalities to share information and shorten the time needed for a widespread application of CCS.

RISCS (Research into Impacts and Safety in CO2 Storage) ***(starting; OGS, Sapienza Rome University)***
RISCS will develop the knowledge base necessary both to storage site operators and regulators to evaluate the potential impacts of leakages on near surface ecosystems, both in terrestrial and marine environments. Such information will also support policy makers, politicians and the general public in their assessments of the feasibility, long-term benefits and consequences of large-scale CO2 capture and storage deployment.

SOCRATES (Scale One CO2 Recovery And Trapping Engineering Studies)
(under negotiation; Ansaldo Energia, ENEL, ENI, OGS, Saipem, Università di Padova)
Socrates aims to develop technical and economic viable integrated concepts for coal zero emission power installations in view of large scale demonstration in 2015-2020. The integration will cover all the components needed to set up the CCS demonstration. Two test cases will be analyzed in depth: an 850 MW IGCC power installation at Teesside, north east of England, and a full scale power installation (3x660 MW units) with post-combustion CO2 capture, transport and geological storage, near Porto Tolle, northern Adriatic sea, Italy.

<u>Other projects, with Italian partners, have terminated their evaluation phase:</u>
- **CO2Care** (CO2 Site Closure Assessment Research): with OGS
- **SiteChar** (Characterisation of European CO2 storage): with OGS, La Sapienza Rome University, ENEL
- **Cal-Pilot** (Demonstration of Carbonate Looping for CO2): with University of Naples.

4. MAIN PILOT AND DEMONSTRATION PROJECTS UNDER WAY AND CLOSE TO STARTING

We will indicate the main projects on individual technologies and on the entire CCS cycle which are of industrial interest and have a demonstration nature; some of them are already under way.

4.1 PROJECTS MANAGED BY ENEL AND ENI

ENEL - Brindisi post combustion capture pilot plant
A first post-combustion capture (via amine scrubbing) project involves the construction of a pilot installation to be installed at the Brindisi Sud coal power plant. The CO2 produced will be liquefied and stored by a criogenic system; it will be transported by way (230 tracks per year) and stored by ENI at the Cortemaggiore site. The plant is composed by a flue gas pre-treatment section (able to remove completely the .particulate and the SO3 and to reduce SO2 level below 20 mg/Nm3) and by a CO2 separation unit. The facility will capture about 2.5 t/h of CO2, treating a flow off lue gases of 10.000 Nm3/h. It i salso foreste to build in Brindisi a closed loop CO2 pilot pipeline to develop knowlrdge to be used in demo design. CO2 injection will statrt in Summer 2011. I twill help the Porto Tolle demo project.

ENI - pilot project of injection into a depleted hydrocarbon field
ENI has run various studies and preliminary evaluations as part of the design of surface infrastructure for CO2 injection and monitoring in the Cortemaggiore field (Piacenza). ENI has also analyzed the legal and social aspects linked to the storage. The injection of 8,000 tonnes of CO2 per year will follow over a 3 year period (24.000 tonnes of CO2 in three years), followed by two years of post injection monitoring. Studies on the utilization of the CO2 will also be run in order to increase the recovery factor from Italian hydrocarbon fields.

ENI-ENEL -Agreement for the development of CCS techniques
The agreement involves a joint study on the potential for CO2 geological storage in Italy and the implementation of the first Italian CCS project: ENEL is busy with the construction of a pilot CO2 post-combustion capture installation; the CO2 will be liquefied in situ and transported to Cortemaggiore, where ENI will inject it into the depleted field. A joint study for a CCS demonstration project of 1 Mt/year is also involved.

ENEL - Porto Tolle demonstration project (ZEPT: Zero Emission Porto Tolle)
The Porto Tolle project is part of a wider programme aimed at large scale application of post-combustion. This technology applies the chemical absorption to remove the CO2 contained in flue gases from power.
The demo plant will treat a flow of flue gases of 810,000 Nm3/h, corresponding to around 250 MWe, equivalent to about 40% of flue gases that are emitted from a unit of 660 MWe to produce about 1 Mt/y of CO2, which will be transported by pipeline to the storage site and injected into underground reservoirs. This project, besides fully demonstrating this technology on an industrial scale, so as to provide a commercial solution for new installations after 2020, will test the possibility of retrofitting highly efficient coal-fired groups. This experience will benefit the entire area of southern Europe where geological storage is possible, mainly in deep saline aquifers. Enel was awarded funding of up to €100 million for Porto Tolle from the European Commission’s European Economic Recovery Plan in December 2009. The demonstration plant is due to be ready by 2012 with storage of CO2 starting in 2015

Oxy combustion project - Brindisi pilot plant (ENEL)
The project regards the “flameless” combustion of coal in an atmosphere of oxygen, carbon dioxide and water vapour, at temperatures of about 1500 to 1700 °C and pressures up to 4 bar. Such process, developed and licensed to ITEA and being used at the present moment on a 5 MWt pilot installation, will be tested on a second installation with a power of 48 MWth.

4.2 PROJECTS MANAGED BY OTHER INDUSTRY

SOTACARBO/CARBOSULCIS - CBM and ECBM CO2 storage in the Sulcis coal basin pilot project
The project has the objective of evaluating the feasibility of methane recovery (CBM) and of CO2 storage (ECBM) in vast parts of the Sulcis coal basin, in South-West Sardinia, which are not suitable for mining activities. Once the characterization of the basin has been completed through studies, analyses of existing data and experimentation, the second stage will follow, with the aim of defining all the remaining aspects for the construction of a pilot injection and storage installation.

SULCIS - 400 MWe coal fired demo plant with CO2 capture and storage
In the framework of the new Italian energy policy - Government and Parliament approved on July 2009 the Law n.99 “Regulations for the development and internationalization of enterprises and on the subject of energy” - an important initiative has been approved consisting in the realization in Sardinia Sulcis area of a medium size (400 MWe) power plant, firing the Sulcis coal and adopting CCS technologies; the CO2 captured will be compressed, transported and stored in unminable coal seems as well as in the underlying aquifers. The project is aimed at demonstrating capture and permanent storage of the CO2 emitted by power plants fed with a poor quality coal.
That law states also national public funding mechanisms and project financing procedures; the regional Government of Sardinia supports this project from the political point of view and will participate to public funding. A detailed feasibility study has been already concluded (by Sotacarbo and ENEA.

SOTACARBO/ENEA - Pre combustion and coal to liquid zero emission pilot project
The main goal is, starting from the existing infrastructures, to realize (in the research area of Sotacarbo-Sardinia) an integrated pilot plant for testing advanced technologies for sustainable use of coal: it consists of a main gasification station and two main units, the first one to demonstrate a low emission coal-to-liquid process, and the second one to demonstrate pre-combustion carbon capture technology for combined generation of electricity and hydrogen; the CO2 captured in the whole process will be injected into coal beds (ECBM) managed by Carbosulcis (coal mine industry) and into the underlying aquifers. In thgis context the Sardinia region will allocate a concession for the management of the coal mine involving the production of electric power, making the capture and storage of the emitted CO2 an integral part of the concession itself.

TECHINT - Post-combustion CCS on gas fired power installation feasibility study for demo plant
The main goal is to apply post-combustion CO2 capture to an existing 120 MWe gas fired co-generative power installation operated by Tenaris at Dalmine steel industry; the feasibility study is finalized. ENEA, ERSE and University of Milan are the research organizations involved.

5. COOPERATION AGREEMENTS (UNDERWAY OR DESIRABLE) AT THE EUROPEAN OR INTERNATIONAL LEVEL

Italy takes part, either directly or via its industry and research centres, in the most important European and international initiatives on CCS:

- CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF)
- ZEP EUROPEAN TECHNOLOGY PLATFORM
- GLOBAL CARBON CAPTURE AND STORAGE INSTITUTE (GCCSI)
- BILATERAL AGREEMENT ITALY-USA ABOUT CCT AND CCS
- EUROPEAN ENERGY RESEARCH ALLIANCE (EERA)
- EUROPEAN FRAMEWORK PROGRAM ON R&D (FW)
- ECCSEL (EUROPEAN CARBON DIOXIDE CAPTURE AND STORAGE LABORATORY INFRASTRUCTURE)

Its many cooperation agreements underway can increase, and offer opportunities to accelerate the application of CCS in Italy and to extend the action range of Italian enterprises and research centres.

- CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF)

The CSLF is an international initiative at government department level, presently involving 22 nations beside the EU. These represent over 3.5 billion people, or 60% of the entire world's population. The mission of CSLF is to facilitate the development and application of CCS technologies through international collaborations, which aim at overcoming the main technical, economical and environmental obstacles, while promoting public awareness and international regulatory and financial improvement.

Italy has always taken part to all the CSLF meetings with its official representatives in the Policy Group and in the Technical Group respectively, and with representatives of stakeholders. Such commitment has allowed our Country, even though it lacks a clear strategy in the sector and a national path, to maintain a strict relationship with all the main international organizations involved

- ZEP EUROPEAN TECHNOLOGY PLATFORM

Founded in 2005, the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) is a unique coalition of stakeholders united in their support for CO2 Capture and Storage (CCS) as a key technology for combating climate change: European utilities, petroleum companies, equipment suppliers, research organizations, academics and environmental NGOs are involved.

Italian stakeholders have a seat in the Advisory Council and participate to the technical Work Groups and Taskforces.

- GLOBAL CARBON CAPTURE AND STORAGE INSTITUTE (GCCSI)

GCCSI is an organization, borne out of an initiative of the Australian Government, whose aim is to marshal public and private resources to spread CCS techniques.

At the G8 Environmental Summit, held in April 2008 at Syracuse, a "Memorandum of Understanding", part of the Italian-Australian agreement for the cooperation of the development of CCS technologies, was signed by ENEL and the Australian minister for Agriculture Fisheries And Forestry, which implies that ENEL will join the Global Carbon Capture and Storage Institute (GCCSI) as a founding member.
Other organizations - as ENEA - expressed interest in becoming member of GCCSI.

- BILATERAL AGREEMENT ITALY-USA ABOUT CCT AND CCS

As part of the bilateral conference Italy - USA, held in may 2009, an agreement has been signed between Italy (Department of Economic Development) and USA (Secretariat for Energy) concerning clean coal and CCS. The sectors of cooperation between Italy and United States pertain: the exchange of experience and researchers, the coordination and monitoring of joint projects, the development of innovative technologies, the protocols to pinpoint sites suitable for CO2 storage, and actions to increase public awareness.

In a recent meeting (Rome, April 20109) the SULCIS Project has been analyzed at the end to start a cooperation between Italy and USA.

- EUROPEAN ENERGY RESEARCH ALLIANCE (EERA)
Ten leading European Research Institutes have taken up the challenge to found a European Energy Research Alliance (EERA). The key objective of EERA is to accelerate the development of new energy technologies by designing and implementing Joint Research Programmes in support of the Strategic Energy Technology (SET) plan. The EERA aims to strengthen, expand and optimise EU energy research capabilities through the sharing of world-class national facilities in Europe and the joint implementation of pan-EU programmes.

ENEA is one of the founding members, and other Italian research centres participate to its joint programmes.

- EUROPEAN FRAMEWORK PROGRAM ON R&D (FW)
Some Italian organizations have been partner of different projects, starting from the 5° FW.
During the 6° FW, the Network of Excellence CO2GeoNet was created. This is today the largest virtual institute in the world when the number of researchers is considered, all of them busy with the study of CO2 geological storage.
Research centres, universities and various Italian industrial stakeholders have taken part in the past EU financed projects (as described in a previous chapter), so 7° FW can offer an opportunity to progress and to extend the Italian presence in the context of European research.

- ECCSEL (EUROPEAN CARBON DIOXIDE CAPTURE AND STORAGE LABORATORY INFRASTRUCTURE)
ECCSEL addresses the need for powerful European research infrastructures with CCS. This requires major and strategic upgrading of existing CCS research infrastructures, the development of new unique laboratories, a goal-oriented approach, as well as the strengthening of the networks that comprise the European CCS laboratories. Such research infrastructure will enhance European competitiveness about CCS technologies, contribute to make work on this topic systematic and to improve the safety of Europe's energy plants. The ECCSEL proposal has been endorsed by ESFRI (European Strategy Forum on Research Infrastructures) and is going to receive support from the EC to help define the elements and rules that can make it function as a multi-centre European infrastructure of the highest level.

OGS and ENEA are main partners of ECCSEL, and others (La Sapienza University of Rome, ENEL, ..) support the project

6. STRENGTHS OF THE ITALIAN SYSTEM

The main strength lies in the new energy policy adopted by Italian Government and Parliament, with the approval on July 2009 of the Law n.99 on "Regulations for the development and internationalization of enterprises and on the subject of energy". It promotes innovation in energy sector – by adopting project financing, three years RDD Plan, and fixing priority on CCS, nuclear and energy efficiency – and foresees a national action plan.
Looking in detail, Art. 38 bears initiatives that promote research and experimentation in various areas of the energy field, amongst which the capture and storage of the CO2 produced and released by power plants.

To such end a working plan will be approved which aims at:

- allowing the implementation of demonstrative projects on the capture and permanent storage of the CO2 emitted by thermoelectric power plants and the implementation, albeit experimental, of permanent storage of CO2 into suitable deep geological formations, also with the aim of an improved exploitation;
- realizing a coal fired with CCS demo plant, and ensuring that the Sardinia region allocates a concession for the management of the Sulcis coal mine involving the production of electric power, making the capture and storage of the emitted CO2 an integral part of the concession.

The second strength is the starring of the main Italian industrial subjects, above all ENEL and ENI, which have started demonstrative projects of the greatest importance, but also Sotacarbo, Carbosulcis ITEA, Techint, and others, that has launched important demonstrative initiatives (both at pilot and industrial scale) and feasibility studies involving, albeit with different stages of development, the three technologies for the capture and the main modalities for CO2 storage.

The third strength is the research and development capability fin the main public bodies and in Universities. These possess a great potential in terms of expertise, laboratories / installations, and a great potential for networking both with industry and with central decision-makers to expand national policies, putting our Country in line with the nations which so far have been the most active in the CCS field. In this context, the role the research system can play in starting actions to get the correct information across to the public on the nature of CCS techniques, also with the involvement of NGOs, in not negligible.

Another important side is the large quantity of geophysical data available for many parts of the Italian territory. These data are owned by the oil companies and are of great value for assessing an overall CO2 storage capacity in Italy, based on sounding geological and geophysical evidences.

7. POTENTIAL ROLE OF ITALIAN STAKEHOLDERS IN THE FOUNDING OF EII

Europe, and Italy with it, is a front line competitor on CCS technologies. The research system operators are able to offer respectable competencies and resources, both in medium - long term activities and in industrial programmes. In fact, Italy is offering a wide ranging demonstrative programme:

- ENEL, together with ENI, is pushing a post combustion technology demo plant (Porto Tolle) and an oxy-combustion facility (to be constructed near Brindisi);
- Sotacarbo and ENEA have carried out a feasibility study for a 400 MWe coal fired demo plant with CCS to be realized in Sardinia (Sulcis demo Project).
- Sotacarbo and Carbosulcis, together with ENEA, OGS, Universities, and others, are managing a project aiming at evaluating the feasibility of methane recovery (CBM) and of CO2 storage (ECBM) in vast parts of the Sulcis coal basin, in South-West Sardinia, which are not suitable for mining activities.
- Sotacarbo and ENEA are carrying out activities on pre combustion CCS and planned to realize a Pre combustion and coal to liquid zero emission pilot plant with CO2 capture and storage
- ITEA has planned Oxy combustion project applied to different sectors – Gioia del Colle pilot plant
- Techint and Tenaris, together with ENEA and ERSE, have completed a feasibility study to retrofit the Tenaris combined cycle plant (of about 120 MWe) with a CO2 post-combustion capture system with storage in a well of the Bergamo area.

Therefore Italy is potentially in a position to study and demonstrate, although at different detail levels, all three capture technologies: this is necessary because today there is no technology which is judged to be better than the others, and there are broad possibilities of diverse applications according to the sector and to the various geographic / socio-political conditions.

On top of that, such an approach addresses the diverse needs of diverse industries who want to compete on the global market and utilize their own expertise. Amongst these are companies like ENEL, ENI, Ansaldo, ITEA, Techint, Snamprogetti, Foster Wheeler, Carbosulcis, Sotacarbo, Universities and research centres like ENEA, ERSE, INGV, OGS, Sardegna Ricerche, beside national and local government organizations. Diverse, technologically inclined groups, like Assocarboni, the recently founded CO2club and environmentalist associations, are fulfilling a growing role.

In conclusion, we have in our Country a broad and diversified set of stakeholders, made up of public and private organizations with different aims who, altogether, can cooperate on one side for the development of the technologies and their utilization at the industrial level, on the other side to contribute to the advance of general knowledge and of public acceptance.

8. SUMMARY REMARKS

In conclusion we can say that in Italy we have several initiatives, of different sizes and at different levels of development The main national and European public funding instruments are:

Fund for R&D on Electricity System that collects the electricity bills (<0.03 c€/kWh) for co-funding technology innovation of the electricity system. More than 35 M€ have been already spent (mainly ERSE and ENEA) in the first 3-y programme.The new 3-y programme 2009-11 foresees 30 M€, and has already allocated, up to now, 19 M€.

Law n. 99/09: New Energy Strategy for Promoting innovation in the energy sector; it introduces a project financing mechanism and a first hree-years RDD Plan: CCS is a priority in this plan.

Industria 2015 in the area of Areas Energy Efficiency a project on mild oxy-comb has been funded.

PNR: National Research Program for financing medium-long term R&D programmes; the last 3-y programme funded more than 2.5 M€ to Zecomix project on advanced pre-combustion technologies; the next 3-y plan is going to be adopted.

EC public contribution ENEL has already received 100 M€ contribution (EERP), but other contribution is expected (NER300, FP, etc..) in order to achieve a feasible national programme.

A first list of Italian main projects to be supported and funded is reported in the following table:

project/ responsible	**national contribution**						**Regional Contribution (Sardinia)**	**EC Contribution**	**priority**
	Fund for R&D on Electricity System		Law 99/09: New Energy Strategy		National Research Programme				
	already given	to be given	already given	to be given	already given	to be given			
DEMO PROJECTS									
Porto Tolle				X				NER 300	1
ENEL-ENI								other	
Sulcis 400 MWe				X			X	NER 300	2
Sotacarbo/ENEA								other	
PILOT PROJECTS									
Precomb (and coal-to-liquid)	X	X		X			X	other	1
Sotacarbo/ENEA								?	
CBM-ECBM in Sulcis basin	X	X		X			X	other	1
Carbosulcis-Sotacarbo								?	
Brindisi post comb				X				other	1
ENEL								?	
Oxycomb			to be evaluated					other	
ITEA								?	
MID-LONG TERM R&D									
pre-comb	X	X					X	X	
ENEA-Sotacarbo-ERSE									
post-comb	X	X					X	X	
ERSE-ENEA-ENEL			to be evaluated		to be adopted				
oxy-comb							X	X	
ENEA-ITEA-Sotacarbo-CNR									
ECBM-wells-aquifers	X	X					X	X	
ENI-Carbosulcis-OGS-Univ., ..									

 Pag. 269

Allegato 6.

Partecipazione a EERA (European Energy Research Alleance)

Accordi generali in ambito EERA

EERA: declaration of intents

EERA: Intellectual Property Rights

EERA: Letter of intents di ENEA

EERA: relazione sulla partecipazione di ENEA

Meeting EERA, Dicembre 2011

agenda della riunione

memo Topics identified for co-operation EUAustralia within CCS

visit to Australia short report

Assemblea generale EERA, Giugno 2012

sintesi impegno ENEA e associati nel Joint Programme

proposta ENEA di un nuovo topic su instabilità di combustione

proposta ENEA di un nuovo topic su uso della CO2

Joint Program, versione integrale in discussione per aggiornamenti

Joint Programme, versione pubblica

 Pag. 269

Pag. 270

Declaration of Intent
relating to the establishment of a
European Energy Research Alliance (EERA)

Context: the SET-plan

As outlined in the European Strategic Energy Technology Plan (SET-plan), energy technologies will be crucial to successfully combat climate change and securing world and European energy supply. Achieving Europe's 2020 and 2050 targets on greenhouse gas emissions, renewable energy and energy efficiency will require the deployment of more efficient and new technologies. Europe's potential to develop a new generation of decarbonised energy technologies is enormous. However EU energy research is fragmented, dispersed and often under-funded. If the opportunity facing the EU is to be seized, actions to develop new energy technologies, lower their costs and accelerate the process to bring them to the market must be better organised and carried out more efficiently.

Towards a European Energy Research Alliance

We, the undersigned, a representative group of leading research institutes in Europe have taken up the challenge to establish a European Energy Research Alliance (EERA). Our initiative has been conceived with the close collaboration and support of the European Commission. The EERA aims to strengthen, expand and optimise EU energy research capabilities through the sharing of world-class national facilities in Europe and the joint realisation of pan-European research programmes. Development of promising technologies is often hampered at national level as there appears to be sub-critical mass in individual countries. National and European energy R&D programmes have to be streamlined and coordinated, to achieve accelerated energy technology development which can subsequently be shared and implemented via the commercial community. The primary focus of the EERA will be on the strategic and targeted development of next generations of energy technologies drawing on results from fundamental research and maturing technologies to the point where it can be embedded in industry driven research.

Governance of the EERA

As soon as the EERA has successfully been established and an appropriate governance structure is implemented, membership of the EERA will in principle be open to all research organisations that can contribute to achieving its objectives. Research organisations from the new Member States will in particular be invited to join. In the foreseen governance structure, a distinction will be made between membership of the steering committee and membership on a programme level. We, the undersigned, agree to constitute the initial founding group and steering committee of the EERA. Participation at programme level will be open to all research organisations that can bring in significant R&D capacity and own resources to a Joint Programme of research in a particular field. The EERA will evolve over time as experience is gained in the

Pag. 270

implementation of Joint Programmes, possibly towards a legal structure in accordance with the EC Treaty.

Key objectives of the EERA

The high-level objectives of the Alliance will be to:

– Accelerate the development of new energy technologies by conceiving and implementing Joint Programmes of research in support of the SET-Plan priorities, pooling and integrating activities and resources, combining national and Community sources of funding and maximising complementarities and synergies, including international partners.
– Work towards a long term, durable integration of excellent but dispersed research capacities across the EU, overcoming fragmentation, optimising the use of resources, building additional research capacity and developing a comprehensive range of world class pan-European energy research infrastructures.
– Strengthen Europe’s capacity to initiate and execute large precompetitive high-risk high-gain research and development programmes.
– Develop links and sustained partnerships with industry to strengthen the interplay between research outcomes and innovation, facilitate industry access to world-class research and ensure the early take-up of promising results.
– Develop training, education and outreach activities, encouraging researcher mobility, providing a training environment for new researchers and professionals in strategic energy sectors and raising public awareness.

Main tasks of the EERA

In order to contribute to achieving the SET-Plan objectives and strengthen the research base in the EU, the EERA aims to:

– Identify and define Joint Programmes of research to be carried out by EERA-coalitions consistent with the SET-Plan taking into account activities of European Technology platforms and Industry Groupings.
– Implement Joint Programmes through the exploitation of existing 'own' resources (staff, facilities and funding as appropriate) from participating organisations, according to agreed rules, and attracting additional resources from other sources adding to scale and impact while ensuring coherence with other activities in the same fields.
– Share information and strategic plans to help identify strengths, weaknesses, overlaps and gaps, to determine potential areas coordinated efforts.
– Proactively engage with industry to create and exploit partnerships of mutual interest and benefit.
– Support prenormative research efforts at Community level for energy technologies.
– When appropriate, engage in International Cooperation actions with leading research organisations in developed and emerging nations in support of the EU strategy on energy technology.
– Systematically monitor and review the progress of the Alliance and its research programmes, using appropriate indicators, in association with the SET-Plan Information System (SETIS).

We, the undersigned, fully subscribe to these objectives and tasks and reiterate our willingness to constitute the initial founding group of the European Energy Research Alliance. To this end we have established a secretariat function and will work proactively over the coming months, with the European Commission, to define the working modalities of the Alliance and the processes needed to launch the first Joint Programmes in 2009.

Paris, 27th of October 2008,

Alain Bugat Hervé BERNARD ad interim
Administrateur Général du CEA

Dr. Juan Antonio Rubio
Director General, CIEMAT

Dr. Harry Kambezidis
Board Member, CRES

Dr. Ton Hoff,
Managing Director, ECN

Professor Luigi Paganetto
President, ENEA

Professor Dr. Harald Bolt
Board Member, FZ Jülich

Professor Maria Teresa Costa Pereira da Silva
Ponce de Leão
President, INETI

cea

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

ΚΑΠΕ
CRES

ECN
Energy research Centre of the Netherlands

ENEA
Italian National Agency for New Technologies, Energy and the Environment

JÜLICH
FORSCHUNGSZENTRUM

INETI
INSTITUTO NACIONAL DE ENGENHARIA TECNOLOGIA E INOVACÃO

....
Dr. Henrik Bindslev
Director , Risø-DTU

Risø DTU
National Laboratory
for Sustainable Energy

....
John Loughhead
Executive Director, UK-ERC

....
Professor Erkki KM Leppävuori
President & CEO, VTT

This initiative is supported by EUA and EUROHORCS.

....
Dr. John Smith
Deputy Secretary General, EUA

EUA
European University Association

....
Dr. Arnold Migus
Vice-president, EUROHORCS

EUROHORCs
EUROPEAN HEADS OF RESEARCH COUNCILS

APPENDIX A – Intellectual Property Rights in EERA Joint Programmes

EERA IPR Policy – October 2009

In the Declaration of Intent ("DoI") the founding members of EERA have described the context, governance, key objectives and tasks of EERA. In line with the DoI the participants of EERA wish to ensure rapid uptake and adoption of new technologies, efficient and effective cooperation with industry and strengthening of European competitiveness and industrial activity. Furthermore, EERA participants wish to create and maintain a sound foundation on which the continuous development of EERA can be based. Hence it is important to ensure that results generated in EERA projects are protected and commercialised. Commercialisation should be done on market terms in order not to distort the competitiveness in the market.

The participants of EERA wish to be able to set up projects quickly and efficiently with a minimum of bureaucracy thereby maintaining speed and focus on the scientific challenges to be addressed. Agreement on an IPR policy within EERA will further this. An IPR policy will provide existing and new participants of EERA a transparent and predictable frame for cooperation and enable EERA to draft template agreements to be used in EERA projects thereby minimising the time spent negotiating agreements for individual projects.

Most participants of EERA are familiar with the existing legal regime of the European Union's 7th Framework Programme. The terminology and principles are well established and recognised and will to the extent possible be used as basis for drafting EERA templates.

The EERA IPR Policy is mandatory for all participants of EERA and should be considered, respected and adhered to in each individual project.

Purpose

This EERA IPR Policy will be the common understanding and foundation for efficient and effective utilisation of results generated in EERA projects and shall ensure that the rights of the EERA participants are properly taken into account.

The policy shall also ensure an equitable transfer of results and know-how to industry thereby furthering the objectives of EERA and generating reasonable return on investments made by EERA participants.

The EERA IPR principles

The EERA policy on intellectual property rights are based on seven principles.

Ownership of results and inventions remain with the inventing institutions

Results and inventions generated in an EERA project should remain with the participants, whose employee(s) generated the results and inventions. In case of a joint effort leading to results or inventions, ownership of such results should be jointly owned in shares according to intellectual contributions of the employees of the participants.

Results must be protected where appropriate
Protection of results is a prerequisite for successful commercialisation. The participants of EERA should always consider carefully whether filing for protection of a result would be reasonable when the value of protection and the prospect for commercialisation are taken into consideration.

Background knowledge should be available to EERA projects
The participants in EERA projects recognise that they all have their individual areas of expertise and valuable background knowledge which could be of particular relevance for EERA projects. All EERA participants should support EERA projects by making available relevant background knowledge to the other participants if it is of relevance to an EERA project. However, no participant is obliged to grant access to its background knowledge.

To ensure that expectations are matched when preparing a joint EERA project proposal, the participants should as part of the preparation consider whether access to existing background knowledge of any of the participants will be required for carrying out the project or for exploiting results after completion of a project. The participants should identify any such background knowledge in writing.

The participants of EERA agree that any access to background knowledge will be subject to an agreement between the relevant participants. The terms and conditions of such access should reflect the purpose for which access to background knowledge is granted (project use/execution or commercial exploitation).

Access to project generated knowledge should be available to other EERA projects
The results from multiple projects within a work program may form a coherent platform for further use or commercialisation. The participants of EERA should always consider the possibility for creating coherent platforms and in good faith negotiate the required access to results to generate such platforms. Access must, however, be agreed between the EERA participants and no participant is obliged to grant access to generated results.

Licensing should generally be non-exclusive
The basic principle for access to EERA results and Background knowledge is non-exclusivity. However, the participants of EERA recognise that in order to find partners willing to fund further development of technology and move this into the market an exclusive license may be required. If an exclusive license is required, the EERA participant should always ensure that such license is defined and limited in its field of use, geographical area and duration. Further appropriate measures should be taken to ensure that the use of exclusively licensed technology will be pursued actively by the licensee.

Especially for enabling technologies the participants should ensure that exclusivity is even more limited in order to secure the possibility of spreading the technology to the widest extent possible.

The participants of EERA also recognise that licensing of results might not be sufficient or the best way to secure commercialisation. On the other hand, an assignment of ownership to results would imply a loss of control of the assigned results which could affect the research of EERA participants. But if assignment is considered as the best way to commercialise results, the participants of EERA may decide to do so.

Joint commercialisation should be pursued where possible
Commercialisation of a coherent set of results from a project is often more attractive to potential buyers of the results. Therefore the EERA participants should in each project and work program consider the possibility to jointly commercialise individually and jointly owned results.

The participants should consider appointing a commercial lead when preparing a joint EERA project. The role of the commercial lead would be to maintain focus on the commercial aspects (potential user feedback) and possibilities of the project and to ensure that these are considered throughout the duration of the project.

The participants should consider the mandate of the commercial lead and if appropriate include it in the contract.

EERA aims for commercialization in a global energy technology arena
The participants of EERA wish to facilitate the most efficient and effective utilisation of EERA results without distorting the competition in the market. Therefore all commercial exploitation of EERA results should be on market term and with no preference to companies registered in Europe.

EERA
European Energy Research Alliance

Letter of Intent

relating to the ENEA participation in the EERA Joint Programme on CO2 capture and storage (CCS).

On 20 GIU 2012 the following Letter of Intent is given to express the intent to participate in the EERA Joint Programme on CO2 capture and storage on behalf of ENEA, Italian National Agency for New Technologies, Energy and Sustainable Development, Lungotevere Grande Ammiraglio Thaon di Revel, 76 – 00196 Rome- Italy by Giovanni Lelli, Commissioner of ENEA who is a duly authorized legal representative of ENEA.

Declaration

ENEA shares the vision, mission and goals of the European Energy Research Alliance ("EERA") as described in the Declaration of Intent relating to the establishment of EERA of 27 October 2008. ENEA declares to support the continued efforts to establish and make effective the EERA as described in the said Declaration of Intent. ENEA confirms that it will collaborate and use all reasonable efforts to apply the resources as to be agreed by the respective Participants and described in the Description of Work for the EERA Joint Programme on CO2 capture and storage. The concrete extent of the rights and obligations of ENEA in a joint project under said Joint Programme will be defined in specific agreements between the parties to a project. ENEA accepts that as the joint programme progresses the initial Description of Work might be modified with the agreement of all Participants. ENEA confirms its commitment to take into account the EERA IPR Policy – October 2009 as given in Appendix A as appended hereto.

Rome, 20 GIU. 2012

ENEA
AGENZIA NAZIONALE
PER LE NUOVE TECNOLOGIE, L'ENERGIA
E LO SVILUPPO ECONOMICO SOSTENIBILE
Il Commissario
(Ing. Giovanni Lelli)

 Pag. 278

Allegato 2 alla Disposizione Commissariale n. 302 /2012/COMM

20 GIU. 2012

 Pag. 278

Pag. 279

RELAZIONE
PARTECIPAZIONE DELL'ENEA AL PROGRAMMA CONGIUNTO "CO_2 CAPTURE AND STORAGE" NELL'AMBITO DELLA EUROPEAN ENERGY RESEARCH ALLIANCE (EERA)

Nel mese di ottobre 2008 a Parigi, l'ENEA ha sottoscritto la creazione della European Energy Research Alliance (EERA). A partire da tale data l'Agenzia è stata attiva nella creazione di programmi congiunti di ricerca per lo sviluppo di tecnologie energetiche a basso impatto di carbonio. In tali programmi congiunti, gli istituti europei partecipanti concordano e sviluppano dei piani di lavoro in cui armonizzano le proprie attività di ricerca nazionali con i programmi nel campo supportati dalla Commissione Europea al fine di evitare frammentazioni e duplicazioni, accelerando in tal modo il raggiungimento degli obiettivi prefissati.
Tali piani di lavoro descrivono pertanto gli obiettivi e le risorse che ciascun partecipante mette a disposizione per la realizzazione di quanto concordato.

Le risorse che ciascun partecipante mette a disposizione non sono peraltro finanziamenti diretti ad EERA, ma si configurano come contributi in-kind quali: attività di R&S finanziate e portate avanti a livello nazionale, scambi di personale, informazioni e condivisione di infrastrutture di ricerca coperte da fondi nazionali o progettuali, ove ciò è ovviamente possibile, e non vincolati da eventuali accordi di confidenzialità con altri soggetti esterni alla EERA.

Una volta concordati i contenuti del programma congiunto all'interno della singola iniziativa EERA ed approvata la relativa descrizione del lavoro (Description of Work - DoW) da parte del board di governo della EERA (di cui l'ENEA fa parte), il programma congiunto viene lanciato ufficialmente e gli istituti possono cominciare a cooperare sulle attività di ricerca descritte.

Al fine di garantire l'impegno promesso, a ciascun istituto partecipante viene richiesta la sottoscrizione di una Lettera di Intenti (Letter of Intent - LoI), il cui testo è riportato in allegato alla presente nota, in cui viene ribadito che sarà rispettato quanto descritto nel DoW.

Il mancato rispetto dell'impegno non comporta problemi di natura legale o perdite pecuniarie, ma solo un danno di immagine dell'organizzazione partecipante e, nei casi estremi, l'eventuale espulsione dalla EERA.

Tra i programmi congiunti a cui l'ENEA partecipa figura il programma tematico "CO_2 *capture and storage - CCS*", coordinato da IFP (IFP Energies nouvelles) di nazionalità francese; tale programma è suddiviso in due sottoprogrammi, a loro volta suddivisi in task, come di seguito indicato:

1. cattura (coordinato da ECN9
   - post combustion
   - pre combustion
   - oxy combustion
   - cross-cutting
2. stoccaggio (coordinato da OGS)
   - static modelling
   - dynamic modelling
   - monitoring

Pag. 279

Pag. 280

ENEA

Foglio n. 2

Il sottoprogramma cattura della CO_2 prevede attività di ricerca su:
- solventi, sorbenti e membrane da impiegare per la cattura post-combustion;
- sorbenti e membrane per la cattura pre-combustion, e turbine a gas alimentate a idrogeno;
- tecnologie di combustione con ossigeno ad alta efficienza, e relative turbine a gas;
- attività orizzontali in relazione al benchmarking e alla simulazione di processi

Il sottoprogramma stoccaggio della CO_2 prevede attività di ricerca su:
- monitoraggio dei siti di stoccaggio;
- modellazione statica;
- modellazione dinamica

Gli obiettivi dei due sottoprogrammi sono lo sviluppo di tecnologie innovative in grado di aumentare l'efficienza complessiva, in considerazione degli alti costi energetici degli attuali metodi di cattura della CO_2, abbattere i costi ancora assai elevati, ed accrescere le conoscenze relative alle varie metodologie correntemente adottate per lo stoccaggio geologico della CO_2.

Il programma condotto da ENEA è relativo al solo sottoprogramma cattura, e prevede la partecipazione di partner associati che già collaborano con l'Agenzia nell'ambito delle attività dell'accordo di programma ENEA-MiSE, oltre al CNR.

In questo programma, di durata biennale, l'ENEA propone – come previsto nell'allegato DoW - un contributo lavorativo pari a 11 anni uomo per anno, pari complessivamente a 22 anni uomo per il biennio di attività. E' inoltre prevista la partecipazione dei seguenti partner associati: a) Sotacarbo, con un impegno di 4.5 anni uomo per anno pari complessivamente a 9 anni uomo per il biennio di attività; b) Università varie, con un impegno di 12 anni uomo per anno pari complessivamente a 24 anni uomo per il biennio di attività; c) CNR, con un impegno di 5,4 anni uomo per anno pari complessivamente a 10,8 anni uomo per il biennio di attività. I compiti assegnati e i relativi e risultati attesi (*tasks* & *deliverables)* sono riportati sempre nella Description of Work allegata.

Poiché il suddetto programma è stato lanciato ufficialmente (avendo concluso il proprio percorso di definizione dei contenuti) è pervenuta alla scrivente Unità UTTEI la richiesta di sottoscrizione della LoI.

Le attività di parte ENEA e dei partner associati sono seguite dall'Ing. Giuseppe Girardi dell'Unità UTTEI, indicato a suo tempo come referente per l'ENEA del Joint Programme CCS il quale sarà responsabile dell'attuazione e del controllo del rispetto degli impegni assunti dall'ENEA e dai partner associati.

Si trasmette pertanto la disposizione commissariale relativa alla sottoscrizione della Lettera di Intenti da parte del legale rappresentante dell'ENEA.

11 GIU 2012

UTTEI
Il Responsabile
(Ing. Gian Piero Celata)

ENEA
Ente per le Nuove Tecnologie,
l'Energia e l'Ambiente
Codice Fiscale 01320740580
Partita IVA 00985801000

Lungotevere Grande Ammiraglio Thaon di Revel, 76
00196 ROMA

Casella Postale 2358 – 00100 ROMA A.D.

Telefono 06 3627.1
Telegax 06 3627.2591
Telex: 610183 ENEA I
Telegrafo: ENEA - ROMA

Pag. 280

Pag. 281

EERA Joint Programme on Carbon Capture and Storage

Steering Committee Meeting

Thursday, December 15, 2011

9h00 – 17h00

IFP Energies nouvelles, Rueil-Malmaison, France

Draft Agenda

9h00	Welcome
9h30	Overview of current status of CCS Joint Programme
10h00	Current membership
10h15	Functioning and governance rules
11h00	Programme fee
11h30	New member candidates
12h30	Lunch
14h00	Feedback from Focus workshops
15h30	Programme and Priorities Task Force
16h15	Relations with other organisations
17h00	Adjourn

Background information to all agenda items will be sent prior to the meeting.

Additional agenda items may be proposed by programme members before December 1, 2011.

Pag. 281

 Pag. 282

SINTEF

SINTEF Energi AS
SINTEF Energy Research
Address:
Postboks 4761 Sluppen
NO-7465 Trondheim
NORWAY

Telephone: +47 73597200
Telefax:+47 73592889

energy.research@sintef.no
www.sintef.no/energi
Enterprise /VAT No:
NO 939 350 675 MVA

Memo

Topics identified for co-operation EU-Australia within CCS

PERSON RESPONSIBLE / AUTHOR
Nils Anders Røkke, Sandrine Decarre, Guiseppe Girardi, Jonathan Pearce, Claudia Tomescu, Rob Arts, Marjolein de Best Waldhober

DISTRIBUTION	FOR YOUR ATTENTION	COMMENTS ARE INVITED	FOR YOUR INFORMATION	AS AGREED
Vassilios Kougnias	X			

PROJECT NO / FILE CODE	DATE	CLASSIFICATION
Project No. or File code	2011-12-10	Unrestricted

Topics identified for possible co-operation between EU and Australia within CCS

A fact finding mission was conducted in the week 5-9 December 2011 to identify possible co-operation possibilities between EU and Australia within carbon dioxide capture and storage (CCS). The EU expert team met with Australian counterparts and discussed topics of mutual interest for Twinning arrangements or similar suitable for future calls of the European Framework Programmes of Research and the corresponding mechanisms for R&D support in Australia.

The following list of topics was extracted based on the visits and discussions and was also presented to the Australian government representatives, R&D institutes and other key CCS stakeholders headed by Ms Margaret Sewell, CEO of the Clean Energy Division of the Australian Department for Resources, Energy and Tourism (RET) in a meeting the 9th of December 2011 in Canberra. The list represents the first iteration of topics of mutual interest and should be further discussed with the Australian counterparts especially as regards details of the headline subject.

1. Capture: **Third generation solvents and/or high capacity sorbents for capture of CO_2.** The topic includes R&D into high potential novel systems of capture of CO_2 based on solids or liquids or a combination of these such as enzyme based systems, bio mimicking systems or MOF's (Metal Organic Frameworks). Environmentally benign systems should be pursued. The topic relates to both post- and pre combustion capture systems.

2. Capture: **Methods, systems and standards for measuring potential harmful emissions from CCS plants.** Amine based capture systems need to be better characterised in terms of the

 Pag. 282

SINTEF

environmental footprint and more specifically to develop methods and standards for measuring substances of HSE concern. R&D should be directed towards developing such methods, testing and validation for the most used and prospective solvent types in CO_2 capture.

3. Transport: **Integrity of large scale CCS infrastructures.** Large scale infrastructures for CO_2 will need to be operated safely and with a no-leak philosophy. Such infrastructures will include many components that are possible sources of leaks such as valves, flanges and seals, compressors, pumps and measuring devices. The R&D work should be directed towards characterisation of current practices and experiences, materials selection and characterisation and development and testing of materials and components to be used in large scale infrastructures for CO_2 transport.

4. Storage: **Monitoring, mitigation and remediation in CO_2 storage**. A key element for stewardship of CO_2 storage is good methods for monitoring, mitigation and remediation. Limited work has so far been conducted on remediation methods and strategies. The R&D work should focus on the effective remediation strategies and methods and the required monitoring techniques and systems for realising this, including monitoring tools for the marine and terrestrial environment Field tests and experience from operating pilots and plants should be pursued.

5. Communication and social aspects: **Energy awareness for CCS.** There is in general a low awareness in the society for the importance of energy, it's origin, production and distribution and the implication of energy usage in terms of security, the environment and climate change. Energy awareness especially directed towards CCS is a topic of interest and should be directed towards understanding the perception of energy in the society, what are the barriers for improving the knowledge and designing measures to improve the general knowledge of these issues especially for CCS. CCS can play a powerful role in mitigation emissions of CO_2 but will not be deployed unless there is a better understanding of the facts of energy and the role different technologies must play in a carbon restrained world.

It should also be noted that there exist possibilities for co-operation in current open calls in FP7, notably for the two stage call which closes in it's second stage in April 2012. These topics include "Sizeable storage pilots" and "Impacts of impurities in CO_2 for transport and the storage complex". These calls have however not been particularly designed for EU-Australian co-operation but relevant and good quality co-operation from other countries are always welcome.

Other possibilities exist in the EERA joint programme for research, this is mainly outside the EU framework programmes for research but can provide a mechanism for early interaction and co-operations, see http://www.eera-set.eu/index.php?index=27.

Pag. 284

EERA
European Energy Research Alliance
CARBON CAPTURE AND STORAGE

EU mission to Australia

Short report

Topics identified for possible co-operation between EU and Australia within CCS

Nils Anders **Røkke**, Sandrine **Decarre**, Giuseppe **Girardi**, Jonathan **Pearce**, Claudia **Tomescu**, Rob **Arts**, Marjolein **de Best Waldhober**

www.eera-set.eu

Pag. 284

EUROPEAN COMMISSION
Community research

Pag. 285

EU delegation

No	Name	Organisation	Projects involved
1	Dr Wiktor Raldow *Head of Unit*	DG for Research, Energy Conversion and Distribution Systems	
2	Dr Vassilios Kougionas		
3	Mr Jonathan Pearce	British Geological Survey (UK) – CO2 storage expert	SiteChar: http://www.sitechar-co2.eu/ CO2Care: http://www.co2care.org/ CGS EUROPE: http://www.cgseurope.net/ RISCS: information on CORDIS http://www.euussciencetechnology.eu/inventory/show/id/317
4	Ms Claudia Tomescu	Institute for Studies and Power Engineering – ISPE (Romania)	GETICA-Turceni CCS power plant Romania http://www.co2club.ro/en/getica-ccs.html
5	Ms Sandrine Decarre	IFP Energies Nouvelles (France) - CO2 transport expert	Coordinator: COCATE http://projet.ifpen.fr/Projet/jcms/c_7831/cocate
6	Ms Marjolein De Best-Waldhober	Energy research Centre of the Netherlands (ECN): Policy Studies - CCS Public Awareness	Coordinator: NearCO2 http://www.communicationnearco2.eu/home/
7	Mr Nils Rokke	SINTEF (Norway) – CO2 capture, EERA, ZEP AC member	DECARBIT: http://www.decarbit.com/ EERA: http://www.eera-set.eu/index.php?index=34 ZEP: http://www.zeroemissionsplatform.eu
8	Mr Rob Arts	TNO (Netherlands) – CO2 storage expert	CO2REMOVE: http://www.co2remove.eu/
9	Mr Giuseppe Girardi	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	Representing European Energy Research Alliance (EERA) http://www.eera-set.eu/
10	Ms Nikki-Lynne Hunter	Delegation of the EU to Australia and New Zealand (Canberra)	

Pag. 285

Pag. 286

Visit programme

1) **Monday 5 December, Melbourne – Otway (Group 1) & Melbourne – Hazelwood / Loy Yang (Group 2)**
2) **Tuesday 6 December, Melbourne:** Meet with Victorian Government
3) **Wednesday 7 December, Newcastle:** visit to CSIRO Energy Research Centre
4) **Thursday 8 December, Hampton:** Ultra battery Demonstration site
5) **Friday 9 December, Canberra**

Pag. 286

EUROPEAN COMMISSION
Community research

Pag. 287

Visit programme: Friday 9 December, Canberra

1015 Meeting with Mr Dick Wells, Chair of the **Australian National CCS Council**
1030 ANLEC R&D meeting with Mr Noel Simento, Managing Director http://www.anlecrd.com.au/

1230 Meet with **Australian Government and stakeholders** - Welcome (Ms Sewell)
1235 Energy White Paper (Mr Wilson)
1250 Low Emissions Coal Policy and Implementation in Australia (Ms Sewell)

1300 European CCS policy, projects and opportunities for collaboration

1) European Commission initiatives (presented by the EC, Wiktor Raldow , Vassilios Kougionas)
2) EU research on CO2 storage (Jonathan Pearce and Rob Arts)
3) EU research on CO2 transport (Sandrine Decarre)
4) EU research on CO2 capture and ZEP platform (Nills Rokke)
5) CCS Public acceptance (Marjolein Best-Waldhober)
6) CCS demonstration in the EU (Claudia Tomescu)
7) EERA (Giussepe Girardi)

1400 Support for Australian-European S&T collaboration (Ms Finlay)
1415 CSIRO developments and EU linkages (Dr Carras)
1420 CO2CRC developments and EU linkages (Dr Aldous)
1425 GCCSI support for EU linkages (Dr Henderson)
1430 Discussion
1500 Meeting concludes

EERA
European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 287

EUROPEAN COMMISSION
Community research

Pag. 288

Latest developments

The EU expert team met with Australian counterparts and discussed topics of mutual interest for Twinning arrangements or similar suitable for future calls of the European Framework Programmes of Research and the corresponding mechanisms for R&D support in Australia.

The following **list of topics** was extracted based on the visits and discussions and was also presented to the Australian government representatives, R&D institutes and other key CCS stakeholders headed by Ms Margaret Sewell, CEO of the Clean Energy Division of the Australian Department for Resources, Energy and Tourism (RET) in a meeting the 9th of December 2011 in Canberra.

The list represents the first iteration of topics of mutual interest and should be further discussed with the Australian counterparts especially as regards details of the headline subject.

EUROPEAN COMMISSION
Community research

Pag. 289

Topics

1) **Capture**: Third generation solvents and/or high capacity sorbents for capture of CO_2

2) **Capture**: Methods, systems and standards for measuring potential harmful emissions from CCS plants.

3) **Transport**: Integrity of large scale CCS infrastructures

4) **Storage**: Monitoring, mitigation and remediation in CO_2 storage

5) **Communication and social aspects**: Energy awareness for CCS

EUROPEAN COMMISSION
Community research

Pag. 290

Capture: **Third generation solvents and/or high capacity sorbents for capture of CO_2**

- The topic includes R&D into high potential novel systems of capture of CO_2 based on:
  1) solids or liquids or a combination of these such as enzyme based systems, bio mimicking systems or MOF's (Metal Organic Frameworks).
  2) Environmentally benign systems should be pursued.
  3) The topic relates to both post- and pre combustion capture systems.

EUROPEAN COMMISSION
Community research

Pag. 291

Capture: **Methods, systems and standards for measuring potential harmful emissions from CCS plants.**

- Amine based capture systems need to be better characterised in terms of the environmental footprint and more specifically to develop methods and standards for measuring substances of HSE (Health, Safety and Environment) concern.
- R&D should be directed towards developing such methods, testing and validation for the most used and prospective solvent types in CO_2 capture.

EERA
European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 291

EUROPEAN COMMISSION
Community research

Pag. 292

Transport: **Integrity of large scale CCS infrastructures**

- Large scale infrastructures for CO_2 will need to be operated safely and with a no-leak philosophy. Such infrastructures will include **many components that are possible sources of leaks** such as valves, flanges and seals, compressors, pumps and measuring devices.

- The R&D work should be directed towards characterisation of current practices and experiences, materials selection and characterisation and development and testing of materials and components to be used in large scale infrastructures for CO_2 transport

EERA
European Energy Research Alliance
Pag. 292
CARBON CAPTURE AND STORAGE

EUROPEAN COMMISSION
Community research

Pag. 293

Storage: **Monitoring, mitigation and remediation in CO_2 storage**

- A key element for stewardship of CO_2 storage is good methods for monitoring, mitigation and remediation. Limited work has so far been conducted on remediation methods and strategies. The R&D work should focus on the effective remediation strategies and methods and the required monitoring techniques and systems for realising this, including monitoring tools for the marine and terrestrial environment Field tests and experience from operating pilots and plants should be pursued.

EUROPEAN COMMISSION
Community research

Pag. 294

Communication and social aspects: **Energy awareness for CCS**

- There is in general a low awareness in the society for the importance of energy, it's origin, production and distribution and the implication of energy usage in terms of security, the environment and climate change.
- Energy awareness especially directed towards CCS is a topic of interest and should be directed towards understanding the perception of energy in the society, what are the barriers for improving the knowledge and designing measures to improve the general knowledge of these issues especially for CCS.
- CCS can play a powerful role in mitigation emissions of CO_2 but will not be deployed unless there is a better understanding of the facts of energy and the role different technologies must play in a carbon restrained world

EUROPEAN COMMISSION
Community research

Pag. 295

Cooperation: calls in FP7

- It should also be noted that there exist possibilities for co-operation in current open calls in FP7, notably for the two stage call which closes in it's second stage in April 2012.

- These topics include "Sizeable storage pilots" and "Impacts of impurities in CO_2 for transport and the storage complex". These calls have however not been particularly designed for EU-Australian co-operation but relevant and good quality co-operation from other countries are always welcome

EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 295

EUROPEAN COMMISSION
Community research

Pag. 296

Cooperation: EERA JP

- Other possibilities exist in the EERA joint programme for research, this is mainly outside the EU framework programmes for research but can provide a mechanism for early interaction and co-operations, see http://www.eera-set.eu/index.php?index=27

Pag. 297

ENEA and its Associates

	POST - COMB				PRE - COMB				OXY FUEL				CROSS-CUTTING ISSUES				
		solvent	sorbent	CO2 membr.		H2 mem.	sorbent	H2 turbine		oxy comb.	CLC	oxy turbine		process simul.	Bio CCS		
	total 1	1.1	1.2	1.3	**total 2**	2.1	2.2	2.3	**total 3**	3.1	3.3	3.4	**total 4**	4.1	4.2	**TOTAL**	
ENEA	10		10		50		30	20	36	18		18	27	15	12	123	?
SOTACARBO	34	30	4		0				0				12	12		46	?
UNIVERSITIES	0				0				0				0			0	
Cagliari - Dip. Ing. Meccanica - DIMECA (Prof. Cau)	0				4		4		3	3			6	6		13	Confirmed
Cagliari - Dip. Ing. Chimica (Prof. Mura)	4	4			0				0				0			4	?
Cagliari - Dip. Scienze Chimiche (Prof. Ferino)	3		3		2		2		0				0			5	?
Roma La Sapienza - Dip. Ing. Chimica Prof. De Filippis	0				0				8	8			0			8	Confirmed
Roma La Sapienza - Dip. DMA – Prof. B. Favini	0				0				6	6			0			6	Confirmed
Roma Tor Vergata - Dip. Chimica - Prof. Baciocchi	5		5		5		5		0				0			10	Confirmed
Roma TRE - Dip. DIMI – Prof. R. Camussi	0				6			6	0				0			6	Confirmed
Pisa - Dip. Ing. Chimica - Prof. Seggiani	5		5		5		5		0				0			10	Confirmed
Pisa - Dip. xxxx - Prof. Tognotti	0				0				10	10			10			20	Confirmed
Politecnico Milano - Dip. DCMIC - Proff.Faravelli, Ranzi	0				2			2	10	6		4	4		4	16	Confirmed
L'Aquila - Prof. Foscolo	0				7		7		0				7	7		14	Confirmed
Napoli Federico II- Dip. Chimica	18	8	10		0				18	6	12		0			36	?
CNR	30	10	20		0				30	18	12		0			60	?
	0				0				0				0			0	
TOTAL	109	52	57	0	81	0	53	28	121	75	24	22	66	40	16	377	
ENEA – UTTEI-COMSO main contacts		Deiana	Stendardo				Stendardo	Cecere		Giacomazzi		Giacomazzi		Stendardo			
Activity Status										STARTED							

Pag. 297

Pag. 298

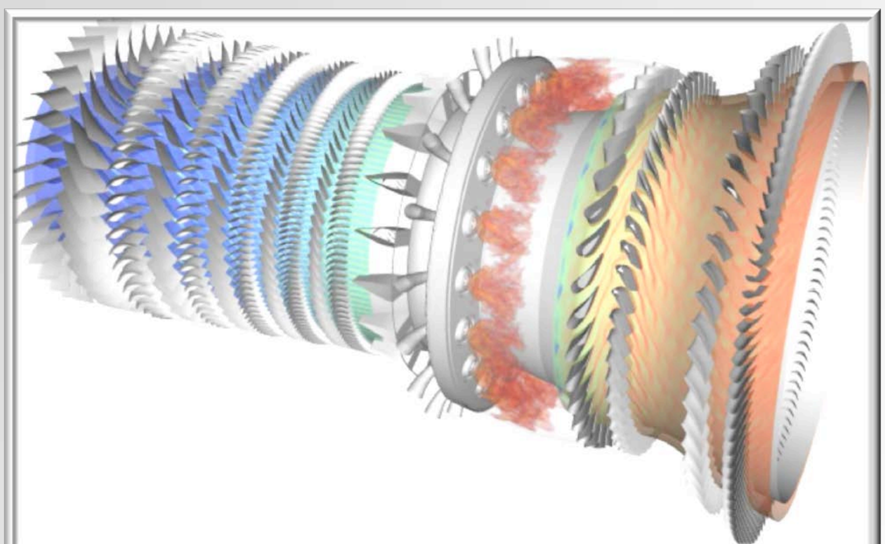
Sustainable Combustion Laboratory

ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Combustion Instabilities in GTs

Eugenio Giacomazzi

ENEA, Sustainable Combustion Laboratory (UTTEI-COMSO),
Unit of Advanced Technologies for Energy and Industry
C.R. Casaccia, Rome, ITALY



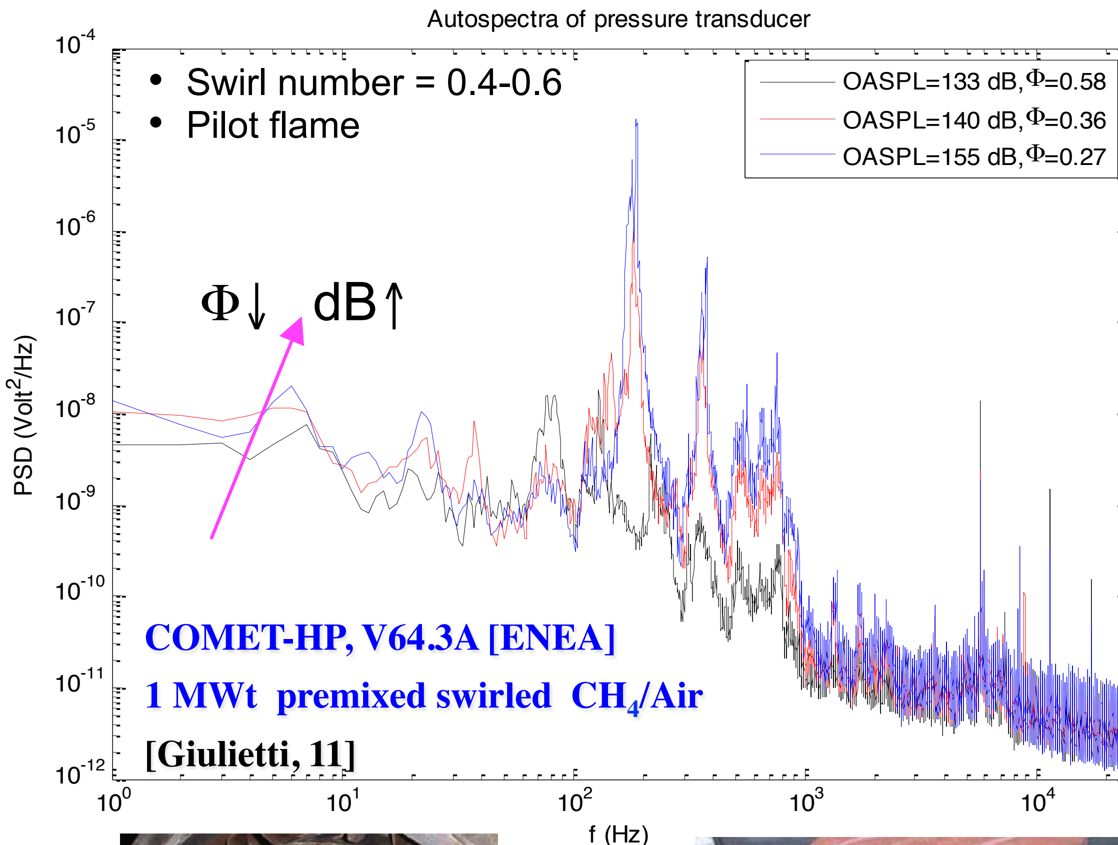
Pag. 298

Lean Premixed Combustion and Its Drawbacks

Pag. 299

- In fact, **Lean-PreMixed** (**LPM**) and **Lean-Premixed-Prevaporized** (**LPP**) **combustion** are the **state-of-the-art technologies** in stationary gas turbines for highly efficient low emission power generation.

- Drawbacks: noisy **large amplitude pressure fluctuations** (>5-10% of the mean chamber pressure), known as thermo-acoustic or "operational" combustion instabilities. They
  - may interfere with engine operation (**flashback** and **Lean Blow Out**);
  - drive **vibrations** in mechanical components;
  - and more dangerously lead to **failure** of the system due to cyclic mechanical and thermal loads to the walls and turbine blades.



Pag. 299

Combustion Instabilities: an Issue in the Next Future

Pag. 300

- Combustion instability in LPM GTs NOT CURRENTLY recognized as a priority. But, …

- Interest in alternative fuels like syngas, biomass, liquefied natural gas, shale gas.

- More renewables in the electricity grid.

Hydrogen "blends"

- CCS technologies as the most challenging answers to limit CO_2 emissions.
- Power2Gas concept as an ideal way to store excess electricity from renewables.

Wind Turbines

- Unpredictable change in the wind intensity makes the supplied power fluctuating.
- Use GTs **load-flexibility** to compensate.
- Loading / unloading phases MUST be fast, stable and with low emissions level.

- H_2 enhances flame stability: designers will tend to use leaner mixtures.
- "H_2 blends" have LHV lower than NG: designers will increase fuel mass flow rate to obtain a certain power.

- Lack of a "gas quality harmonization" code: undesired and uncontrolled fuel composition changes (**fuel-flexibility**).

- Enhancement of flame dynamics with respect to NG.
- But acceptable operation of GTs requires "weak" dynamics.

Pag. 300

ETN Position Paper

Pag. 301

- ETN is going to submit a Position Paper on *combustion instabilities* to the **E**uropean **C**ommunity to pose attention on their *dynamics, monitoring and control in gas turbines*.

"Thermo-Acoustic Instabilities in a Load- and Fuel- Flexible, CCS Enabled Gas Turbine Market"

- Authors:

From Research	: Eugenio Giacomazzi	[ENEA, Italy]
From Research	: Wolfgang Meier	[DLR, Germany]
From Producers	: Sergio Rizzo	[ANSALDO Energia, Italy]

- Reviewers:

From Users	: David Abbott	[E.ON, United Kingdom]
From Research	: Rob J.M. Bastiaans	[TU/e, The Netherlands]
From OEMs (sensors)	: Alex Winterburn	[OXSENSIS, United Kingdom]
From Research / Users	: Hannes Laget	[GdF Suez / Laborelec, Belgium]

Pag. 301

CO_2 is **an opportunity for process industry being an useful raw material (carbon source) to produce different type of compounds**:

- **Plastics** (CO_2-containing polymers, in alternative to those derived from fossil fuels), which may thus be produced by more sustainable processes.
- **Chemical** (to decrease the carbon-footprint of the chemical industry), **both base chemicals and products with high added value (fine chemicals)**.
- **Fuels** (methanol, methane and others), to enter a market where global demand is strong and growing.
- **Raw materials for the construction industry**, **such as inorganic carbonates**, which can also be produced from industrial waste materials, contributing to their reuse as an alternative to disposal.

Although it is often observed that the market for chemicals is small with respect to the size of the CO_2 emission,

For these reasons, **the use of CO_2 is one of the central issues of the roadmap of the PPP (Public Private Partnership) SPIRE (Sustainable Process Industry and Energy for Resource Efficiency)** and will be among the key issues present in the new Framework Program of the European Community (Horizon 2020) which will start in 2013.

The interest in the **use of CO_2 is also growing as a system for energy storage to mitigate fluctuations in the production of renewable energy as well as to store the energy produced in excess with respect to that possible to introduced in the grid, for example the electrical energy produced by wind during night**.

The main possible alternatives of conversion of CO_2 by catalytic technologies are the following:
(i) **methane** (which can be introduced in the natural gas distribution grid),
(ii) **methanol** (for easy storage / transportation in liquid form) and
(iii) **formic acid** (as a reversible method for storage / transport of H_2 in a liquid form).

It may be thus outlined a **roadmap**, which
(i) in the short term is based on processes using CO_2 which are already close to be commercial (production of CO_2-based polymers, and conversion of CO_2 as a way to use surplus electrical energy or available in remote areas from where it is not possible to transport through the grid),

(ii) in the medium term is based on the production of fuels such as methane, methanol etc. and base chemicals (light olefins) to make more efficient the introduction of renewable energy in the process industry and to optimize the renewable energy production net, and

(iii) in the long term is moving towards a decentralized energy system, first through the introduction of reverse fuel cell using directly CO_2 (or integrated solar cells to produce H_2) to arrive finally to the fully integrated devices ("artificial leaves", eg. artificial photosynthesis).

EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

CO_2 capture and storage (CCS)

Version: *2.1*
Last modification date: *January 7, 2011*
Contact person: *Andreas Ehinger – andreas.ehinger@ifpenergiesnouvelles.fr*

Page intentionally left blank

SUMMARY OF THE JOINT PROGRAMME ON CCS

The Carbon Capture and Storage Joint Programme (CCS-JP) involves over 30 members from more than 12 countries who have committed more than 270 person years /year to carry out joint R&D activities.

The CCS-JP is completely dedicated to reaching the objectives that the international community has identified as necessary enablers for large scale deployment of CCS and thus for holding its promise to contribute a very significant part to the required world-wide CO_2 emissions reduction :

- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ confidence in storage technologies, based on subsurface knowledge and understanding;

The program is thus structured in two sub-programmes corresponding to the two mayor steps in the CCS chain: CO_2 capture and CO_2 storage. In the future, and depending on the dynamics of the programme, it is expected that other research themes, e.g. CO_2 transport, may become part of the programme.

In CO_2 capture, collaborative R&D will take place on pre- and post-combustion capture as well as on oxyfuel capture. Technologies that will be investigated include CO_2 solvents and sorbents, polymeric, metallic and ceramic membranes, solid looping processes, and advanced gas turbines. Also several cross-cutting issues will be addressed. These include integration of CO_2 capture in power plants, CCS in industry and Bio CCS.
The general objectives of the CO_2 capture sub-programme are to:

- develop more energy efficient and more cost efficient CO_2 capture technologies with a low environmental impact.
- develop more efficient designs for integration of CO_2 capture technologies in new and existing power plants and other industrial facilities (steel, cement, refineries, biofuels production, etc.).

In CO_2 storage, the R&D activity will focus on static and dynamic modelling of the subsurface and its interaction with injected CO_2 and on associated monitoring methods. The general objective of this programme is to produce significant advancements on the issues that are recognised as key elements for a safe and wide deployment of geological CO_2 storage:

- identification and characterization of suitable geologic complexes that may be used for storing CO_2, with no interference with other human activities, no impact on the ecosystem, having capacities that match the sources and that guarantee safe conditions for the whole period of storage operations, closure and post closure;
- development of tools that allow better understanding and evaluation of the behaviour at different time scales of the injected CO_2 and its interactions with the storage complex and the surrounding formations up to the surface;
- further development and integration of a large set of currently-available monitoring techniques and the definition of recognised protocols for their use in a variety of geological, environmental and operative contexts.

The CCS-JP management will be particularly attentive to efficient interfacing with other initiatives in the field of CCS research, in particular the ZEP technology platform, the CCS-EII, the ESFRI-listed ECCSEL project, etc. It will also seek contact with the European Commission and with Member States in order to streamline R&D priorities.

Page intentionally left blank

Contents

Page intentionally left blank

1. Background

CO_2 capture and storage (CCS) is potentially one of the major technology solutions for reducing man made greenhouse gas emissions. The important role that can be played by CCS in the battle against climate change has been recognized by many international bodies like the International Energy Agency, the Carbon Sequestration Leadership Forum or the Global Carbon Capture and Storage Institute. In its latest documents, the International Energy Agency estimates that CCS could contribute as much as 20% of the total emissions reduction required by 2050 in order to maintain global warming below 2°C. Quite naturally, CCS is thus one of the key technologies mentioned in the Strategic Energy Technologies (SET) Plan that the European Commission has published in 2008.

In Europe, the European Commission has actively supported CCS research since the 1990s through its R&D framework programs. Furthermore, in 2005, European CCS RD&D got a large impulse through the launch of the European Technology Platform on Zero Emission Fossil Fuels Power Plants (ETP-ZEP). This platform brings together stakeholders from industry, public R&D and NGOs and is very active in all aspects related to CCS. Concerning R&D, ZEP has published in September 2006 a Strategic Research Agenda and in 2009 its "Recommendations for research within EU and national programs in support of deployment of CCS in Europe beyond 2020".

During the last years, CCS research has already achieved significant progress permitting today to conceive, build and run first large scale CCS pilot and demonstration projects. The first six European projects, funded by the European Economic Recovery package, cooperate within the framework of the CCS project network set up by the European Commission, and the European Industrial Initiative (EII) launched in June 2010 is dedicated to setting up a complete, comprehensive CCS demonstration program.

However, for economic reasons, the currently available technologies used for the first demonstration plants will not allow the large scale deployment of CCS and we will thus fall behind the exploitation of the full potential contribution of CCS in the climate change battle. Moreover, the public acceptance of CO_2 storage has still to be gained. We need thus to intensify the R&D activities in order to develop

- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ public confidence in storage technologies, based on subsurface knowledge and understanding.

While a number of collaborative R&D projects are on-going in Europe, both in the framework of FP7 funding and national funding, the advent of EERA will allow the main public R&D organisations active in this area to further intensify their cooperation. Indeed, the overarching objectives of the EERA CCS Joint Programme (CCS-JP) are to ensure that short, medium and long term R&D challenges are recognized, translated into R&D programs and met through the joint execution of R&D projects by the CCS-JP members. Industry relevance of this research will be guaranteed by a close coordination both with the ZEP platform and with the EII on CCS.

In order to maximize the added value of cooperative research, the CCS-JP will also be very attentive to interfacing with existing and future bodies and activities, like for example the CO_2GeoNet association in the field of geological storage of CO_2 or the ESFRI-labelled ECCSEL project aiming at setting up a pan-European research infrastructure for CCS.

2. Value added

The EERA Joint Programme on Carbon Capture and Storage provides added value through the enhanced coordination and cooperation of the activities of the major European R&D players in CCS.

Strategic leadership

Strategic leadership builds upon a vision of the future and of the transition pathways to reach that future. Bringing together the major European R&D players in a Joint Programme will allow to share individual visions and to gradually build a common one, providing true strategic leadership on a global scale. Communication, information exchange, mutual understanding, trust building, through meetings and effective collaborations, in the framework of an efficient governance, and strongly interfaced with industrial and other players, will be key for reaching this goal.

Speeding up the realization of SET-plan goals

The SET-Plan aims at accelerating the development and deployment of new energy technologies in response to the climate change challenge. Joint R&D planning and programming, knowledge sharing, grouping of resources, joint execution of R&D projects are the means to achieve this acceleration. The CCS-JP is completely focused on the efficient implementation of these means: organisation of meetings and workshops, elaboration of shared program documents, joint execution of projects, coordination with other initiatives.

The CCS-JP will also contribute to the acceleration of the realisation of the SET-Plan goals through its role as an open alliance bringing together all relevant R&D players. Indeed, there exists a number of European structures dedicated to CCS research, with restricted memberships, and the coordination between those structures will be facilitated as all the involved actors will meet, exchange and cooperate in the framework of the CCS-JP.

3. Objectives

The massive deployment of CCS after 2020 requires that three essential points will have been achieved until then:

- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ confidence in storage technologies, based on subsurface knowledge and understanding;
- ✓ first successful demonstrations of the full CCS chain, including capture, transport and storage

The latter point is currently being addressed in the recently awarded CCS demonstration projects under the EU Economic Recovery Program and will be further pursued by the European Industrial Initiative on CCS. The EERA CCS-JP aims at the first two points.

<u>CO_2 Capture</u>
Several capture technologies are currently being investigates. It is important to continue the investigation of all of them since none of them has emerged yet as superior to the others. Moreover, the different technologies do not cover necessarily the same time horizons, in other words the short/medium term improvements of known technologies have to be researched simultaneously with the next generation, medium/long term technologies.

The main R&D objectives in the area of CO_2 capture are

- ✓ improved CO_2 separation technologies (solvents, sorbents, membranes);
- ✓ improved fuel firing systems (hydrogen gas turbines, oxy-boilers);
- ✓ new processes (carbonate cycles, chemical looping combustion).

Pag. 311

CO_2 storage

Safe CO_2 storage requires good knowledge of the subsurface conditions and of the dynamic interaction of injected CO_2 with the subsurface environment. The basic approach for achieving this aim is the coupling of predictive modelling with experimental observation.

The main R&D objectives in the area of CO_2 storage are

- ✓ improved capacity to characterize the subsurface;
- ✓ improved methods for predicting the fate of injected CO_2;
- ✓ enhanced capabilities to monitor all components of the CO_2 storage complex.

4. Description of foreseen activities

General program activities

A number of general program activities will be performed to make the CCS-JP become a reality. In particular, the CCS-JP will

- set up a mechanism to identify and to include under the CCS-JP umbrella ongoing and new projects performed by CCS-JP members, including those funded under FP7
- help CCS-JP members to discuss common R&D interests and to prepare joint projects (funded by external sources or by own resources), e.g. through the organisation of topical workshops
- establish relationships with the European Commission and with Members States, in particular in the context of future financial support
- formalize links with different organisations / structures in Europe in order to insure coordination and overall coherence of European R&D activities in the field of CCS:
  - EIT/KICs (InnoEnergy and Climate)
  - Zero Emissions Platform ZEP
  - European industrial initiative EII-CSS
  - Pan-European CCS infrastructure project ECCSEL
  - Association of CO_2 storage R&D organisations CO_2GeoNet
  - ...
- establish contacts with other EERA JPs that may have some intersection with the CCS-JP, e.g.
  - Biomass JP - CO_2 capture by algae
  - Biomass JP – use of biochar as CO_2 capture and storage option
  - Geothermal Energy JP – coupling of CO_2 geological storage and geothermal energy recovery
  - Basic science for energy

R&D activities in the sub-programmes

The EERA CCS Joint Programme is currently organized into two sub-programmes:

- CO_2 capture
- CO_2 storage

This "natural" structuring has been adopted for the time being and will allow efficient management of the JP activities. In the future, new sub-programmes may be added (e.g. a sub-programme on CO_2 transport) or the two existing sub-programmes may be split in view of the volume of activities. The guiding ideas for the structuring of the JP into sub-programmes are and will be thematic coherence and organisational efficiency. Interfacing between sub-programmes will be achieved in a general way at JP meetings (e.g. executive board meeting) or in a detailed way by inter-project cooperation or, in some cases, by cross-sub-programme projects.

Pag. 311

It has to be noted that this first description of work (DoW) of the EERA CCS-JP does not pretend to be a comprehensive document covering all R&D aspects related to CCS. It is rather a document presenting a first set of identifies subjects the program members wish to work on in a collaborative way. Thus the DoW of the CCS-JP is expected to evolve over time to include more subjects.

The two sub-programmes are structures into several R&D areas. For each area the program members have identified key objectives and they have defined dedicated work packages in order to further structure the R&D activity. Below is a summary of these objectives and work packages; for more details, please refer to the sub-programme descriptions (Annexes of this document).

CO_2 Capture sub-programme

The Sub-programme on CO_2 capture is broken down in four areas with specific objectives and work program structures.

- **Post-combustion CO_2 capture**
  - Objectives
    - Develop second generation solvent systems and processes with improved performance (energy requirement, costs, environmental impact) compared to the first generation solvent systems and processes.
    - Develop proper control schemes and improved online analysers for large scale integrated capture facilities.
    - Develop improved methods for avoidance of emission of species (amines, degradation and by-products), which could be harmful to the environment
    - Investigate and develop solid sorbents and carbonate looping cycles for more efficient post-combustion capture.
    - Development of polymeric and ceramic membranes with improved separation properties
    - Developing advanced techniques for monitoring and abatements of CO_2 contaminants as NOx, hydrocarbons, and particulate for allowing efficient and safe CO_2 capture.
  - The Work program is structured around the three main technologies for post combustion capture:
    - CO_2 solvent systems
    - CO_2 sorbent systems
    - CO_2 selective membranes

- **Pre-combustion CO_2 capture**
  - Objectives
    - Development of high-temperature membrane materials, membrane modules, and membrane reactors, testing them at realistic conditions and designing schemes for integration of membrane systems in power plants.
    - Development of high-capacity CO_2 sorbents for combined CO_2 and sulphur removal, for sorption-enhanced reforming and sorption-enhanced water-gas shift. Designing schemes for integration of sorption systems in power plants.
    - Investigate and develop hydrogen-fired gas turbines, including CFD models, and the use of membranes in the combustion chamber.
  - The Work program addresses separation methods (membranes, sorbents) as well as dedicated gas turbine technology:
    - Hydrogen selective membranes
    - CO_2 sorbent systems
    - Hydrogen fired gas turbines

- **Oxyfuel CO_2 capture**
  - Objectives

- Study the implication of using pure oxygen in coal combustion in boilers and fluidized beds, develop CFD models, and investigate CO_2 purification.
- Develop mixed ionic electronic conducting materials and thin film membranes for O2/N2 separation
- Develop chemical looping combustion technology: design reactors, develop oxygen carriers for both gaseous and solid fuels.
- Investigate and develop oxyfuel gas turbines, including CFD models

▪ The Work program comprises 4 work packages:
  - Oxy-combustion
  - Oxygen selective membranes
  - Chemical looping combustion
  - Oxyfuel gas turbines

➢ **Cross-cutting issues**

▪ Objectives
  - Define common starting points and boundary conditions for modelling and economic evaluation of all the technologies to be used in the CO_2 capture sub-programme.
  - Developing proper steady state and dynamic models of CO_2 capture installations integrated in power plants and compare technologies on an equal basis. Study the possibilities for CO_2 capture technologies in biomass conversion schemes, such as the production of biofuels, aiming to achieve negative CO_2 emissions.
  - Investigate the possibilities and technological challenges for CO_2 capture in non-power applications like the steel, chemical and cement industries and refineries.

▪ The Work program is composed as follows:
  - Benchmarking, process simulation, and economic evaluation
  - Bio CCS
  - CO_2 capture from other sources

<u>CO_2 Storage sub-programme</u>

The Sub-programme on CO_2 geological storage is broken down in three areas with specific objectives and work program structures.

➢ **Monitoring**

▪ Objectives
  - Developing passive, long-term monitoring techniques (these may include autonomous active techniques, such as ERT or seismic measurements with permanent source-receiver deployment...).
  - Establishing or improving methods to detect and quantify CO_2 in different parts of the storage complex.
  - Preparing for a field test of a suite of monitoring techniques.
  - Developing a method for constructing monitoring scenarios (monitoring plans).

▪ The Work program comprises three work packages with respect to the sub-systems to be monitored and one work package dedicated to the monitoring-modelling integration:
  - Surface and near-surface
  - Reservoir and overburden
  - Wellbore system
  - Integrated closed-loop monitoring and modelling

➢ **Static modelling**

▪ Objectives
  - Further defining reservoir and cap-rock characteristics that are relevant to injectivity, capacity and storage integrity.
  - Providing means for predicting spatial characteristics of the reservoir and storage complex, while assessing their uncertainties.

  - Defining a robust storage potential assessment methodology.
- The Work program comprises five work packages:
  - Geological structure of the storage complex
  - Petrophysical, geomechanical and geochemical characteristics of the storage complex
  - Storage potential estimation
  - Uncertainties management
  - Alternative geological storage solutions

➢ **Dynamic modelling**
- Objectives
  - improve and certify dynamic modelling approaches
  - enable large scale, coupled modelling
- The Work program is structured in three work packages:
  - Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches
  - Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling
  - Workflow design methodology and validation.

5. Milestones

The milestones for CO_2 capture and CO_2 storage are directly taken from the corresponding sub-programmes. Please refer to those programmes in the Annexes for details.

Milestone	Title	Month
General program activities		
M 1	Mechanism for including externally funded projects under EERA umbrella	12
M 2	First Steering Committee meeting	10
Capture sub-programme		
M1.1	Common criteria defined for comparing solvent systems. Document describing comparison criteria based on capture efficiency, energy consumption, environmental impact, costs, operational challenges, etc.	12
M1.2	Short list of second generation solvents available. List of solvent names and class of solvent to be tested in pilot plant evaluated against common criteria	24
M1.3	Dynamic model in place. Model (or models) that is suitable to be used in developing control schemes is running and described in a document	24
M1.4	Common criteria defined for comparing sorbent systems for the three different applications. Document describing comparison criteria based on capture efficiency, energy consumption,etc. evaluated against solvents as a benchmark	12
M1.5	Short list of second generation sorbents available, evaluated against common criteria. Computational screening tools available to allow systematic screening of a wide variety of available materials and estimation of effects on plant performance of sorbent properties improvements.	24
M1.6	Test reporting CO_2 selective membrane with a CO_2 permeance of 5 $Nm^3/(h\ m^2\ bar)$ and a CO_2/N_2 selectivity higher than 60 at 20°C	18
M1.7	Design concept of high capacity membrane module available.	24
M2.1	Selected membranes for bench scale test and as the basis of module design, that have been scaled up to at least 25 $cm^2$and tested in relevant conditions in presence of H_2S or at high temperature	24

Milestone	Title	Month
M2.2	Results of lab-scale testing of microporous and proton conducting membranes available. Decision whether these types show enough promise for CCS application to make the step to bench scale testing	24
M2.3	Common criteria defined for comparing high-temperature sorbent systems. Document describing comparison criteria based on capture efficiency, energy consumption, etc. evaluated against physical solvents as a benchmark (Month 12)	12
M2.4	Short list of novel sorbents for CO_2 and H_2S separation and for SEWGS and SER based on common criteria available	24
M2.5	Numerical model in place for the design of efficient high-temperature PSA and TSA cycles	24
M2.6	Results of experiments on flammability limits, ignition, etc. available as input for CFD modelling	24
M3.1	Advanced physical sub models implemented and validated relating to pollutant emission, combustion and radiation within commercial CFD code	24
M3.2	Initial results obtained of 3D flame imaging, coal ash, and boiler material behaviour under oxycoal combustion conditions	12
M3.3	Process simulation models constructed for Oxy-coal boiler and oxy-CFB plant optimisations including linking CFD code with process simulation as a part of virtual power system simulation	24
M3.4	Decision on most viable integration options for membranes in a power plant	12
M3.5	Selected membranes for 2000 h test and as the basis of module design, that have been upscaled to at least 25 cm^2	24
M3.6	Common criteria defined for comparing oxygen carriers, based on integration studies of CLC in power plants and materials properties	12
M3.7	Short list of novel oxygen carriers based on evaluation against common criteria and results of labscale testes available. Selection of novel oxygen carriers to be tested in large-scale test installations	24
M4.1	Agree with the EBTF on expansion of the work into EERA	12
M4.2	Consistent set of economic performance measures for use in the other SPs	12
M4.3	Identification of a first set of CCS technologies for use in Bioenergy processes that will be studied in more detail. Based on an inventory of bioenergy and CCS options.	24
M4.4	Select the most feasible capture technologies for more detailed analysis based on an overview of industrial CO_2 sources and possible capture technologies for those sources.	18
Storage sub-programme		
M 1.1.1	Deploy a benthic chamber to measure the baseline in terms of fluxes and isotopes at several locations	12, 24
M 1.1.2	Deploy areal and point measurements at natural analogues (sites where CO_2 is leaking naturally)	24
M 1.1.3	Establish a preliminary list of damages to the environment, as a result of CO_2 leaking from the storage reservoir to the environment	12, 24
M 1.1.4	Develop and validate remote sensing monitoring methods to detect the impact of CO_2 leakage at natural analogue sites, over wide areas	12, 24
M 1.2.1	Develop or test new methods of processing seismic data to image and quantify CO_2 in the reservoir	12, 24
M 1.2.2	Exchange with the EERA program on Geothermal Energy on induced seismicity	12
M 1.2.3	Deploy passive seismic instruments over an active storage site	24
M 1.3.1	Perform and analyse the results of long-term (>5 years) laboratory experiments on the effect of CO_2 on casing and cement	24
M 1.3.2	Measure the integrity of wells at active injection sites	24
M 1.3.3	Assess the feasibility of permanent downhole geochemical tools	24
M 1.4.1	Create an inventory of current guidelines for the design of monitoring plans	12

Milestone	Title	Month
M 1.4.2	Participate in a field test of CO_2 leakage	24
M 1.4.3	Link with SP2 and SP3 to establish modelling uncertainties, and define methods to assess uncertainties in monitoring data	12, 24
M 2.1.1	Identify problems and pitfalls on reservoir characterisation from real situations experience	24
M 2.1.2	Compilation of existing CO_2 experience on fractures and faults	24
M 2.1.3	Assess methods and workflows from other industries to evaluate fractures and faults and its applicability to CO_2 storage	24
M 2.1.4	Evaluation of existing experience and data on EU borehole leakage	24
M 2.1.5	Develop stochastic methods to characterise fractures and faults and their connectivity in the storage complex	12
M 2.2.1	Defining the achievable inputs from petrophysical, geomechanical and geochemical features to SP3 – Dynamic modelling	24
M 2.2.2	Review the existing models to describe petrophysical parameter variation and heterogeneity	24
M 2.3.1	Compare existing approaches for application of storage efficiency factor	24
M 2.3.2	Compile existing engineering techniques for pressure limitation management	24
M 2.3.3	Agree on a standardized methodology for Atlas calculations	24
M 2.4.1	Define a list of scenarios to address routinely in CO_2 storage	24
M 2.4.2	Develop stochastic methods to consider matrix properties and fracture distribution uncertainty in static models	12
M 2.5.1	Organize a workshop with players working for other geological solutions	24
M 2.5.2	State of the art of the research conducted in alternative storage solutions	24
M 2.5.3	Identify the EU regions where such alternatives may be appropriate	24
M 3.1.1	First thermodynamic database for reservoir mineralogy	24
M 3.1.2	Porosity/permeability constitutive laws for pure CO_2	24
M 3.1.3	Comparison results of injectivity studies	24
M 3.2.1	Simplify model to study leakage system	24
M 3.2.2	Diffusion/dissolution up scaling	24
M 3.2.3	Comparative assessment of input data and modelling uncertainty	24
M 3.3.1	Benchmark on reactive transport	24

6. Participants and Human Resources

Membership to the CCS-JP is to be formalized by signing a general "EERA Declaration of support" and a CCS-JP specific "Letter of intent". As of today, no such signatures have been requested from the organisations that have contributed to the elaboration of the programme. Thus, the below "membership" statistics and tables refer to those organisations that have committed themselves informally during the process of writing this document.

General structure of membership and human resources commitment (in person years / year (py/y)):

Total number of JP members	34
Number of participants	24
Number of named associates (some participants have already consolidated their numbers with those of some non-named associates)	10
Number of members in capture sub-programme	19
Number of members in storage sub-programme	23
Number of members present in both sub-programmes	8
Total human resource commitment (py/y)	275
Human resources committed to capture sub-programme (py/y)	167
Human resources committed to storage sub-programme (py/y)	108

The following table lists the members of the CCS-JP, their role in the programme and their human resources commitment. Details (including contact information) can be found in the sub-programme descriptions.

Name	Country	Role	Sub-programme		Human Resources committed (py/y)
BGS	UK	Participant		Storage	6,6
BRGM	France	Participant		Storage	10,0
CSIC	Spain	Participant	Capture		5,0
ECN	Netherlands	SP coordinator	Capture		8,5
EMEPC	Portugal	Associate		Storage	1,0
ENEA/CNR	Italy	Participant	Capture		33,6
ETHZ	Switzerland	Participant	Capture	Storage	7,5
FZJ	Germany	Participant	Capture		18,6
GEUS	Denmark	Associate		Storage	3,5
GFZ	Germany	Associate		Storage	1,5
HZG	Germany	Associate	Capture		3,3
IFE	Norway	Associate	Capture		0,5
IFP Energies nouvelles	France	JP coordinator	Capture	Storage	8,9
Imperial College / MERG	UK	Participant		Storage	9,0
IRIS	Norway	Associate		Storage	2,5
KIT	Germany	Participant		Storage	7,8
LNEG	Portugal	Participant	Capture	Storage	11,0
NIVA	Norway	Associate		Storage	1,0
OGS	Italy	SP coordinator (Interim)		Storage	6,5
POLIMI	Italy	Participant	Capture		5,5
PSI	Switzerland	Participant	Capture		7,6
RC Rez	Czech Republic	Participant	Capture	Storage	9,0
RISO/DTU	Denmark	Participant	Capture		6,5
RSE	Italy	Participant	Capture	Storage	16,0
SCCS	UK	Participant		Storage	7,5
SINTEF	Norway	Participant	Capture	Storage	8,3
TNO	Netherlands	Participant	Capture	Storage	6,8
UKCCSC	UK	Participant	Capture		28,6
U Bristol	UK	Associate		Storage	3,0
U Evora	Portugal	Participant		Storage	7,1
U Nottingham	UK	Associate		Storage	2,5
U Rome	Italy	Associate		Storage	3,5
VITO	Belgium	Participant	Capture	Storage	9,2
VTT	Finland	Participant	Capture		7,8
TOTAL HUMAN RESSOURCES COMMITMENT (py/y)					**275,2**

7. Infrastructures and facilities

Most of the programme members have at their disposal R&D infrastructures that they will use for the purpose of the programme. These infrastructures are described in the corresponding sub-programmes.

The investigation of the possibilities for putting in place a joint European CCS research infrastructure is the purpose of the upcoming ECCSEL project. ECCSEL, the European Carbon Dioxide Capture and Storage Laboratory, is part of the ESFRI roadmap and has recently been the subject of an FP7 call concerning a so-called Preparatory Phase Project (PPP). This project, expected to run from 2011 to 2013, has as objective to design ECCSEL in all its aspects, including technical (which infrastructures will make up ECCSEL?), contractual (who will have access under which conditions?) and financial (who will pay?) issues. The ECCSEL PPP is headed by Trondheim University (NTNU) and it involves all major European CCS R&D organisations and in particular those present in the CCS-JP. Thus there is an automatic, inherent connection between the CCS-JP and ECCSEL through the presence of the same actors in both structures. In addition, a more formal relationship will be established between the CCS-JP and ECCSEL.

In summary, the CCS-JP will not work on the subject of infrastructure sharing but will seek a close integration of ECCSEL and the CCS-JP, e.g. in the sense that CCS-JP projects will be able to use ECCSEL infrastructures.

8. Management of the Joint Programme

Interaction with existing and emerging initiatives

In the field of carbon capture and storage there exists a wide variety of initiatives, organisations and structures. The EERA CCS-JP will establish close contacts with the most prominent ones:

- Zero Emissions Technology Platform (ZEP), in particular with the Technology Task Force of the ZEP
- European Industrial Initiative on CCS
- CO_2GeoNet – Association of European R&D centres in the field of CO_2 geological storage
- ECCSEL –European ESFRI infrastructure in CCS

Furthermore, contacts will be established with the two EIT/KICs working on CCS, the InnoEnergy KIC and the Climate KIC.

Interaction between the CCS-JP and the other initiatives will consist in formal and informal meetings and in reciprocal participation as observers in governance structures. The short term objective of the interaction will be to make sure that information on strategic work (e.g. roadmaps) and on R&D activities flows seamlessly between the different initiatives.

EERA internal communication will be established with those JPs that might have some intersection with the CCS-JP (Biomass, Geothermal Energy, Basic science for energy).

Governance structure

The EERA CCS Joint Programme is currently organized into two sub-programmes, CO_2 capture and CO_2 storage. This "natural" structuring has been adopted for the time being and will allow efficient management of the JP activities. In the future, new sub-programmes may be added (e.g. a sub-programme on CO_2 transport) or the two existing sub-programmes may be split in view of the volume of activities. The guiding principles for the structuring of the JP into sub-programmes are and will be thematic coherence and organisational efficiency.

The governance structure of the CCS-JP is set-up following the relevant EERA guideline.

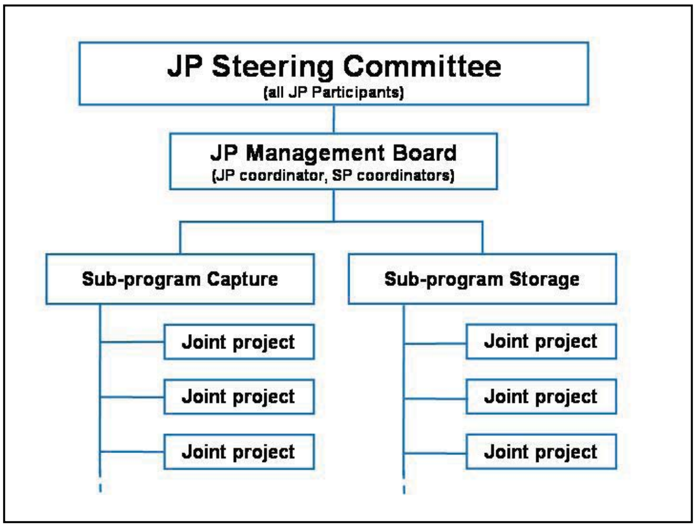
JP membership

Publicly funded R&D organisations or private companies recognized as R&D organisations by the European Commission can joint the program as ***participants*** if they commit more than 5 person years/year (py/y) to the program. Other organisations or those committing less than 5 py/y to the program can join as ***associates***. The contributions of an associate, both in terms of human resources and R&D work, are consolidated with those of the participant that the

associates has chosen. Several small members may associate and name one of them as representative, becoming a program participant if the consolidated contribution surpasses 5 py/y.
JP membership (either as participant or as associate) is formalized by signing a general "EERA letter of support" and a program specific "letter of intent".

JP Steering Committee
The JP Steering Committee is composed of one representative of each JP participant. The JP Steering Committee

- selects the Joint Programme Coordinator
- selects the Sub-programme coordinators
- reviews the progress and achievements of the JP
- provides strategic guidance to the management board
- approves new JP members (participants or associates)
- approves updates of the Description of Work of the JP.



The JP Steering Committee is chaired by the JP Coordinator; the sub-programme coordinators participate as observers in the Committee. It convenes twice a year.
The JP coordinator and the sub-programme coordinators cannot act as representatives of their respective R&D organisation in the Steering Committee.

JP Management Board
The JP Management Board is the executive body of the JP and is composed of the JP Coordinator (chair) and the sub-programme coordinators.
Tasks and responsibilities:

- Financial management of the JP budget (if applicable)
- Contractual oversight
- IP (intellectual property) oversight
- Scientific co-ordination, progress control, planning on programme and sub-programme level
- JP internal communication
- External communication with other organisations (European Commission, ZEP, EII, ...)
- Reporting to Steering Committee and EERA ExCo

The JP Management board meets four times a year.

Sub-programme execution team
The Sub-programme execution team is the coordinating body on the sub-programme level. It is composed of the sub-programme coordinator (chair) and the leaders of the projects within the sub-programme. It meets on request.

JP Coordinator
The JP Coordinator (JPC) is selected by the JP steering committee for a mandate of two years. The mandate can be renewed. The JPC chairs the Steering Committee and the Management Board.
Tasks and responsibilities

- Co-ordination of the scientific activities in the joint programme and communication with the EERA ExCo and the EERA secretariat.
- Monitoring progress in achieving the sub-programmes deliverables and milestones.
- Reporting scientific progress and unexpected developments to the EERA ExCo.
- Propose and coordinate scientific sub-programmes for the joint programme.
- Coordinate the overall planning process and progress reporting.

Sub-programme coordinator

The Sub-programme coordinators are selected by the JP steering committee for a mandate of two years. The mandate can be renewed. The sub-programme coordinator takes part in Steering Committee meetings, is a member of the management board and chairs the sub-programme execution team.

Tasks and responsibilities

- Oversee the sub-programme projects
- Co-ordination of the scientific activities in the sub-programme to be carried out by the participants according to the agreed commitment. The SPC communicates with the contact persons to be assigned by each participant.
- Monitoring progress in achieving the sub-programmes deliverables and milestones.
- Reporting progress to joint programme coordinator
- Propose and coordinate scientific actions for the sub-programme
- Monitor scientific progress and report unexpected developments

Project leaders

The joint activities will be performed in the form of projects that are expected to be set-up in variable configurations (in terms of project members) and in the framework of project specific contracts. The project leaders are responsible for the execution of their projects; they are members of the sub-programme execution team.

9. Risks

The most important risk concerns the effective set-up of joint R&D activities (i.e. projects). This will in general require the detailed definition of a work program, a consortium and a legal contract. If the EERA project is to be proposed for external funding (e.g. FP7) the corresponding procedures and rules commonly used by the programme members will be applied. However, in the case of a non-externally-funded activity there exists a risk concerning the effective engagement of the actors. It will be the task of the JP coordinator and the sub-programme coordinators to minimize this risk.

10. Intellectual Property Rights

It is expected that the projects, e.g. the R&D work performed by the program, will be subject to individual project contracts (consortium agreement). This implies that the CCS-JP members freely decide on the composition of any given project consortium. So, while the CCS-JP is open to all R&D organisations provided they commit themselves to a substantial contribution to the program, any given project will be run as a consortium with its agreed-on mechanisms for including new members. Concerning IPR, it is expected that the projects follow the EERA IPR policy.

11. Contact Point

Andreas Ehinger
IFP Energies nouvelles
1&4 avenue de Bois-Préau
92852 Rueil-Malmaison
France

andreas.ehinger@ifpenergiesnouvelles.fr
T: +33 14752 6744
F: +33 14752 7026
M: +33 68016 4716

Annexe 1 – Sub-programme on CO_2 Capture

Pag. 322

Pag. 322

Pag. 323

EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

CO_2 Capture and Storage (CCS)
Sub Programme on CO_2 capture

Version: 4.1
Last modification date: 06.01.2011
Contact person: Ruud van den Brink, vandenbrink@ecn.nl

Pag. 323

Table of contents

SUMMARY OF THE SUB-PROGRAMME ON CO_2 CAPTURE

The sub-programme on CO_2 capture focuses on the development and testing of CO_2 capture technologies that will reduce costs compared to the technologies that will be tested in the EU CCS demonstration plants. In the CO_2 capture sub-programme 17 institutes from 12 different countries will share results, infrastructure and will co-develop these technologies. In total over 170 manyears/year have been committed to this sub-programme.

The sub-programme follows the recommendations of the ZEP technology platform and is related to the EII on CCS. This means that collaborative R&D will take place on the pre- and post-combustion and oxyfuel capture. Technologies that will be investigated include CO_2 solvents and sorbents, polymeric, metallic and ceramic membranes, solid looping processes, and advanced gas turbines. Also several cross-cutting issues will be addressed. These include integration of CO_2 capture in power plants, CCS in industry and Bio CCS.

The general objective of the EERA CO_2 capture sub-programme is to:

- Develop more energy efficient and more cost efficient CO_2 capture technologies with a low environmental impact.
- Develop more efficient designs for integration of CO_2 capture technologies in new and existing power plants and other industrial facilities (steel, cement, refineries, biofuels production, etc.).

1. Background – Vision 2020 – 2050

CO_2 Capture and Storage (CCS) is one of the key technologies to reduce Europe's CO_2 emissions in the EU Strategic Energy Technology (SET) plan. The two great challenges for the implementation of CO_2 capture plants is (1) to gain industrial experience of existing CO_2 capture technologies on power plant scale and (2) to reduce the CO_2 capture costs. The first challenge is currently being addressed in the recently awarded six 250 MW CCS demonstration projects under the EEPR scheme. This programme to demonstrate the so-called first generation technologies (see Figure 1 below) will be expanded in a second European demonstration programme (NER300) and also several national CCS demonstrations have been announced. The first generation technology to be demonstrated is:

- Post-combustion CO_2 capture from the flue gases of pulpherized coal (PC) or Natural Gas Combined Cycle (NGCC) power plants using amine solvents,
- Pre-combustion CO_2 capture in an Integrated Coal Gasification Combined Cycle (IGCC) using conventional water-gas-shift catalysts and CO_2 solvents,
- Oxyfuel CO_2 capture in PC plants and fluidized bed coal burners using conventional cryogenic air separation units.

The second challenge, reduction of the CO_2 capture costs, is addressed by numerous R&D projects in EU Framework programmes, national programmes, in industry, research institutes and universities. Although estimation of CO_2 capture costs varies widely, there is general agreement in both industry and the research community that there is ample potential and a great need to reduce both capital and operating costs of CO_2 capture technologies. This EERA CO_2 capture sub-programme aims at developing second and third generation capture technologies and power cycles with integrated CO_2 capture that are less energy consuming and have lower investment costs than the first generation. When technologies are successfully past pilot and demonstration stage, they should be ready for implementation in 2020 – 2030.

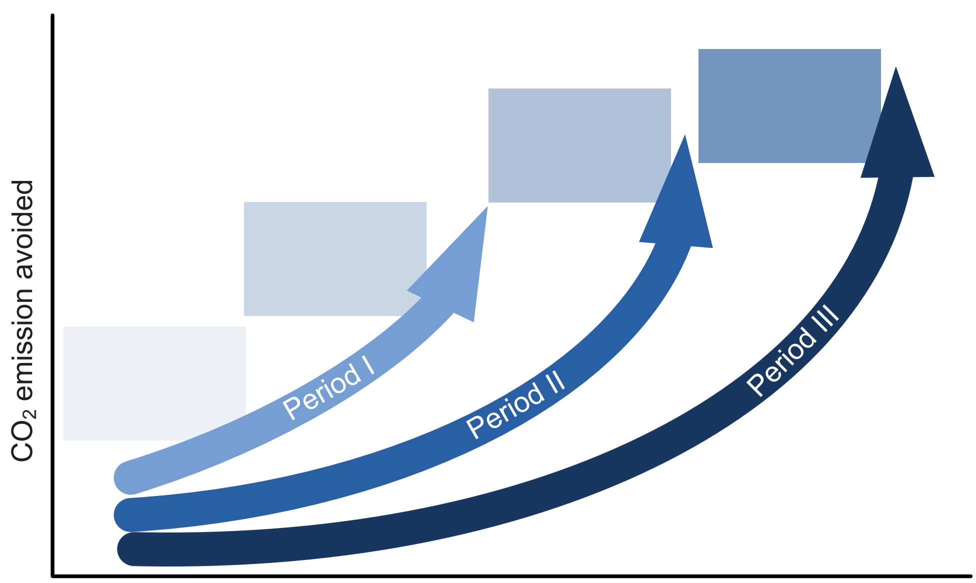


Figure 1: Timing of R&D, demonstration and deployment of CO_2 capture technology (source: ZEP).

This programme strongly links to existing and emerging initiatives, such as the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP), the FP7 programme, the European Industry Initiative (EII) on CCS, and the research infrastructure project ECCSEL. The EERA programme aims to increase efficiency of R&D on second generation CO_2 capture technologies, by combining and aligning the research carried out in Europe's leading research centres. The programme is based on the ZEP document *Recommendations for research to support the deployment of CCS in Europe beyond 2020* published in 2010. It follows the recommendation that R&D is necessary on all three options to capture CO_2 in a power plant (post-combustion, pre-combustion and oxyfuel) and on the design of power plants with integrated CO_2 capture. ZEP distinguishes three period or generations in the development of CO_2 capture technology (see Figure 1).

- Period I, up to 2020: Medium term, not part of this EERA programme.
- Period II, 2020-2030: 2nd generation technologies: Improvements and refinements of technologies employed in Period I.
- Period III, 2030 and beyond: Long-term (3rd generation) technologies.

The technologies developed in Periods II and III are the core of this EERA programme.

2. Objectives / research questions

The general objective of the EERA CO_2 capture sub-programme is to:

- Develop more energy efficient and more cost efficient CO_2 capture technologies with a low environmental impact.
- Develop more efficient designs for integration of CO_2 capture technologies in new and existing power plants and other industrial facilities (steel, cement, refineries, biofuels production, etc.).

The major R&D items to achieve these goals have been identified by ZEP and are (in general) included in this document. However, with respect to the ZEP document, this programme is currently limited to CO_2 capture technologies and enabling technologies, but does not address increasing the efficiency of power plants as such (e.g., USC boilers, coal gasification). Also some more short term topics (e.g., water-gas-shift catalysis, cryogenic air separation) in the ZEP research agenda will not be addressed in the EERA CO_2 capture programme.

The time frame for achieving the above mentioned general objectives covers the next two decades. Indeed, more efficient technologies are critically important for large scale deployment beyond 2020. In order to be ready in time, R&D has to be performed now and this strongly supports the development of the EERA CO_2 capture programme.

The programme is broken down in four main areas with specific objectives:

1. Post-combustion CO_2 capture
    a. Develop second generation solvent systems and processes with improved performance (energy requirement, costs, environmental impact) compared to the first generation solvent systems and processes.
    b. Develop proper control schemes and improved online analysers for large scale integrated capture facilities.
    c. Develop improved methods for avoidance of emission of species (amines, degradation and by-products), which could be harmful to the environment
    d. Investigate and develop solid sorbents and carbonate looping cycles for more efficient post-combustion capture.
    e. Development of polymeric and ceramic membranes with improved separation properties
    f. Developing advanced techniques for monitoring and abatements of CO_2 contaminants as NOx, hydrocarbons, and particulate for allowing efficient and safe CO_2 capture.

2. Pre-combustion CO_2 capture
    a. Development of high-temperature membrane materials, membrane modules, and membrane reactors, testing them at realistic conditions and designing schemes for integration of membrane systems in power plants.

b. Development of high-capacity CO_2 sorbents for combined CO_2 and sulphur removal, for sorption-enhanced reforming and sorption-enhanced water-gas shift. Designing schemes for integration of sorption systems in power plants.
c. Investigate and develop hydrogen-fired gas turbines, including CFD models, and the use of membranes in the combustion chamber.

3. Oxyfuel CO_2 capture
   a. Study the implication of using pure oxygen in coal combustion in boilers and fluidized beds, develop CFD models, and investigate CO_2 purification.
   b. Develop mixed ionic electronic conducting materials and thin film membranes for O_2/N_2 separation
   c. Develop chemical looping combustion technology: design reactors, develop oxygen carriers for both gaseous and solid fuels.
   d. Investigate and develop oxyfuel gas turbines, including CFD models

4. Cross-cutting issues
   a. Define common starting points and boundary conditions for modeling and economic evaluation of all the technologies to be used in the other work packages.
   b. Developing proper steady state and dynamic models of CO_2 capture installations integrated in power plants and compare technologies on an equal basis. Study the possibilities for CO_2 capture technologies in biomass conversion schemes, such as the production of biofuels, aiming to achieve negative CO_2 emissions.
   c. Investigate the possibilities and technological challenges for CO_2 capture in non-power applications like the steel, chemical and cement industries and refineries.

3. Description of foreseen activities

SP1 Post-combustion capture

SP1.1 CO_2 solvent systems

Background

Reactive absorption of CO_2 using caustic solutions (*e.g.*, aqueous amine solutions) can be considered as state of the art. The principles behind this have been studied to a large extent, also reactive absorption of CO_2 has been demonstrated already at relative large scale in industry. Reactive absorption is an important technology to be applied to flue gasses, where CO_2 is present in low concentration. This technology can be applied to flue gasses from all kind of industrial processes.

Current Status

At this moment the monoethanolamine (MEA) based technology can be considered as state of the art. Several fairly large scale installations have been constructed based on this technology. However, if this technology should be applied to power plant scale a further scale-up with a factor of 30 is needed. At this moment in Europe several companies are planning to construct a demonstration plant (to be operational in 2015) based on post combustion capture. However, MEA has certain disadvantages such as high regeneration energy and degradation. Alternative solvents are in development, and the stage of development ranges from lab-scale to pilot scale.

Major remaining R&D issues

The following R&D directions can be envisaged

- Decrease operational cost
  → Development of low energy consuming regeneration of absorption liquid

Current technology has an efficiency penalty of about 10-12% (including CO_2 compression) due to the high energy demand for the regeneration of the absorption liquid. This leads to high cost of CO_2 .

→ Integration of the capture plant with the power plant

Although post combustion capture is an end-of-pipe technology, this does not mean that the integration with the power plant is less important. On contrary, improved integration with the power plant and compression units can lead to substantial decrease in efficiency penalty %-points. Development of proper control schemes is also essential. Work needed in this area includes development of robust online analysers and complementary dynamic models.

→ Development of stable solvents

The performance of the capture solvents will decrease in time due to the impact of impurities present in the flue gases, and thermal and oxidative degradation of the amines.

- Decrease capital cost

  → Improvement in contactors and materials

  Due to the relative low concentration of CO_2 in the flue gases and their large volumes to be treated the installations tend to be substantial. This leads to significant capital cost.
  Improved packing materials and improved construction methods and design are important aspects to be considered.

- Decrease environmental footprint

  → Development of processes with very low overall emissions

  Emissions with the current solvent systems can occur due to the volatility of the solvent itself and from degradation products. The emitted species can may have a detrimental effect on the environment.

Vision on implementation

The results of the above mentioned R&D directions will be available in the coming five years. However, piloting and demonstrating can take more time. Nevertheless, some outcomes can already be implemented on a shorter time schedule. It is of great importance that the large scale demonstration plants (in operation by 2015) should be constructed in such a way that demonstration of improved technology (*e.g.*, low energy consuming solvents) can still be done using these demonstration plants. This will lead to a shorter time to market with an overall decreased cost for demonstration.

Description of work

- Perform experimental and theoretical studies to build up knowledge how the molecular structure of the absorptive components influence performance
- Develop second generation solvent systems and processes with improved performance (energy requirement, costs, environmental impact) compared to the first generation solvent systems and processes.
- Develop control schemes and improved online analysers for large scale integrated capture facilities.
- Study the impact of impurities like NOx and SOx on the working of the solvents. Research deep NOx removal systems based on a two-step process: efficient adsorption of NO on a Cu-ZSM5 adsorber/catalyzer bed, followed by thermal decomposition of adsorbed NO and regeneration of the adsorber.

- Study the effect of any emitted species (amines, degradation and by-products), and if necessary develop improved methods for avoidance of emission of species which could be harmful to the environment. Measurements of emissions of possible harmful substances from an amine unit on an existing power plant and determine chemical kinetics of solvent degradation.

Build up simulation modelsto improve integration and dynamic modelling with the power plant and the CO_2 compression sectionAlso study modelling fundamentals such as pressure drop relations

Objectives four year program

Apply the knowledge on how the molecular structure of the absorptive components affects their performance as CO_2 solvents in order to have available:

- second generation solvent systems and processes with improved performance (lower energy requirement, lower costs, lower environmental impact). Demonstrate the second generation solvents in pilot plant tests.
- proper control schemes based on knowledge on the dynamics of the full system and improved online analysers for large scale integrated capture facilities.
- improved methods for avoidance of emission of species (amines, degradation and by-products), which could be harmful to the environment

Milestones for first 24 month period

1. Common criteria defined for comparing solvent systems. Document describing comparison criteriua based on capture efficiency, energy consumption, environmental impact, costs, operational challenges, etc. (Month 12)
2. Short list of second generation solvents available. List of solvent names and class of solvent to be tested in pilot plant evaluated against common criteria, (Month 24)
3. Dynamic model (or models) in place that is suitable to be used in developing control schemes is running and described in a document (Month 24)

Partners

IFP Energies nouvelles, SINTEF, TNO, ENEA/CNR, LNEG, SCCS, CLCF, RC Rez

SP1.2 CO_2 sorbent systems

Background

The use of solid CO_2 sorbent systems have been identified as a way to reduce the energy consumption of post-combustion CO_2 capture compared to liquid amines. Major benefits include lower regeneration energy and better opportunities for efficient heat recovery when operating at high temperatures. Many different sorbent systems are being developed, which can be classified in three major categories:

1. Vacuum swing adsorption processes, that selectively capture CO_2 from the flue gas and release CO_2 at vacuum. Typical sorbents are zeolites, carbons or materials like Hybrid Organic/Inorganic Frameworks (MOFs). Key challenges are the selectivity for CO_2 , the capacity of the sorbents, the fate of impurities, the kinetics of the adsorption and desorption, the energy requirements for vacuum production, together with the low pressure of the resulting CO_2 requiring extra energy to compress.
2. Low-temperature thermal swing sorbents. For this process supported amine systems, that operate at about 50°C for adsorption and 120°C for desorption, are used. Alternatively, materials like supported sodium or potassium carbonates operate at somewhat higher temperatures. A major challenge is to deal with the large gas flows over the packed bed, which causes pressure drop. Also heat transfer over the bed and poisoning of sorbents by SOx and NOx are important issues.
3. High-temperature thermal swing carbonate looping processes. A promising system in terms of overall CO_2 capture efficiency is carbonate looping, where a calcium containing mineral or a synthetic sorbent is used at high temperature (around 550-650°C for absorption of CO_2 by carbonation) and regenerated above 900°C by calcination (normally in an oxyfired fluidized bed combustor). The carbonate looping system is can be highly integrated in the power production cycle, leading to an extremely low efficiency penalty for CO_2 capture. Key issues concern sorbent performance (chemical and mechanical) and those related with the scaling up of interconnected circulating fluidized bed reactors.

Current Status

The research on supported amines or polyamines (supports include silica's, mesoporous materials, metal-organic-frameworks, carbons), MOFs and high surface area solid carbon sorbents is mainly carried out on labscale, although there are commercially available materials. The use of supported sodium and potassium carbonates for CO_2-capture at low temperature has been demonstrated in a small 10 kW circulating fluidized bed system. Carbonate looping R&D is being carried out at a somewhat larger scale: several small pilot test installations (10s of kW) have been succesfully operated in recent years and others in the MW range are under construction in Europe (ie. CaOling FP7 project).

Major remaining R&D issues

1. Vacuum swing adsorption processes. Key challenges are mainly related to sorbent development: the selectivity for CO_2 and the prevention of accumulation of other flue gas constituents (esp. steam) and the overall capacity of the sorbents for CO_2, together with overall process integration.
2. Low-temperature thermal swing sorbents. There are R&D issues in the system design such as the major challenge to deal with the large gas flows over the packed bed, which causes pressure drop. Also heat transfer over the bed is an issue. In general, designing simple yet efficient systems is a challenge. On the sorbent side poisoning of sorbents by SO_x and NO_x are important issues, as well as the overall CO_2 capacity and regenerability. As far as the supported sodium/potassium carbonates are concerned, improvements of reaction kinetics and mechanical properties are still an issue. For use of fluidized bed reactor systems, heat management due to the small temperature difference between the reactors is also an issue.
3. High-temperature thermal swing carbonate looping processes. Major R&D issues on the process side are improved reactor modelling, alternative calciner designs to avoid the need of oxycombustion in current system designs. On the materials side, important issues are increasing mechanical and chemical stability of the sorbent , investigation of combined CO_2 and SO_2 capture, reactivation methods (by steam, doping agents etc), pre-treatment methods to increase sorbent stability, use of CaO rich purge materials for other industrial applications (i.e. cement, desulfurization etc).

Vision on implementation

The timing for implementing these technologies differs. The most developed is probably carbonate looping, which has two pilot scale rigs being designed and built, which should be operational within 3 years and a large-scale demonstration within 10 years.

Description of work

1. Vacuum swing adsorption processes.
    - Develop improved adsorbents for vacuum swing processes having higher CO_2 selectivity and cyclic capacities.
    - Production of solid carbon adsorbents from well-controlled fuel-rich combustion sources and treatment of carbon sorbent materials for enhancing the adsorption capacity.
    - Develop reliable molecular modeling methods to predict CO_2 capture and to gain understanding of the relationship between the molecular properties of adsorbents and their CO_2 capture performance.
    - Develop computational tools that allow assessing the stability of adsorbents and their behavior in presence of pollutants.
    - Design of VSA systems and integration in the power cycle. Consider specific issues like large-scale vacuum pumps.
2. Low-temperature thermal swing sorbents.
    - To develop and to fully characterise a targeted range of novel CO_2 adsorbents (carbons, supported amines, generally low temperature <150 °C materials), using fundamental understanding of adsorption processes, and thus to design and optimise material properties and form.

- Investigation of multipollutant (NOx, SOx, etc) control systems for adsorbent systems.
- To determine the performance of adsorbents in simulated flue gas using fixed and moving bed apparatus.
- Develop novel reactor concepts for adsorption based temperature swing post combustion processes giving low pressure drop and improved heat management
- To develop regeneration / cyclic operation strategies and define operational conditions. For example novel TSA and stripping techniques. Lifetime and understanding of underlying chemistry of any degradation reactions.
- To compare efficiency, cost of capture and electricity with base case solvent capture technologies.

3. High-temperature thermal swing carbonate looping processes.
    - Develop joint methods for sorbent performance characterization in lab scale installations, in order to accelerate the delivery of relevant information for larger scale testing
    - Developing methods to enhance the performance of existing sorbents, regenerate their reactivity and reduce both attritive and chemical deactivation.
    - Evaluation and development of agglomeration methods for the production of sorbent particles from synthetic micro-powders. Evaluation of the production costs for such synthetic sorbents.
    - Joint development of reactor models for carbonation and calcination reactors operating under realistic process conditions, integrating state of the art knowledge on fluid-dynamics of circulating fluidized bed systems with gas-solid reaction models at particle level.
    - Joint experimental campaigns to test improved materials and conditions in test facilities already available (interconnected circulating fluidized bed test facility at among others CSIC and ENEA).
    - Improvement of models for the thermal integration of the carbonate loop for CO_2 capture in the overall power plant, maximizing efficiency gains, exploring synergies with other industries, and exploring the viability of advanced carbonate looping concepts using different calcination strategies and/or sorbent materials. Studying effect of sorbent properties and regeneration strategies on the performance of power plants or application in other industries like cement focusing on steam and heat requirements.
    - Develop combined CO_2 and SO_2 capture using CaO-based materials
    - Evaluate the techno-economical potential of the high temperature thermal swing carbonate looping process for CO_2-capture from large major industrial sources like cement and metallurgical plants or refineries.

<u>Objectives four year programme</u>

1. Vacuum swing adsorption processes.
    - To have available a novel sorbent with a high cyclic capacity and selectivity for CO_2
    - Optimal operating conditions determined.
2. Low-temperature thermal swing sorbents.
    - To have available an optimised reactor design, cycle design and sorbent, and to give a proof-of-concept on lab scale
    - Systems integration show that the novel concepts are more efficient than amine solution solvents
3. High-temperature thermal swing carbonate looping processes.
    - To produce enhanced sorbents with long-term activities double those currently exhibited and to develop methods to enhance this reactivity over a long number of cycles
    - Demonstrate the novel sorbents in pilot scale fluidized bed test installations
    - Design of an integrated carbonate looping cycle in a power plant and other applications

Partners
IFP Energies nouvelles, SINTEF, ECN, RSE, IFE, ENEA/CNR, LNEG, Imperial, Nottingham, SCCS, POLIMI, CSIC, RC Rez, ETHZ

Milestones for first 24 month period
1. Common criteria defined for comparing sorbent systems for the three different applications. Document describing comparison criteria based on capture efficiency, energy consumption,etc. evaluated against solvents as a benchmark (Month 12)
2. Short list of second generation sorbents available, evaluated against common criteria. Computational screening tools available to allow systematic screening of a wide variety of available materials and estimation of effects on plant performance of sorbent properties improvements. (Month 24)

SP1.3 CO_2-selective membranes

Background
Separation of CO_2 from flue gases by membranes requires high selectivities and fluxes, given the low CO_2 partial pressure in the flue gas, which means that the driving force for CO_2 transport over the membrane is relatively low. Large membrane areas are necessary and the membranes should be resistant to fouling and to temperature and pressure changes. Furthermore membrane module as well as process concepts are to be developed which take account of the power plant specific boundary conditions.

Current Status
Polymeric membranes are being employed for CO_2 separation in natural gas and biogas processing. However, the requirements for membranes in post-combustion capture are different. Hence new generations of CO_2 selective membranes are currently being developed. The development is largely on lab and pilot scale. Membranes with a CO_2 permeance of 2.7 $Nm^3/(m^2$ h bar) and a CO_2/N_2 selectivity of 60 at 20°C can be manufactured in 100 m^2 scale. First lab and pilot scale tests of membrane units in power plants have been reported. Microporous ceramic membranes show at the moment no sufficient separation of CO_2/N_2 under power plant conditions. Currently the modification of these membranes with organic groups is under development to increase the separation properties. Ceramic membranes have advantages in aggressive environments and have higher temperature resistances in comparison to polymeric membranes.

Major remaining R&D issues
For membrane processes, the following R&D directions should be addressed:
- Membrane material development
  Polymeric membranes should be further developed with respect to their active separation layer as well as their production as multilayer composite membrane in large scale. The former will include the investigation of block copolymers and additives for this promising class of materials. Pore condensation and activated transport membranes could also play a role. The development of the composite structure will focus on the optimisation of porous supports and the development of protection and sealing layers for the ultrathin CO_2 selective layers. Modified microporous ceramic membranes should be developed with increased separation properties. To reach the required flux defect free thin film structures with membrane thickness below 1 µm are required. Therefore the substrate quality and the quality of the intermediate layers should be improved. The stability of the membrane materials and layers in real life power plant environments should be investigated thoroughly.
  Development of mixed-matrix and /or hybrid membranes are valuable, in order to improve permeability, selectivity and stability of polymeric membranes.
- Membrane module design
  Membrane modules currently employed in gas separation reflect the modular nature of membrane technology. Even large scale installations such as natural gas processing

facilities consist of hundreds of modules. It would be necessary to design modules with a high packing density allowing for large membrane areas whilst minimising transport resistances. Furthermore, alternative module construction materials to steel should be investigated.

- Membrane process design
  The largest gas phase membrane processes are currently employed in natural gas processing with boundary conditions entirely different to those encountered in post combustion. One big issue would be the provision of the required driving force to the process which is likely to involve large scale vacuum compressors and blowers. Furthermore efficient filtration technologies are required in order to protect the membrane surfaces from dust deposits. Studies on integration into the power cycle to show that efficiency penalties and costs can be reduced compared to amine systems are also required.

<u>Vision on implementation</u>
Within the next ten years, the results of the described R&D directions should be available. With respect to the membrane materials, considerable headway already has been made. It is expected that the materials will be tested in power plant environments on pilot scale within the next three years. These tests are expected to give the required information for devising the large scale membrane production processes. Also important information on the required quality of filtration will be available. The membrane module designs will first of all be of theoretical nature. In order to put them into practice, large scale demonstration facilities are required in order to test their performance. One possibility would be to combine this with the large scale demonstrations envisioned for post-combustion solvents as described in SP 1.1.

<u>Description of work</u>
- Investigate different membrane materials for application to CO_2 separation.
- Increase CO_2 permeance of membrane materials
- Development of defect free thin film structures
- Improvement of stability of membrane materials in power plant conditions
- Develop production of composite membranes to allow for the transfer of superior membrane materials properties into practical application at competitive costs.
- Address the decreasing CO_2/N_2 selectivity for polymeric membranes with increasing temperatures.
- Develop permeation models describing the transport behaviour as function of temperature, pressure and composition.
- Develop membrane module concepts with high packing densities and low transport resistances suitable for application to CO_2 removal from flue gases.
- Investigate process concepts transferring the advantages of membrane and module developments into practical application.
- Investigate different filter concepts.
- Conduct pilot plant studies to assess performance of membrane materials in power plants with respect to separation properties and long term stability and effect of potentially detrimental components as SO_2.
- Provide process simulation tools to investigate the integration of membrane units into power plants.

<u>Objectives four year program</u>
- Provide multilayer composite membrane with a CO_2 permeance of 10 $Nm^3/(m^2$ h bar) at a CO_2/N_2 selectivity of 80 at 20°C.
- High capacity membrane module for flat sheet membranes with a maximised packing density at low transport resistances and designed for vacuum assisted operation. The module should employ low cost materials.
- Determine required filtration efficiency.
- Demonstration of membrane process viability and economic parameters on pilot scale.

Milestones for first 24 month period

1. Test reporting CO_2 selective membrane with a CO_2 permeance of 5 $Nm^3/(h\ m^2\ bar)$ and a CO_2/N_2 selectivity higher than 60 at 20°C. (Month 18)
2. Design concept of high capacity membrane module available. (Month 24)

Partners

SINTEF, SCCS, HZG, FZJ

SP2 Pre-Combustion Capture

SP2.1 Hydrogen-selective membranes

Background

Hydrogen-selective membranes are pieces of equipment for separation of hydrogen from a gas stream that yield a continuous stream of both hydrogen and a CO_2-rich stream. Integrated in a power production scheme with CO_2 capture, membranes generally show low efficiency penalties. However, high temperature hydrogen-selective membranes are currently only available at small scale and are not mass-produced, while for application in CO_2 capture thousands of square metre of membrane area is needed. Also the life time of the membranes under power plant conditions is a serious issue. Furthermore, the integration of the membranes in modules and of the modules in power plants is an issue on which much R&D is still needed. This EERA project focuses on high-temperature membranes (approx. 300°C and higher) for hydrogen separation from syngas and oxygen separation from air. It also addresses the design and testing of membrane modules and membrane reactors.

Current status

For Pd-membranes membranes, tubular membranes of approx. 1 m length and 1 to 5 cm diameter are available at R&D institutes in Europe. Also small modules are available. The membranes have been proven to work under simulated power plant conditions in bench-scale tests. Other types of membranes, e.g., microporous membranes and proton-conductors, are being made and tested on lab scale. Some proton conductors shows high stability up to 1000°C and in aggressive atmospheres Application of membranes in more advanced configurations (such as integrated reactors, sour conditions) have been tested in lab scale experiments.

Major remaining R&D issues

For membrane materials the following R&D issues have a high priority to be resolved:

- Mass manufacture of membranes at the scale necessary for industrial application against acceptable costs
- For Pd-based membranes: long term stability, poisoning by CO and/or sulphur, reduction of costs
- Manufacturing of thin film microporous and proton conducting membranes with improved flux, upscaling to 1 m length, testing under realistic conditions

For membrane modules and reactors:

- Sealing technologies for connection of ceramic membranes to the metal outer world
- Efficient module designs aimed at keeping costs as low as possible
- Long-term testing under industrial conditions

For membrane systems:

- Hydrogen membrane systems: integration in IGCC, interaction with sulphur removal

Vision on implementation in the next ten years

Five years from now large numbers of membranes should be available, and membrane modules of several m^2 membrane area as well. The hydrogen membrane modules should be tested for hydrogen separation from syngas in a side stream of an industrial plant (e.g., refinery, coal gasifier). For novel membrane types, larger bench-scale tests will be performed and membrane manufacturing will be scaled up. In ten years time, Pd-based membranes units are moving into the demonstration phase and the other membrane technologies are in the industrial pilot test phase.

Description of work
- Hydrogen selective membranes:
  - The starting point for the hydrogen-selective membranes are Pd-based membranes,
  - Resitance of Pd-based membranes to impurities and high temperature operation (>400 C). Development supports and alloys for these operations.
  - Development of thin films and active nanostructured surfaces for H_2 separation.
  - Novel membranes like mixed-conducting ceramic and microporous membranes will be investigated.
  - Theoretical and experimental studies of proton transport in binary oxides
- Modelling of the processes occurring in the membranes in order to design efficient membrane modules and reactors.
- Develop post combustion systems able to reduce hydrocarbons and residual oxygen below the low limits required for CCS (order of few ppm)
- Integration studies of membrane modules and reactors in power plants

Objectives for four year program
- More than 2000 h stable behaviour of novel membrane module in simulated power plant conditions for Pd-based membranes at high temperature and/or in presence of H_2S.
- Testing of novel microporous and/or proton conducting membranes on bench scale and evaluation of the prospects of these membrane types against Pd-based systems.
- Module design for pilot plant installation available

Milestones for first 24 month period
1. Selected membranes for benchscale test and as the basis of module design, that have been scaled up to at least 25 $cm^2$and tested in relevant conditions in presence of H_2S or at high temperature. (M24)
2. Results of lab-scale testing of microporous and proton conducting membranes available. Decision whether these types show enough promise for CCS application to make the step to bench scale testing (M24)

Partners
SINTEF, ECN, FZJ, RSE, SCCS, CSIC, Risoe, HZG, POLIMI, VITO

SP2.2 CO_2 sorbents

Background
The current state-of-the-art CO_2 solvents used in pre-combustion CO_2 capture are operated at ambient or even sub-ambient temperatures. Operating the CO_2 sorption at higher temperatures (> 300°C – 800°C) improves the efficiency of the capture process. It also offers the opportunity to combine the CO_2 sorption with the conversion of CO into CO_2 or the methane reforming reaction in a single step. A recent addition is a system in development at CSIC for sorption enhanced methane reforming, in which the heat for the calcination of $CaCO_3$ is provided by metal oxide reacting with CH_4. However, the design of efficient sorption-regeneration cycles that yield high purities of both hydrogen and CO_2 is still under development. Also, the lifetime of the sorbents especially in presence of sulphur is an unresolved issue. Reactor design and integration of the sorbent processes in high-efficiency power cycles needs to be addressed.

Current Status
Currently, on hydrotalcite based sorbents, CaO-sorbents, and sorption-enhanced water-gas-shift and reforming, bench-scale tests on full cyclic systems are running in several research institutes

across Europe. For application of SEWGS and sorbents for combined CO_2 and H2S removal, successful tests at lab-scale have been reported. Process integration studies have been done mainly on natural gas combined cycles and show improved efficiencies over solvent systems.

Major remaining R&D issues

For sorbent materials:

- Sorbents that can simultaneously remove CO_2 and H_2S and can deliver three different products: hydrogen, CO_2 and H_2S.
- More chemically and mechanically stable CaO-based materials and development of other materials facilitating temperature swing adsorption (TSA) at very high temperatures.

Reactor and cycle design:

- Fluidized bed reactor technology development and studies for sorption-enhanced reforming and other temperature swing adsorption processes.
- Combining CaO-based sorption-enhanced reforming with chemical loping combustion to provide heat for the calcination step.
- Design and testing of pressure swing adsorption (PSA) and TSA cycles for CO_2 capture and sorption-enhanced water-gas-shift for sulphur-containing gases.
- Heat transfer issues for the regeneration of sorbents operating at very high temperatures in a rich atmosphere of CO_2(ie CaO)

Process design:

- Integration of PSA and TSA processes in coal- and natural gas-based power cycles and industrial processes.
- Cost estimations.

Vision on implementation 2020

Within the next five years CO_2 sorbents should be tested in a pilot plant several MW in size to capture CO_2 from syngas from a industrial reformer or gasifier. When results are positive and the technologies shows significant benefits in terms of cost and efficiencies over first generation pre-combustion capture, a full scale demonstration will be initiated in 2020. the For the sorption-enhanced reforming process: demonstrate and test at a kW-scale using available Ca-based sorbents.

Description of work

- For the sorption-enhanced water-gas-shift (SEWGS) process, sorbents based on hydrotalcites will be developed for application in a pressure swing adsorption (PSA) process. The numerical modelling and testing of the PSA-cycle is an important task in this project.
- For sorption-enhanced reforming (SER), CaO- and Lithium-based sorbents will be developed for a temperature-swing adsorption process. Both the morpholigical parameters of the sorbents and the kinetics of CO_2 uptake, steam reforming and of the calcination or regeneration step will be studied. Circulating fluidized beds are one of the reactor concepts, as well as fixed beds operating with new materials and reactor designs to overcome the heat transfer problem for regeneration at very high temperatures. For fluidized bed designs, test campaigns will be carried out at actual fluidized bed test facilities by partners like ENEA and IFE. The experimental work will be strongly supported by modelling on micro and macro scale.
- Development of novel materials with enhanced properties, combining both CO_2-sorbent and active catalyst for the SER and SEWGS processes.
- Investigate the techno-economical potential of the SER process for stand-alone hydrogen production and for power production. Consideration of different reactor designs, configurations and operating conditions.
- For the combination of sorption-enhanced reforming with chemical looping combustion work is needed on process integration, catalysis for the reforming reaction, reactor and cycle design, and experimental demonstration of the concept.

Objectives for four year program

- Proof-of-concept for sorption-enhanced reforming with different sorbent materials and reactor concepts
- Proof the concept of combined CO_2/H_2S sorption and water-gas-shift (SEWGS) for several thousand cycles with low steam consumption.
- Develop catalyst/sorbent combinations for sorbent enhanced reforming that can withstand the harsh sorbent regeneration conditions needed
- Develop sorbents having improved physiochemical properties and stable cyclic capacity over prolonged cycling

Milestones for first 24 month period

1. Common criteria defined for comparing high-temperature sorbent systems. Document describing comparison criteria based on capture efficiency, energy consumption,etc. evaluated against physical solvents as a benchmark (Month 12)
2. Short list of novel sorbents for CO_2 and H_2S separation and for SEWGS and SER based on common criteria available (Month 24)
3. Numerical model in place for the design of efficient high-temperature PSA and TSA cycles (Month 24)

Partners

SINTEF, ECN, RSE, IFE, ENEA/CNR, LNEG, Nottingham, SCCS, CSIC, Polimi, ETHZ

SP2.3 Hydrogen-fired gas turbines

Background

The pre-combustion path to CCS requires gas turbines that can be operated on hydrogen-rich fuels and match the performance and emission levels of today's and tomorrow's natural gas-fired turbines. Low NOx-burners for hydrogen-rich fuels are to be developed yet eliminating the need for large amounts of diluents. Turbine inlet temperatures and water content of the flue gases through EGR will be increased to improve performance of hydrogen-fired turbines. R&D in the field of advanced materials, numerical design tools, high pressure combustion experiments is needed.

Current Status

Currently, gas turbines for hydrogen-rich fuels employ non-premixed burner technology using diluents such as N2 and H2O in order to keep flame temperature and NOx emissions down. Reduced turbine inlet temperature in order to compensate higher moisture content and increased heat transfer is also used. The drawbacks related to fuel dilution and low turbine inlet temperature could be overcome by a dry low NOx (DLN) combustor design for hydrogen-fired gas turbines ultimately resulting in increased efficiency.

Major remaining R&D issues

- Dry Low NOx burner technology without the need for large amounts of diluents
- Burner concepts for better fuel flexibility, availability and reliability
- Increased turbine inlet temperature for higher efficiency

Vision on implementation 2020 – 2025

During the next ten years a fuel flexible burner technology with the ability to operate at high hydrogen content with low amount of diluents and increased turbine inlet temperatures should have been verified in pilot plants at realistic engine conditions and being ready for full scale implementation.

Description of work

- Experimental investigation into the limits of flammability, ignition and deflagration-to-detonation transition potential under a range of high hydrogen content fuels in exhaust

systems for CCGT applications. Component testing and demonstration under relevant conditions
- Improve or develop new hydrogen burner concepts based on a lean premixed mode of operation. Experimental testing of the new concepts for hydrogen combustion.
- Investigation into fast-response gas composition measurement for turbine controls
- Develop and validate numerical design tools including detailed resolution of fuel/air mixing patterns and turbulent combustion
- Identification of instability mechanisms in hydrogen blends combustion by means of Large Eddy Simulation and experimental diagnostics, development of control strategies and implementation in systems at laboratory and industrial scale.
- Investigate the use of selective, high-temperature membranes in combustion chambers
- Develop new GT cooling technologies, high temperature materials and hot path coatings
- Testing of a large gas turbine in the scope of a demonstration plant

Objectives four year program
- Identify and chart the key challenges in the development of hydrogen-fired lean premixed gas turbine burners (fuel injection scheme, flame holding & intrinsic flashback safety etc)
- Having validated numerical CFD models and tools against both simple geometry / laboratory scale high pressure flames and complex geometry / full scale high pressure combustors
- Provide a detailed system analysis that generates realistic techno-economical results for future gas turbine based IGCC plants.

Partners
ENEA/CNR, CLCF, PSI

Milestones for first 24 month period
1. Results of experiments on flammability limits, ignition, etc. available as input for CFD modeling (Month 24).

SP3 Oxyfuel

SP3.1 Oxy-combustion

Background
Combustion of a fuel with oxygen enables relatively easy CO_2 capture. It poses, however, various demands on the power plant design and construction and it changes the combustion behaviour of the fuel. This sub-project focuses on the oxy-combustion of coal also from the fundamental point of view in order to verify the effect of oxygen-rich environment on the coal devolatilization/pyrolysis leading to slagging and fouling phenomena as well as to pollutant emissions. The project addresses the design of the whole plant, and in particular the boiler and the CO_2 clean-up section. It also studies the materials that need to be used in an oxygen environment and the slagging and fouling behaviour of the combustion of fuels in oxygen. Alternative oxygen production techniques by membranes are addressed in the EERA sub-project 2.1 (high-temperature membranes), but interfaces with this topic.

Current Status
Currently, demonstrations of 100s of MW on oxyfuel boilers are running and extensive R&D is ongoing on oxycombustion in these plants. Lab-scale experiments into oxy combustion fundamentals and modelling of the process are ongoing. R&D on oxyfired CFB is currently being performed on a smaller scale.

Major remaining R&D issues

- In-depth knowledge on corrosion, slagging and fouling, supporting the current demonstration plants.
- R&D on fundamentals of oxy-combustion process of coal with specific regard to devolatilization/pyrolysis processes and pollutant formation/emission.
- Effect of coal properties and oxygen concentration on the yield and quality of condensed phases (unburned carbon (char), slag) formation
- Flue gas recycle rate optimization
- Determine the impact of oxycobustion on radiation properties, flame properties, etc. By physical modelling
- Develop and upscaling oxy-fired CFBs to reduce the size and costs.
- Minimization and optimization of flue gas emissions (before CPU) of oxy-CFB combustor utilizing wide variety of fuels; emissions are optimized by using verified CFB combustor models and taking into account performance of CPU

Description of work

- Performing detailed CFD simulations of oxycoal and biomass combustion and ash deposition in ordinary boilers and circulating fluidized beds.
- Development of advanced radiation models and flue gas emission modelling, complemented by fundamental chemical kinetic studies of combustion chemistry, species transformation and pollutant formation (mercury, sulphur oxides, nitrogen oxides) from coal and biomass combustion.
- To characterize the shape of the primary zone of the oxycoal flame, under low excess O_2 levels, when operating with over-fire air for further NOx reduction
- Performing experimental studies under carefully controlled experiments in lab scale systems composed of a premixed flame burner and on pilot scale oxycoal/biomass combustion test rig facilities in the UK, Spain and Italy.
- Optimization of oxy-CFB plant performance (efficiency and costs) by scale-up, higher steam parameters and process integration
- Improvement of oxy-CFB plant availability by dynamic process simulations of integrated units - ASU, CFB boiler burning wide variety of fuels and CPU - and development of process control systems
- Identifying improved materials for novel ASU using solid sorbents
- New boiler and furnace concepts for flameless oxycombustion with internal recirculation

Objectives four year program

- To make available and evaluate a novel 3D flame imaging technique for the measurement of the external dynamics and the internal structure of the flame under oxycoal combustion conditions
- To generate experimental data on coal ash and boiler material behaviour under oxyfuel conditions in order to analyse the interaction of oxy-combustion products with boiler materials, based on realistic flue gas environments and ash slagging behaviour under oxyfuel combustion conditions
- Implementation and validation of computational models for key areas e.g. radiation (gas and particle), particle ignition, combustion and emission (Hg, Cl, Br, etc) in CFD code. Experimental validation of the code.
- To optimise oxy CFB plant performance on availability and minimisation and optimisation of flue gas emissions.
- Identify the effect of oxygen-rich environment on the oxidation, devolatilization and pyrolysis routes through which coal particles are consumed.

Partners

IFP Energies nouvelles, ECN, ENEA/CNR, CLCF, VTT, SCCS, RC Rez

Milestones for first 24 month period

1. Advanced physical sub models implemented and validated relating to pollutant emission, combustion and radiation within commercial CFD code. (Month 24)
2. Initial results obtained of 3D flame imaging, coal ash, and boiler material behaviour under oxycoal combustion conditions. (Month 12)
3. Process simulation models constructed for Oxy-coal boiler and oxy-CFB plant optimisations including linking CFD code with process simulation as a part of virtual power system simulation task. (Month 24)

SP3.2 Oxygen-selective membranes

Oxygen-selective membranes separate oxygen from air, in order to produce oxygen for oxycombustion at lower energy requirement and lower costs. There are several options for using oxygen membranes in a power plant. The first is for producing pure oxygen for oxycombustion or in an IGCC (pre-combustion capture). The second option is the integration of membranes in a oxyfuel power plants, in which the oxygen is consumed by combustion with a fuel. A third option is integration in a combustioon plant, in which the CO_2-rich flue gases are used as a sweep gas to transport the oxygen from the permeate side of the mebrane to the combustor. This EERA project focuses on high-temperature membranes (approx. 800°C and higher) for oxygen separation from air. It also addresses the design and testing of membrane modules and membrane reactors.

Current status

High temperature oxygen-selective membranes (mostly perovskite-based) are currently only available at small scale and are not mass-produced, while for application in CO_2 capture thousands of square metre of membrane area is needed. Also the life time of the membranes under power plant conditions is a serious issue. Furthermore, the integration of the membranes in modules and of the modules in power plants is an issue on which much R&D is still needed.

Major remaining R&D issues

For membrane materials the following R&D issues have a high priority to be resolved:

- Mass manufacture of membranes at the scale necessary for industrial application against acceptable costs
- For perovskite-based membranes: low-cost base materials with low environmental impact, high flux, high stability, resistance to poinsons such as CO_2 and SO_x.
- Other membrane types: upscaling and testing under realistic conditions
- Defect free thin film membranes with optimized microstructure and active surfaces for fast oxygen transport

For membrane modules:

- Sealing technologies for connection of ceramic membranes to the metal outer world
- Efficient module designs aimed at keeping costs as low as possible
- Long-term testing under industrial conditions

For membrane systems:

- Integration in power cycle, selection of most viable integration: stand-alone oxygen production, using flue gas as sweep, etc.

Vision on implementation in the next ten years

Five years from now large numbers of membranes should be available, and membrane modules of several m^2 membrane area as well. Large bench-scale tests will be performed and membrane manufacturing will be scaled up. In ten years time, oxygen membrane units are in the industrial pilot test phase.

Description of work

- Oxygen-selective membranes:
  - Development of mixed-conducting membranes for production of oxygen for use in oxy-fuel power plant, or for the production of syngas. In the case of

sweeping with flue gas, it should be considered that the oxygen concentration in the sweep is already 2% and therefore the driving force is severely reduced.
  - Develop active surfaces for O_2 separation.
  - Development of membrane supports, ultrathin membranes and electrocatalytic materials for use in gas separation membranes.
  - Also, more integrated concepts will be studied where the membrane materials must withstand reducing conditions, high CO_2 concentrations, or the presence of SO_2. Stability of oxygen transport membranes
- Modelling of the processes occurring in the membranes in order to design efficient membrane modules and reactors.
- Integration studies of membrane modules and reactors in power plants

Objectives for four year program
- More than 2000 h stable behaviour of novel membrane module in simulated power plant conditions
- Module design for pilot plant installation available

Milestones for first 24 month period
1. Decision on most viable integration options for membranes in a power plant (Month 12)
2. Selected membranes for 2000 h test and as the basis of module design, that have been upscaled to at least 25 cm^2 (Month 24)

Partners
SINTEF, FZJ, ECN, RSE, SCCS, Risoe, POLIMI, VITO

SP3.3 Chemical looping combustion

Background
Chemical Looping Combustion (CLC) is a technology that is based on oxidizing metals to a metal oxide using air in an exothermic reaction (the depleted hot air can be used for energy production). The metal oxide can be reduced using a fuel gas (eg natural gas, syn gas). The off-gas consists of CO_2 and water. The metal can then be used in a next cycle. The typical modus of operation is in a dual fluidized bed system. However, research also conducted to employ alternating fixed beds

Current Status
CLC was first introduced in the 1950s. In the 1980s it received more attention. However, since 2000 the amount of research focussed on CLC increased significantly. In 2004 a 10 kW and 50 kW units were presented. In 2008 a 120 kW unit was developed at Vienna University of Technology. The above mentioned units are based on fluidized beds. TNO research is focussed on fixed bed technology, which is being tested at bench scale.

Major remaining R&D issues
- Effect of impurities on oxygen carrier material, stability of oxygen carriers under cyclic conditions
- Solids separation
- Scaling up fluidised and fixed bed CLC systems
- Operation at higher pressures
- CLC for solid fuels
- Non conventional oxygen carriers for chemical looping combustion with high OTC

Vision on implementation
The next steps should be focussed on demonstrating the efficiencies of CLC on a relevant scale.

Description of work
- Develop more stable and cheaper oxygen carriers. Experimental study in a lab scale fluidized bed of the stability of oxygen carriers, mainly metals like copper, iron, etc. in conditions typical of the CLC process, in the presence of real-world contaminants..
- Modeling and characterization of DIFB (Dual Interconnected Fluidized Beds) systems as a function of support material characteristics and main process parameters (temperature, pressure, gas velocity)
- Perform experimental and modelling studies of fixed-bed CLC
- Develop an alternative CLC scheme, based on the use of coal itself as oxygen carrier, is also in course of study/development.
- System simulation to evaluate and optimize CLC combined with gas turbines.

Objectives four year program
- Creating a portfolio of oxygen carriers suitable for various fuels and conditions, based on laboratory research and evaluations.
- Materials proven in a test at bench scale at a pressure of 10 bar.
- Show the potential of CLC oxygen carriers by testing in DIFB systems and fixed-bed systems.
- Make avaialble a system simulation for assessing power production efficiencies and costs of CLC.

Partners
IFP Energies nouvelles, SINTEF, TNO, CLCF, ENEA/CNR, POLIMI, VTT, PSI, VITO, ETHZ

Milestones for first 24 month period
1. Common criteria defined for comparing oxygen carriers, based on integration studies of CLC in power plants and materials properties (Month 12)
2. Short list of novel oxygen carriers based on evaluation against common criteria and results of labscale testes available. Selection of novel oxygen carriers to be tested in large-scale test installations (Month 24)

SP3.4 Oxyfuel gas turbine

Background
The oxy-fuel alternative applied gas turbine based power generation with CO_2 capture is still an immature technology, despite the potential for high efficiency. To date no pilot plant has demonstrated the operation of such unit. The gas turbine semi-closed cycle requires CO_2, eventually mixed with steam as the working fluid, implying a re-design of turbomachinery and combustor units. Therefore, there is a high demand on both fundamental knowledge and engineering practice for oxy-fuel gas turbine cycles systems.

Current Status
Oxy-fuel combustion based capture technology is at pilot and demonstration stage for coal fired boiler process. However, this novel type of combustion is almost not documented at high pressure and no validation of the kinetics and numerical models has been done to allow for a trustworthy upscaling. All the common issues in combustor design as stability, heat transfer and kinetics although being investigated at atmospheric pressure needs to be reviewed and qualified in the light of the new oxidizer and pressure environment.

Major remaining R&D issues
Basic research and development into the oxy-fuel gas turbines cycles to establish a sound engineering basis for these designs, in particular:
- Combustor behaviour at high pressure

- Unmeasured basic combustion properties (flame speed, …)
- Cooling issues due to higher gas heat capacity and higher local temperature
- Efficiency optimization of turbomachinery for CO_2

Vision on implementation
Fundamental combustion and turbomachinery design and developments in a 5 years period leading to the erection of a CO_2 semi-closed gas turbine pilot (100 kWel) within the next 5-10 years.

Description of work
- Development and testing of oxy-fuel burners at high pressure to determine the viable operational stoichiometry and CO_2 distribution in the combustor
- Assessment of technology challenges of oxy-fuel gas turbines and combined cycles developed for highest gas inlet temperatures (1300°C+)
- Developing a better understanding of the oxy- fuel (gas, syngas, H_2 enriched) combustion flame and of heat and mass transfer in oxy-gas turbine combustion systems
- An experimental and chemical kinetics study of the combustion of syngas and high hydrogen content fuels in order to predict experimental ignition delay, burning rate, and homogenous chemical kinetic oxidation characteristics of hydrogen and syngas fuels with oxygen enriched oxidizer.
- Model development and simulation of syngas particulate deposition and erosion at the leading edge of a turbine blade with film cooling

Objectives four year program
- Identify the importance of common combustor problems at under oxy-fuel environment (dynamic stability, cooling, soot, ignition, …)
- Develop and test a combustor design to achieve reliable and efficient operation of oxy-fuel combustion which emissions comply to CO_2 specifications for transport and storage
- Definition of a pilot CO_2 semi-closed gas turbine
- Validation of numerical models and tools against laboratory scale high pressure oxy-fuel combustor

Partners
SINTEF, CLCF, ENEA/CNR, PSI

Milestones for first 24 month period
Have combustor models in place and verified against a first set of experimental data

SP4 Cross-cutting issues

SP4.1 Benchmarking, process simulation, and economic evaluation

Background
Process simulation for CO_2 capture processes plays a very important role. Indeed, simulation / modelling activities can be used to explore and understand why particular experimental results have been obtained and also to identify priorities for future practical work at various scales by numerically pre-evaluating the performances of new process ideas. Improvements in process simulation should thus allow optimizing the experimental work to be done and consequently reducing the time and cost required for experimental studies. Simultaneously, those experimental studies will allow to validate and to enrich the process simulation tools.

Current Status
As of today, the process simulation community is mainly confronted with two problems: limitations in the inherent performance of the simulation tools on one hand and the large

variability of the cases currently used to test the tools; indeed, this variability makes it almost impossible to compare simulation results obtained by different research groups.

The limitations in the inherent performance of the simulation tools are linked to missing knowledge about e.g. fundamental relationships (equations of state, ...) or complex mechanisms involved in start-up and shut-down processes. Model integration and overall system optimisation are another bottleneck of current simulation tools.

Currently there exists no common or uniform framework to perform process simulations. Thus, results obtained by different research groups for the same processes are often difficult to compare and thus the progress on the learning curve is small. The European Benchmarking Taskforce (EBTF) group has been set-up in the framework of the three FP7 projects Cesar, Decarbit and Ceasar and the work performed in the framework of this EERA programme will build upon the results of the EBTF group. Several EBTF members are active in this sub project.

Description of work

This project will incorporate and expand the work of the EBTF. It adopts a co-ordinated approach to modelling over a range of scales and, in particular, will consider:

- Modelling fundamentals (e.g. equations of state, pressure drop relations etc)
- Model integration and system optimisation (steady state and dynamic modelling)
- Validation of models (steady state and dynamic) e.g., against existing pilot and demonstration plants
- Normalisation (e.g. agreement of battery limits for technology comparison)
- Economic evaluation

Modelling fundamentals

A thorough analysis of currently available options in the simulation tools and the reality of processes and their practical uses will allow identifying those gaps that are related to missing fundamental knowledge like e.g. equations of state. Experimental work will be required to acquire such knowledge that has then to be integrated into the process simulation tools and to be validated on test case applications. Sensitivity analyses will be an important part of this work in order to understand the robustness of the simulation results with respect to the underlying physical assumptions.

Model integration and system optimisation

Overall model integration, required for global system optimisation, and the integration of the relevant physical processes and quantities will be at the heart of this activity, which will draw on the detailed modelling of different CO_2 capture technologies occurring in several other SPs. For example, dynamic processes (start-up, shut-down) will constitute a particular focus for work on post-combustion capture solvent systems and the dynamic processes inherent in effective operation of adsorption and membrane systems will also be examined. Additionally, methodologies to use existing tools for fast-track evaluation of new technologies/processes will be researched. In the synthesis activity undertaken within this SP, work will focus on determining the impact of key model/system input parameters (e.g. feed properties) on process configuration, component selection, plant performance.

Validation of models

Process simulation tools will have to be validated in a wider scale with respect to existing pilot or demonstration units. Where this is not possible, key data that is unavailable and approaches that could be used to obtain/collect this data will be identified.

Normalisation

In order to allow comparisons between simulation results obtained by different research groups it is important to have an agreement on e.g. battery limits or operational parameters (operation cycles parameters). Work performed by the EBTF will be continued and consolidated, drawing on the work undertaken in other SPs of this programme. Dynamic processes will be given particular focus.

Economic evaluation
When CO_2 capture processes are compared, it is essential to carry out robust economic analysis that uses consistent boundary conditions and input assumptions so that comparable results are obtained for different processes and/or by different analysts considering the same technology. A focus of this work will be to identify different approaches used to estimate and report both costs and revenues associated with CCS projects, and particularly power plants with CO_2 capture. Key criteria to consider in checking whether economic evaluations are using a common baseline will be identified and recommendations for economic assumptions to be used in other SPs will be made.

Objectives four year program

- Integrate the outcomes of the European benchmarking taskforce (EBTF) in this project's activities;
- Continue and expand the work started by the EBTF on harmonising the assumptions, starting points and base cases for process simulations and cost calculations;
- Improve understanding of the potential for new technologies/processes to improve overall plant performance;
- Provide modelling outputs that give the insights needed for experimental work (especially on novel technologies) to be able to focus on improvements that could be most beneficial for overall plant performance;
- Enable a better understanding of dynamic performance of a range of CO_2 capture systems through model development and application of process simulation tools;
- Validate modelling results with experimental data, where possible;
- Explore the economic implications of the technical insights gained by process modelling and simulation for realistic power plant operating scenarios.

Partners
IFP Energies nouvelles, FZJ, SINTEF, ECN, ENEA/CNR, LNEG, RSE, CLCF, SCCS, POLIMI, VTT

Milestones for first 24 month period

1. Agree with the EBTF on expansion of the work into EERA (Month 12)
2. Consistent set of economic performance measures for use in the other SPs (Month 12)

SP4.2 Bio CCS

Background
A large share of CO_2 emissions are from biogenic sources including several large point sources and emission clusters, both in energy production and industry. As carbon dioxide is bind to biomass in photosynthesis, carbon capture from biomass fired installations would lead to negative emissions on a life cycle basis, in other words removing CO_2 from the carbon cycle and thus lowering the CO_2 content of the atmosphere. This was also pointed out in the IPCC Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC). Current policies for lowering greenhouse gas emissions do not recognize negative emissions from power plants, and thus no fiscal incentive exists for capturing CO_2 from biomass installations. However, the discussion is on, if captured and stored CO_2 from biogenic sources could be regarded as a negative emission. In this context BIO CCS is referred to as capturing of CO_2 from process or flue gases from processes utilizing biomass as raw material.

Current Status
Generally the same technologies that are planned to be used with fossil fuels would be applicable also to bio energy CCS (also referred to as BECCS), although there are differences in CO_2 capture from biomass and fossil power plants. Regarding flue gas composition in energy

generation applications there are no fundamental technical restrictions for applying CO_2 capture to biomass-fired power plants. In some processes, such as FT diesel or bio-SNG, very pure CO_2 stream is available, because the CO_2 needs to be removed from the process. Similar, low cost cases can be found in other biomass applications as well for example in biogas upgrading and hydrogen production technologies.

There is a very limited amount of work done regarding CO_2 capture from biomass-fired power plants not to mention other applications. Several studies and development work are on their way in Finland and also within broader context of IEA Greenhouse Gas Programme, but not much has been published thus far. Some work has also been done in Sweden regarding economics of bio-CCS, mainly concerning pulp and paper industry.

Major remaining R&D issues

- Identification of major technical and market based issues related to CCS from biogenic sources
- What are the technological solutions and special requirements in applying CCS to processes using biomass as raw material?
- What is the potential for Bio-CCS and what is the role that bio CCS can and will play in the energy system.
- Life cycle assessment of bio CCS

Vision on implementation

Bio CCS is amongst the first commercial applications of CCS due to the favourable processes needed in some applications. In the long run, there will be an incentive for capturing CO_2 from also biogenic sources. Biomass installations will be on the same line with fossil installations in considering applying CCS.

Description of work

- Identification of most technically and economically feasible Bio CCS applications
- Improve understanding of the potential for technologies/processes
- Effect of different place in the merit order differences in plant size and location on technical and economical viability of various solutions
- Improve most potential bio-CCS concepts
- Testing and demonstration of CCS under relevant conditions in different bio-CCS applications
- Experimental studies to investigate the effect of oxy-coal/biomass combustion on both radiative and convective heat transfer, slagging and fouling, pollutant emissions and carbon-in-ash compared to air under dry/wet simulated recycle conditions .
- To obtain detailed information based on full system simulation.

Objectives four year program

- Assess potential, sustainability and feasibility of BIO-CCS: A comparison of biomass to power with CCS with other forms of CCS in terms of costs, CO2 savings, technology readiness levels, and energy balance with a range of feedstocks
- An economic analysis of application of CCS to processes utilizing biomass as raw material?
- Identify and address major technical bottlenecks in Bio CCS applications

Partners

SINTEF, ECN, ENEA/CNR, LNEG, CLCF, SCCS, VTT

Milestones for first 24 month period

1. Identification of a first set of CCS technologies for use in Bioenergy processes that will be studied in more detail. Based on an inventory of bioenergy and CCS options. (Month 24)

SP4.3 CO_2 capture from other sources

Background

Apart from application in power plants, CCS is also an important technology to mitigate emissions from industry. The steel industry is has very large CO_2 emissions per site and offers possibilities for post-combustion, pre-combustion and oxyfuel CO_2 capture. Also cement industry and chemical plants are large CO_2 sources for which CCS is an option. Refineries offer a range of CO_2-rich sources, that vary widely in concentration and composition. In other words, for each industrial CO_2 source, specific questions exist which CO_2 capture technology to choose or whether novel technologies are needed.

Current Status

In several industry and European projects technology for CO_2 capture in specific industry is in development. The steel industry is working on piloting several technologies in the ULCOS project. Also oil companies are looking at CO_2 capture from certain CO_2-rich streams. But compared to the power industry, CCS in industry is lagging behind.

Major remaining R&D issues

- Identification of major sources and most prospective capture technologies
- Testing of known capture technologies for application in industries
- Development of novel capture technologies specific for certain CO_2 streams

Vision on implementation

CO_2 capture from some industrial CO_2 streams could be regarded as quick-wins and can be implemented in the next few years. For others R&D and piloting is necessary.

Description of work

- Identification of most technically and economically feasible Industrial CCS applications
- Perform detailed case studies for the implementation of certain technologies (e.g., solvents, membranes, CLC) for specific industrial CO_2 sources, including:
    - Technical, process design and economic evaluation
    - Experimental (lab scale) studies under specific conditions of the industrial process
- Study demands on CO_2 purity for either geological storage or re-use in the industry
- Integration of the CO_2 capture process in industrial sites concerning use of waste heat, steam, etc.

Objectives four year program

- Have finalised several detailed studies of the implementation of certain capture technologies to specific industrial CO_2 sources.
- Defining opportunities for the integration into the heat, cooling, steam, and other networks present at industrial sites

Partners

SINTEF, TNO, ECN, CLCF, VTT, Polimi, SCCS

Milestones for first 24 month period

1. Select the most feasible capture technologies for more detailed analysis based on an overview of industrial CO_2 sources and possible capture technologies for those sources. (Month 18)

4. Milestones

Milestone	Measurable Objectives	Project Month
M1.1	Common criteria defined for comparing solvent systems. Document describing comparison criteria based on capture efficiency, energy consumption, environmental impact, costs, operational challenges, etc.	12
M1.2	Short list of second generation solvents available. List of solvent names and class of solvent to be tested in pilot plant evaluated against common criteria	24
M1.3	Dynamic model in place. Model (or models) that is suitable to be used in developing control schemes is running and described in a document	24
M1.4	Common criteria defined for comparing sorbent systems for the three different applications. Document describing comparison criteria based on capture efficiency, energy consumption, etc. evaluated against solvents as a benchmark	12
M1.5	Short list of second generation sorbents available, evaluated against common criteria. Computational screening tools available to allow systematic screening of a wide variety of available materials and estimation of effects on plant performance of sorbent properties improvements.	24
M1.6	Test reporting CO_2 selective membrane with a CO_2 permeance of 5 $Nm^3/(h\ m^2\ bar)$ and a CO_2/N_2 selectivity higher than 60 at 20°C	18
M1.7	Design concept of high capacity membrane module available.	24
M2.1	Selected membranes for bench scale test and as the basis of module design, that have been scaled up to at least 25 $cm^2$and tested in relevant conditions in presence of H_2S or at high temperature	24
M2.2	Results of lab-scale testing of microporous and proton conducting membranes available. Decision whether these types show enough promise for CCS application to make the step to bench scale testing	24
M2.3	Common criteria defined for comparing high-temperature sorbent systems. Document describing comparison criteria based on capture efficiency, energy consumption, etc. evaluated against physical solvents as a benchmark (Month 12)	12
M2.4	Short list of novel sorbents for CO_2 and H_2S separation and for SEWGS and SER based on common criteria available	24
M2.5	Numerical model in place for the design of efficient high-temperature PSA and TSA cycles	24
M2.6	Results of experiments on flammability limits, ignition, etc. available as input for CFD modeling	24
M3.1	Advanced physical sub models implemented and validated relating to pollutant emission, combustion and radiation within commercial CFD code	24
M3.2	Initial results obtained of 3D flame imaging, coal ash, and boiler material behaviour under oxycoal combustion conditions	12
M3.3	Process simulation models constructed for Oxy-coal boiler and oxy-CFB plant optimisations including linking CFD code with process simulation as a part of virtual power system simulation	24
M3.4	Decision on most viable integration options for membranes in a power plant	12
M3.5	Selected membranes for 2000 h test and as the basis of module design, that have been upscaled to at least 25 cm^2	24
M3.6	Common criteria defined for comparing oxygen carriers, based on	12

Pag. 350

	integration studies of CLC in power plants and materials properties	
M3.7	Short list of novel oxygen carriers based on evaluation against common criteria and results of labscale testes available. Selection of novel oxygen carriers to be tested in large-scale test installations	*24*
M4.1	Agree with the EBTF on expansion of the work into EERA	*12*
M4.2	Consistent set of economic performance measures for use in the other SPs	*12*
M4.3	Identification of a first set of CCS technologies for use in Bioenergy processes that will be studied in more detail. Based on an inventory of bioenergy and CCS options.	*24*
M4.4	Select the most feasible capture technologies for more detailed analysis based on an overview of industrial CO_2 sources and possible capture technologies for those sources.	*18*

Pag. 350

5. Participants and Human Resources

The program participants commit more than 167 man years to the program[1]. The commitments in detail:

			Total	Post			Pre			Oxy				Cross		
				1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3
Name	**Country**	**Contact**	**Man months/year**	solvent	sorbents	CO2 membrane	H2 membrane	sorbent	H2-turbines	combustion	O2 membranes	CLC	oxy-turbine	process simulation	Bio CCS	other sources
IFP EN	France	Sylvie Haxaire, Claude Mabile	54	12	6					18		12		6		
SINTEF	Norway	Hanne Kvamsdal Rune Bredesen	83	8	8	3	8	8	6		6	8	8	8	6	6
ECN	Netherlands	Ruud van den Brink	94		20		20	30		6				12	6	
TNO	Netherlands	Earl Goetheer	42	20								10		8		4
RSE	Italy	Pietro Pinacchi	66		18		24				12			12		
IFE	Norway	Julien Meyer	6		3			3								
ENEA/CNR*	Italy	Guiseppe Girardi	370	52	57			56	31	73		24	22	40	15	
LNEG	Portugal	Dulce Boavida	66	12	6		6	6		12				12	6	6
UKCCSC**	UK	Hannah Chalmers	315	24	96	12	12	24	6	54		3	6	54	24	
HZG	Germany	Torsten Brinkmann	36			36										

[1] Based on 11 months per year

Pag. 352

Name	**Country**	**Contact**	**Man months/year**	solvent	sorbents	CO2 membrane	H2 membrane	sorbent	H2-turbines	combustion	O2 membranes	CLC	oxy-turbine	process simulation	Bio CCS	other sources
FZJ	Germany	Wilhelm Meulenberg	204			24	60					60			60	
POLIMI	Italy	Matteo Romano	60		6		12	12				12		12		6
Risoe/DTU	Denmark	Nikos Bonanas	72				36				36					
VTT	Finland	Antti Arasto Matti Nieminen	86							40		20		10	12	4
CSIC	Spain	Carlos Abanades	55		10		15	15		15						
VITO	Belgium	Frans Snijkers	50				10				30	10				
PSI	Switzerland	Peter Jansohn	84						36			24	24			
RC Rez	Czech Republic	Olga Ubra	55	22	11					22						
ETHZ	Switzerland	Marco Mazotti	44		11			22				11				

* ENEA participates associating several organizations:

- Sotacarbo, which is a research organization controlled (50%) by ENEA operating in CCT and CCS
- CNR, which is a major research council in Italy covering several areas, and operating in CCS too
- Several universities: Cagliari, Roma La Sapienza, Roma Tor Vergata, Roma TRE, Pisa, Milano, L'Aquila, Napoli

** UKCCSC is part of UKERC. Participating institutes are: CLCF (Leeds), UNOT (University of Nottingham), SCCS (Scottish centre for CCS), Imperial College.

Pag. 352

6. Infrastructures and facilities

Short Name	Facilities (to be completed)
IFP EN	• IFP Energies nouvelles has at its disposal a sound set of experimental equipment (lab and small pilot scale) in the fields of post combustion capture with amine based solvents, chemical looping and oxycombustion
SINTEF	• Full height pilot plant facility for solvent testing at real conditions • Lab pilot facility for initial solvent testing • Lab pilot facility for testing of packing material and specifically studying pressure drop and hydrodynamics in absorber and stripper columns • Several lab equipment for characterization of possible solvents • Steady state simulator for CO_2 absorption in different solvent systems (CO2SIM) • Material synthesis; Solid-state synthesis, Hydrothermal synthesis, High throughput synthesis • Material characterization; XRD, In-situ HT XRD, Atmospheric TGA, High pressure TGA, TGA/MS, SEM, TEM, BET, pressure / temperature swing adsorption, Solid-state NMR lab, Low- and high pressure single component Sorption sorption isotherms, Quantum chemical modeling, • Laboratory reactor testing (PSA, CFB reactor,…) • Automated 8-bank high throughput instrumentation for multicycle breakthrough measurements using realistic gas mixtures (<30 bar, <800°C). • Membrane preparation facilities (microwave sputtering equipment) • Membrane test units • High pressure combustion facility designed for oxy-fuel and hydrogen based studies (20 bar, 90g/s CO2 @ 300C) • Instrumentation for combustion emission characterisation designed for oxy-fuel • Laser diagnostics lab for velocity and species concentration measurements in combustion processes • Computational facility for parallel processing of reactive flows in the order of magnitude ~ 1000 cores • CFD codes for turbulent combustion (RANS&DNS), multiphase flow
ECN	• CO_2 sorbent pressure swing adsorption units, including full PSA unit with six tubes of sic metres each. • Membrane reactor test unit for membrane water-gas shift and membrane reforming • High-pressure test units for sorbents and calatysts equiped with sulphur feeding • Labs for preparation of CO_2 sorbents, Pd-based membranes and oxygen selective membranes • Test equipment for oxygen selective membranes
TNO	• Fully equipped laboratories for measuring reactive absorption processes • Equipment for Kinetic measurements • Vapour liquid equilibrium measurements • Vapour pressure measurements • Micro- and miniplant (mobile fully automatic demonstrators for 24/7 absorption/desorption) • Pilot plant (full height pilot plant located at the E.ON power plant at the Maasvlakte) • Fully equipped analytical laboratories (NMR, GC, LC MS etc,) • Laboratories for investigation chemical looping combustion (ao fixed bed laboratorium pilot plants)
RSE	• High temperature membranes and WGS testing facilities • Membrane preparation facilities • Material characterisation (SEM, mechanical testing) • Solid sorbents preparation facilities • Solid sorbent testing facilities
IFE	• Laboratories for CO_2-sorbent production and testing (TGA, fluid bed

	agglomerator, SEM, XRD, mechanical strength measurement, attrition test apparatus) • Laboratories for testing of SER and SEWGS reactions in bench-scale fixed bed reactors (micro GC gas analysis). • Fluidized bed reactor test installation (10-30 kW) for testing of the SER reaction in a batch mode. • Test pilot installation in construction (30 kW) for testing of the SER process in a continuous mode with a dual bubbling fluidized bed reactor system. • Circulation model for design of fluidized bed rector system for the SER-process. • Different CFD-softwares, COMSOL Multiphysics software.
ENEA/CNR	• Laboratories for enhanced coal gasification and syngas testing • Laboratories for CO2 solid sorbent testing and characterization • Laboratories for basic chemistry • Laser diagnostic laboratory for local thermo-fluid dynamics measurements in test rigs and pilot plants • Advanced diagnostic laboratory for combustion and gasification • Zecomix platform (pilot) with fluidized bed reactor for sorption-enhanced water-gas-shift and CH4 reforming process • IDEA test rig for H2 combustion testing, using laser spectrometry and advanced diagnostics • COMET facility for high pressure (10 bar) combustion testing, using laser spectrometry and advanced diagnostics • Sotacarbo platform for CO2 capture and hot desulphurization processes tests • Advanced CFD (RANS and LES) • High performance simulation systems (parallel computing) • Combustion systems equipped with optical diagnostics, sampling probes and chemical instrumentation for the analysis of gas and condensed phases produced from typical pyrolysis/combustion systems • Chemical lab equipped with SEM, EDS, TGA, ICP-MS, ESI-APPI-MS, and analytical instrumentation for preparation and characterization of CO2 sorbents. • Lab scale burner for studying the oxidative and pyrolytic behaviour of coal particles injected a high-temperature flame conditions. • Lab scale fluidized bed reactors for calcium looping studies • Lab scale and bench scale fluidized bed reactors for chemical loping combustion studies • Plug flow reactors equipped with optical diagnostics • HydroPyrolyzers • Analyzers and impactor systems for particle size distribution measurements
LNEG	• Analytical Support (GC for gases samples) • Hydrogen separation membrane reactor • Separation membrane reactor • GC for liquids and gases samples, • HPLC, GPC, GC/MS, heating value, Capillary Electrophoresis, FTIR • TGA • Fluidised bed gasifier with 3.7 m in total height and 0.2 m of square section. • Fluidised bed gasifier with 1.5 m in total height and 0.08 m of internal diameter • Syngas cleaning installation • Water gas-shift reactor • Pilot scale fluidized bed oxyfuel facility/ Combustion gas analysers; • AAS, ICP-OES, CHNS analysers, Ion Chromatography, Fusibility muffle, SEM/EDS, XRD , X Ray Diffraction • Fluent, gPROMS and GAMS softwares
UKCCSC - CLCF	• 300kw oxy-coal/biomass state of the art pilot scale combustion test rig facility with hot flue gas recycled • 250kw Rotary kiln for gasification of coal/biomass/waste + gas cleanup system • pilot-scale

	• 250 kw oxy-gas/liquid combustion test rig facility • Virtual System Simulation codes (Techno-economic, Process, CFD and , Carbon footprint) for system integration/optimization • Laser diagnostic (PIV, PLIF and LDV) for velocity and species concentration measurements in combustion processes • QA/QM modelling, CFD, Process simulation software with in-house physical sub models (e.g., radiation, Hg retention, slag/deposition, SO2/SO3, Cl/Br chemistry, process-CFD link, etc.) • CO2 Characterization laboratory • Material characterization, including XED, TEM, SEMs with Link Systems to EDX facilities, X-ray and Electrical tomography, FTir Spectrometry, TGA; TGA/FTir; STA/MS, Ultimate (CHNSO) analysis, Surface area and porosity of solids, etc.. • We also work closely with leading Chinese research groups in the area and industries both in the UK and China on experiments on larger scale industrial furnaces from 0.5 MW up to 300MW (funded projects with and Collaborative agreement on CCS/clean coal technology with Zhejiang and University) • Spectro-Mobile ICP-OES lab capable of continuous measurement of up to 70 species • Analytical lab equipment for characterisation of various solvents
UKCCSC – Nottingha m	• Material characterization; XRD, Atmospheric TGA, SEM, TEM, BET, NMR lab, Sorption isotherms, MLA.
UKCCSC-IC	• 2 Fluidised beds capable at operation with 20 – 30 g of sample at pressures up to 20 bar with simultaneous temperature of 950^{o}C. • Wire mesh reactors capable of heating samples at rates of up to 10,000 K/s, to temperatures of 1000^{o}C and pressures of 70 bar • Fixed bed reactor with similar P / T capabilities to the fluidised beds. • New laboratory, designed for integrated research in capture and storage • Amine-based CO_2 capture pilot • Material characterization; XRD, Atmospheric TGA, SEM, TEM, BET, pressure / temperature swing adsorption, Hg intrusion, skeletal and envelope density pycnometry • Trace elements laboratory, including all digestion equipment and ICP-AES. • Profilometry, AFM • Tabletting and pelletisation suite for the production of artificial sorbents.
UKCCSC – SCCS	• Dual-piston PSA/VSA apparatus to measure column dynamics with fast (up to 1 Hz) pressure cycling. • Zero Length Column (ZLC) chromatographic apparatuses for quick performance evaluation of the adsorbent with less than 10 mg of sample. • High pressure volumetric adsorption apparatus. • Mercury porosimeter for the measurement of pore size distribution (0.007μm to 300μm) and pore structure • Volumetric adsorption system with vapour module and MS interface for the measurement of adsorption isotherm and pore size distribution (3.5 to >4,000 A). • Tapped density Analyser and ultrapycnometer for skeletal or bulk density measurement for an adsorbent. • TG-DSC to measure gravimetric adsorption isotherm and heats of adsorption. • Rigorous simulation of cyclic adsorption processes (PVSA). • Unisim process model on a variety of amine process configurations. • Ansys CFD for reactor modelling • gPROMS (and Mathcad) power plant modelling, including full integration with capture plant models • 200L oxyfuel pulverised coal ignition test apparatus (funded) • High temperature wire mesh apparatus for coal and biomass characterisation • Single particle biomass ignition and combustion apparatus for suspension firing measurements

HZG	• Laboratory scale polymer synthesis • Analytical infrastructure for polymer characterisation as SEM, TEM, TGA, DSC, GPC, NMR • Flat sheet membrane production facilities: phase inversion for asymmetric and integral asymmetric membranes, roller and immersion coating for composite membranes, breadth up to 600 mm, length up to 250 m • Autodesk Inventor for membrane module design • Aspentech Aspen Custom Modeler and Aspen Plus for membrane module and process modelling and simulation • Various laboratory scale membrane test units for single and mixed gases • Gas permeation pilot plant for investigation of membrane processes, possibility to be integrated with pressure swing adsorption unit, feed flowrate up to 50 Nm^3/h, feed pressure up to 4 bar, permeate pressure down to 33 mbar, water saturated feed gas
FZJ	• Materials synthesis, processing, characterization and testing especially of planar (multi-)layered functional ceramics for gas separation membranes • Determination of environmental stability and thermo-mechanical properties in process gases • Sol-gel facilities; clean room; spray drying; pressing technology (multiaxial/isostatic, cold/hot); coating technology (wet powder spraying, vacuum slip casting, screen printing, spin coating, dip coating) • thermo-mechanical and chemical testing in controlled atmosphere; permeation measurements • characterisation methods for ceramic membranes (XRD, SEM, TEM, Ellipsometrie, He-Leak rate, flux measurements, SIMS) • Tape casting facilities, warm pressing facilities • Plasma spraying facilities • Phisical vapor deposition equipment, Screen printer, Roller coating machines • Hot isostatic pressing (HIP) • Software for process and LCA simulations
POLIMI	• Dedicated modeling software for modeling of power plants
Risoe/DTU	• Ceramic processing equipment suitable for manufacture of high temperature oxygen and hydrogen membranes like; tape casters, extruders, lamination machinery, screen printers, air spray guns etc. • Equipment for characterization of material properties like XRD, TG, DSC, SEM/TEM, conductivity (ionic and electronic) • Secialised test rigs for measuring permeation fluxes through high temperature oxygen and hydrogen membranes. • Test rigs for high pressure testing of oxygen and hydrogen membranes.
VTT	• CLC development: spray dryer, sintering furnaces, lab & bench scale fluidised bed reactors, SEM, EDS, TGA etc. • Oxyfuel CFB: lab/bench scale oxyfuel CFB, pilot scale Oxyfuel CFB • Software tools and in-house codes (Apros, Aspen plus dynamics, Balas etc.)
CSIC	• CO_2 sorbent TG units adapted for very long multicycle testing in temperature swing mode. • 30 kWt twin circulating fluidized bed test facility (two interconnected reactors of 0.1 m i.d.and 6.5 m height). Used for carbonate looping testing so far. • High temperature catalytic testing and membrane permeation rigs for flat disc membranes. • Lab scale facilities for material synthesis(sol-gel, hydrothermal, freeze-drying, etc) and membrane manufacture. • Surface chemistry, textural and electrochemical characterisation characterization (XPS, UV-Vis, Raman, FTIR, IRAS, N_2/Ar sorption, Interferometry, TPR/TPO/TPD-MS, Calorimetry, EIS, etc.)
VITO	• Ceramic processing equipment for membranes and O-carriers: spray dryers, freeze dryers, sintering furnaces (oxides and non-oxide ceramics, metals and alloys), shaping of dense and porous structures by uni-axial and cold isostatic pressing, tape casting, gel casting, 3D-fiber deposition, spinning of hollow fibers, ... • Analysis and characterization: oxygen permeation measurements, IS, SEM,

Pag. 357

	EDX, EPMA, IA, TGA, (M)DSC, zetapotential, granulometry, ceramography, BET-N_2-adsorption, MIP, ...

7. Contact Point for the Sub-Programme on *CO_2 capture*

Dr. R.W. van den Brink
ECN Hydrogen Production & CO2 Capture
Westerduinweg 3
NL-1755 LE PETTEN
The Netherlands
Tel: +31-224564188
vandenbrink@ecn.nl

Pag. 357

Pag. 358

Pag. 358

Pag. 359

Annexe 2 – Sub-programme on CO_2 Storage

Pag. 359

Pag. 360

Pag. 360

EERA

EUROPEAN ENERGY RESEARCH ALLIANCE

CO_2 Capture and Storage (CCS)

Sub Programme on CO_2 storage

Version: 2.3

Last modification date: 04.01.2011

Contact person: Sergio Persoglia, spersoglia@ogs.trieste.it

Table of Contents

Summary of the Sub Program on CO_2 Storage

The knowledge acquired in the last decade thanks to research performed by companies, universities and research centres in Europe and worldwide at laboratories, sites of naturally occurring subsurface CO_2 emissions and test and pilot sites for subsurface CO_2 geological storage, has demonstrated that geological storage of CO_2 is a viable and secure technology, which can contribute in meeting the reductions of CO_2 emissions to the atmosphere that are needed to mitigate climate change.

To do so, ZEP suggests having 10-15 storage sites of 2 MCO_2/year fully operative within 2015, 30-40 within 2020 and 80-120 within 2030. The IEA Blue Map scenario considers 120-180 storage sites by 2050, while the Bellona scenario fixes the number to 340-510 for the same period. This means that a very large deployment of CCS techniques has to happen in the coming decades and that it has to be accepted by the general public in a large number of European countries and elsewhere.

Moreover, if we consider that a fully integrated project can take 6,5-10 years before it becomes operational, an that the research for completely new concepts and techniques can have a similar order of magnitude, it appears evident that the stakeholders active in CCS have to improve and exploit now the existing techniques and, at the same time, to start now new researches for innovative methodologies.

Both these actions require multidisciplinary expertise and coordinated efforts to share the existing knowledge in view of its full exploitation and to plan and start executing innovative research.

During the first period, which the EERA Participants have fixed in four years, the focus will be on research advancements able to contribute to a wide and quick start of the first CCS demonstration projects. At the same time, the EERA Participants intend to build upon past experiences of collaboration and integration among them, to quickly progress along the learning curve on how to better achieve the joint research targets. Alliance is, hence, an appropriate term underlying the definition and execution of the EERA Sub Programme on CO_2 storage.

The general objective of this programme is to produce a meaningful advancement in the following specific issues that are recognised as key elements for a safe and wide deployment of the CCS techniques:

- identification and characterization of suitable geologic complexes that may be used for storing CO_2, with no interference with other human activities, no impact on the ecosystem, having capacities that match the sources and that guarantee safe conditions for the whole period of storage operations, closure and post closure;
- development of tools that allow better understanding and evaluation of the behaviour at different time scales of the injected CO_2 and its interactions with the storage complex and the surrounding formations up to the surface;
- further development and integration of a large set of currently-available monitoring techniques and the definition of recognised protocols for their use in a variety of geological, environmental and operative contexts.

The major R&D items identified in this programme correspond to those in a series of roadmap documents of ZEP (Zero Emission Fossil Fuels Technology Platform), CSLF (Carbon Sequestration Leadership Forum) and GCCSI (Global CCS Institute), and are aimed at fulfilling the requirement of the EU Directive on CO2 geological storage.

The Sub Programme on CO_2 geological storage is broken down in three sections with specific objectives and identified activities.

- **SP1 Monitoring**
  - Surface and near-surface

- Reservoir and overburden
- Wellbore system
- Integrated closed-loop monitoring and modelling

➢ **SP2 Static modelling**
- Geological structure of the storage complex
- Petrophysical, geomechanical and geochemical characteristics of the storage complex
- Storage potential estimation
- Uncertainties management
- Alternative geological storage solutions

➢ **SP3 Dynamic modelling**
- Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches
- Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling
- Workflow design methodology and validation.

For each specific objective, the envisaged activities are described in a longer view, with indication of the objectives for the initial four-year program and the intermediate milestones.

Finally, there is a quick overview of facilities already available that the Participants intend to use in their joint activities.

1. Background

The knowledge acquired in the last decade resulting from research performed by companies, universities and research centres in Europe and worldwide at laboratories, sites of naturally occurring subsurface CO_2 emissions and test and pilot sites for subsurface CO_2 geological storage, has demonstrated that geological storage of CO_2 is a viable and secure technology that has to be used, together with energy saving and renewable energies, if we want to meet the reductions in CO_2 emissions to the atmosphere that are needed to mitigate climate change.
Two key issues that may constrain large-scale deployment of CCS techniques are recognized: the costs for capturing CO_2 at the large industrial sources and the acceptance by the general public of the storage in deep geological formations.
And, of course, “there is no reason for capturing CO_2….if we have no places where to store it in the underground” or, in other words, “no capture without storing options”.
Moreover, we should not forget the “dimension” of the problem: the European CCS Demonstration Plan by ZEP suggests having 10-15 storage sites of 2 MCO_2/year fully operative within 2015, 30-40 within 2020 and 80-120 within 2030. The IEA Blue Map scenario considers 120-180 storage sites by 2050, while the Bellona scenario fixes the number to 340-510 for the same period.
If we consider that the time needed to choose a suitable storage site, from the first identification at basin scale, up to the definition “where to drill” may be in the order of more than 5 years, it is easy to understand that it is essential to quickly develop methodologies that will ensure the efficient and safe management of large CO_2 storage sites within wider regions onshore and offshore. This goal, that requires multidisciplinary expertise, exceeds the research capabilities of single companies or research institutes. Joining efforts and resources within an agreed joint programme of activities may therefore be a key factor to achieve the required results.

2. Objectives

The general objective of the EERA Sub Programme on CO_2 storage is to produce a meaningful advancement in the following specific issues that are recognised as key elements for a safe and wide deployment of the CCS techniques:

- identification and characterization of suitable geologic complexes that may be used for storing CO_2, with no interference with other human activities, no impact on the ecosystem, having capacities that match the sources and that guarantee safe conditions for the whole period of storage operations, closure and post closure;
- development of tools that allow better understanding and evaluation of the behaviour at different time scales of the injected CO_2 and its interactions with the storage complex and the surrounding formations up to the surface;
- further development and integration of a large set of currently-available monitoring techniques and the definition of a recognised protocol for their use in a variety of geological, environmental and operative contexts.

The major R&D items required to achieve these goals have been the subject of a series of meetings and roadmap documents of ZEP (Zero Emission Fossil Fuels Technology Platform), CSLF (Carbon Sequestration Leadership Forum) and GCCSI (Global CCS Institute).

The time frame for achieving the above mentioned general objectives covers the next ten years, if we seriously want to have a large-scale deployment of CCS techniques beyond 2020. In order to be ready in time, R&D has to be performed now by mutualising capabilities, instruments and infrastructures available at the EERA members and associate participants.

Of course, another implicit and very important objective is to deepen the collaboration between the members and to follow “a learning curve” on how to efficiently interact for reaching common research goals that require multidisciplinary expertise.

We are confident to be able to progress quickly along this pathway, because many of the members of this EERA Sub Programme have already collaborated in the past and continue to do so, e.g. in the framework of CO2GeoNet, the European Network of Excellence that had, as a major goal in the period 2004-2009, to reach a progressive and durable integration among its members. Now the goal of the European Energy Research Alliance is even more ambitious, but we can take benefit from existing experience to shorten the times and to start the joint activities foreseen in the four years program.

The Sub Programme on CO_2 geological storage is broken down in three sections with specific objectives.

- **SP1 Monitoring**
  - Surface and near-surface
  - Reservoir and overburden
  - Wellbore system
  - Integrated closed-loop monitoring and modelling

- **SP2 Static modelling**
  - Geological structure of the storage complex
  - Petrophysical, geomechanical and geochemical characteristics of the storage complex
  - Storage potential estimation
  - Uncertainties management
  - Alternative geological storage solutions

- **SP3 Dynamic modelling**
  - Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches
  - Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling
  - Workflow design methodology and validation.

3. Description of foreseen activities

SP1 Monitoring

Background

Current CO_2 storage projects demonstrate that techniques exist to monitor the behaviour of CO_2 stored in deep subsurface reservoirs. The requirements defined in the EU storage directive 2009/31/EC can be met through a combination of techniques that together cover the entire storage complex. While current monitoring systems and operational practices provide a good starting point for near-term, large-scale CCS projects, several challenges remain.

Monitoring techniques often detect CO_2 in the subsurface indirectly. For example, seismic methods measure the effect of CO_2 on the seismic velocity and contrast. The relation between the parameters actually measured and the quantity of CO_2 at depth is often not uniquely defined. It is expected that quantification of volumes of CO_2 in any location in the storage complex is best obtained through combination of monitoring techniques. Combinations must be found that have an optimum performance in terms of durability, resolution and cost.

The design of a monitoring system, the strategy for monitoring in the different phases of storage (preparation, injection, post-closure and post hand-over) is not a mature process yet. Monitoring should be aimed at the storage complex elements with the highest associated risk, but it is presently not clear which monitoring technique is most efficient, in terms of detection level, cost and durability.

Monitoring, especially post-closure, will also require techniques that are passive and can be run autonomously for a long period of time. Such techniques must be developed and tested.

Finally, all the elements of a comprehensive monitoring infrastructure must be tested at real or realistic sites. Some test sites should be deliberately chosen to allow CO_2 migration from an injection point, through the overburden to the surface and into the atmosphere. Natural analogues may be used and experiments of deliberate and controlled release of CO_2 at depths will be crucially important.

Objectives

The research activities of the sub-programme on monitoring focus on meeting and resolving these challenges:

- developing passive, long-term monitoring techniques (these may include autonomous active techniques, such as ERT or seismic measurements with permanent source-receiver deployment...);
- establishing or improving methods to detect and quantify CO_2 in different parts of the storage complex;
- preparing for a field test of a suite of monitoring techniques;
- developing a method for constructing monitoring scenarios (monitoring plans).

Current CO_2 storage projects and projects that will be started in the near term will be used to apply and test new developments.

The work program is structured into four parts:

- surface and near surface;
- reservoir and overburden;
- well bore system;
- integrated closed loop monitoring and modelling.

This division is the result of an approach to monitoring that is demand driven, rather than technology driven. In each of the storage complex areas, the central question to be answered is: “How and how well can we detect CO_2?” This question is not necessarily aimed at CO_2

migrating out of the reservoir, but also at detecting the behaviour of CO_2 inside the target formation. Key parameters in this regard are detection limits and accuracy. Current and future research aims at combining monitoring techniques to increase detection levels and to quantify volumes of CO_2. Rather than striving to improve individual monitoring techniques, advances are expected to arise from combining information from different techniques to improve detection and quantification of CO_2 in the storage system, to be able to provide the data required by the EU storage directive.

The final area of work on integrating the monitoring techniques into a monitoring system for the entire storage complex includes ranking available techniques and selecting those techniques that are best suited for the site at hand. Another aspect of integration is combining monitoring data and models of the injection complex. The significance of monitoring data and deviations from the expected behaviour can only be established through comparison with predictions from up-to-date models of the storage complex. Monitoring data will lead to both updates of these models and, if necessary, updates of the monitoring strategy and, also if needed, remediation measures. The feedback link between monitoring data and storage site models is essential and is an integral part of any monitoring plan. Relevant research in this area is done in the framework of hydrocarbon production.

SP 1.1 Surface and near-surface

Background

Even if the main objective of risk management is to prevent any leakage to the surface, monitoring at the surface is absolutely necessary in order to demonstrate to stakeholders that the storage is safe and to answer any “what if” scenarios. There are two aspects to monitoring this compartment of the storage site:

- from the safety point of view, it is the last opportunity to characterize leakage prior to CO_2 reaching the surface, and then to trigger mitigation measures in affected areas;
- in order to comply with the ETS Directive 2003/87/EC, monitoring should be able to quantify any emission of CO_2 back to the atmosphere and evaluate the amount of emissions trading allowances that should be surrendered.

In both cases, monitoring methods should be fit for purpose, covering areas as wide as possible, detecting and quantifying quantities of CO_2 as low as possible (over the natural background emission level) and, if possible, autonomous. Measured parameters are of physical, geochemical or environmental order and then chemical, biochemical, geochemical and geophysical methods are to be used.

Description of work

The following R&D directions can be envisaged.

Developing methods for wide area covering

The extension of the future storage sites, several tens of km², implies that baseline measurements for natural CO_2 emission and repetitive measurements during and after storage operations should cover large extensions. Methods such as vehicle or airborne mounted or even remote sensing should be developed for onshore sites, with particular attention to new sensors, sensitivity and repeatability of measurements. Airborne sensors should be able to measure CO_2 emissions both directly and indirectly through the stress on vegetation. Offshore, new sensors should be developed, towed by a vessel as for sea-beam or seismic, to map CO_2 leakage at the sea bottom, or behaviour change of marine organisms.

Data acquired with sensors, should be integrated, during baseline surveys and subsequent monitoring surveys, by experimental physical, chemical and biological data selected in order to obtain the best performance in terms of cost/benefit ratio.

Developing permanent passive and active systems

The lifetime of storage, including closure and post-closure phase, will take several tens of years and need monitoring systems that can work for many years with real time transmission and low maintenance. Choice of methods and sensors will be based on detection threshold, ease of deployment and durability. Even if the environment at the sea bottom is definitely adverse, such offshore permanent arrays of sensors could be considered in the future.

Integrating experimental mature and emerging devices in autonomous systems for quantifying the leakage flux in offshore environment

The term "leakage" is generally used for phenomena that can be quantitatively characterized by evaluating a "flux". Such evaluation is possible only by coupling sensors to oceanographic platforms able to evaluate water dynamics like gliders, floats, acoustic current meters (ADCP, ADV). Those platforms could be employed following a wide range of experimental strategies dictated by the need to properly sample the physical processes active in sea (tide, internal waves, wind waves, turbulence) and by the geometry and dimensions of the potential leakage: point source or diffuse source. Accuracy of quantification depends on the ability of the devices to resolve high frequency processes up to the scale of turbulent diffusion.

An alternative method is to undertake routine surveys by remotely operated (unstaffed) submersibles, to detect seabed changes, or bottom-fauna changes, which can be calibrated by laboratory and seabed experimental releases of CO_2.

Accurate and fast response sensors for measuring chemical species for participating into marine inorganic carbon cycle (pH, pCO_2, Talk, DIC) are needed both for implementing emerging systems like a moored eddy correlation system or to be installed on moving platforms. The lack of such sensors is currently a limiting gap in quantification of leakage flux.

In order to understand if the low fluxes of CO_2 determined by benthic chambers at the sediment-water interface are due to natural processes (i.e. degradation of organic matter and/or dissolution of $CaCO_3$) or to the seepage of the stored CO_2 from the geological complex, it is important to establish its origin. This can be obtained measuring the isotope composition of carbon (d13C) in the bottom water. Furthermore, due to the seawater characteristics (pH about 8,1) and in presence of small fluxes, CO_2 should be mainly present in the aqueous phase as dissolved inorganic carbon (DIC). So, it is essential to determine this chemical form, other than the gaseous CO_2 (as bubbles or free solvated), in order to keep into account the CO_2 speciation in seawater. The determination of pH and alkalinity in the same water sample would define the marine carbonate system. The knowledge of the carbonate system in seawater, together with information about the sedimentary compartment (pore water and solid phases for other chemical parameters), is useful to better understand the processes responsible of the observed CO_2 fluxes.

Developing methods to measure the impact on the environment and evaluate the efficiency of remediation measures

Many monitoring methods already exist in areas such as industrial and agricultural contamination, dispersion of pollutants, etc…, but there is very little knowledge about evaluating the impacts of diffuse and long term CO_2 leakage on the environment (e.g., the risks associated with the bioaccumulation and biomagnification due to the bioavailability of contaminants enhanced by acidification). Consequently, there is a large field of investigation about what should be measured and what should be the indicators of damage to the environment and its possible remediation over mid and long term. Projects such as RISCS or the Norwegian shallow laboratory, or the SCCS shallow marine seabed test site, should help to define these indicators, as well as projects dedicated to natural analogues.

Moreover, only limited knowledge is available to date on the rate, extent, and dynamics of CO_2 fixation in soils, especially in terms of non-phototrophic microbial activity. In normal conditions on a yearly time scale, the C input by plant litter to soils is more or less balanced by soil respiration being the mineralization activity of microorganisms; however in certain soil environments, the uptake of CO_2 may be larger than mineralization of carbon. This can be used to investigate changes in soil bacterial ecology. In fact there are at least two possibilities. It can be expected that when the soil air CO_2 concentration increases, due to leakage of underground storage, the bacterial population will change in general. On the other hand increased soil air CO_2 levels can lead to direct increase of chemolithoauthrophic growth, and this can be investigated by making use of primers.

Developing microbial monitoring

A CO_2 storage site might be monitored by investigation of the local prokaryotic community composition, making use of the fact that some microorganism proliferate better at higher CO_2 availability, being able to its assimilation. So, the increment in CO_2 availability results in a similar increase in these populations. Such microbial monitoring is based on an assumption that CO_2 migration induces detectable alteration of the local prokaryotic community. The literature reveals little information about existing solution on microbiological monitoring method used at CO_2 underground storage sites. Research should be aimed at defining: abundance of important microbial physiological groups occurring in seawater environments at higher CO_2 concentrations, such as environment micro-biocenotic composition and identification of indicative microorganisms sensitive to CO_2 supply.

Integration of the different monitoring methods at sea

Because CO_2 is also produced by biological processes that vary in time and space, it can sometimes be difficult to interpret results in terms of separating the shallow background values from a potential deep contribution. It is thus critical to quantify the range of biological CO_2 production and consumption over different time scales (daily, seasonally) and in different climatic conditions in order to better distinguish a leakage signal from the natural background. Therefore baseline surveys should take account of biological carbon cycling processes and permanent passive and active monitoring systems should be integrated by discontinuous sampling of wide areas in order to monitoring biological communities and detect and measure the effects of leakage on marine organisms and ecosystems.

The use of stable carbon isotopes (δ13CDIC) could be very useful to understand the origin (fossil or biogenic) of the CO_2 fluxes at the sediment-water interface. Furthermore, the knowledge of the carbonate system in seawater, together with information about the sedimentary compartment (pore water and solid phase) for other chemical parameters (nutrients, macro elements, etc.), is useful to better understand the processes responsible of the observed fluxes.

<u>Objectives four year program</u>

- Develop method for wide-area monitoring
- Develop methods to measure the impact of CO_2 leakage on the environment
- Deploy long-term active and passive monitoring systems, both onshore and offshore
- Establish or improve methods to detect and quantify CO_2 fluxes from the storage complex at or near the surface

<u>Milestones for first 24 month period</u>

Milestone	Measurable Objectives	Project Month
M 1.1.1	Deploy a benthic chamber to measure the baseline in terms of fluxes and isotopes at several locations	12, 24
M 1.1.2	Deploy areal and point measurements at natural analogues (sites where CO_2 is leaking naturally)	24
M 1.1.3	Establish a preliminary list of damages to the environment, as a result of CO_2 leaking from the storage reservoir to the environment	12, 24
M 1.1.4	Develop and validate remote sensing monitoring methods to detect the impact of CO_2 leakage at natural analogue sites, over wide areas	12, 24

Participants

BGS, BRGM, EMEPC, IFPEN, LNEG, MERG-Imperial, NIVA, OGS, RSE, TNO, UK-SCCS, UK-UNOTT, University of Evora, University of Rome, VITO.

SP 1.2 Reservoir and overburden

Background

Monitoring is an essential tool to check if the injected CO_2 is behaving as anticipated and if it is interfering with the cap-rock in such a way of decreasing its containment capabilities. This requires:

- defining monitoring strategies dedicated to the control of the migration of the CO_2 inside the target formation (migration and quantification);
- detecting and quantifying early migration through the overburden layers close to the target formation.

Description of work

The following R&D directions can be envisaged.

Image / measure CO_2 in the target formation

Detecting the behaviour of the CO_2 inside the target formation requires deployment of complementary technologies sensitive to CO_2 in different physical states: free CO_2, dissolved CO_2 and mineralized CO_2 as far as long-term monitoring of the injected CO_2 is concerned.

Seismic methods are now well known to be able to detect the presence of free CO_2, but taken alone, these methods often fail to precisely quantify the gas saturation. It is then necessary to combine seismic data with other ones sensitive to the fluid saturation, as for instance electromagnetic or gravity measurements. The way to efficiently combine seismic information and other measurements like electromagnetic data to obtain a precise CO_2 saturation determination in the target formation is a key element in improving the monitoring of free CO_2.

Following the dissolved CO_2 is not crucial during the early stage of the storage operations. Nevertheless, it is important to be able to monitor year after year the quantity of the dissolved CO_2 to confirm that the storage behaves as expected. Due to the uncertainty related to modelling of the dissolution process, calibration data from a controlled experiment would be desirable.

The efficiency and reliability of seismic, electromagnetic and gravity methods in determining the CO_2 variation in saturation in the target formation will be tested through modelling, based on advanced and non conventional representations of the porous media and of the fluid contained in them, to design the optimal and low cost acquisition pattern, that guarantees the repeatability of the measurements for a long time interval. Even with previously acquired geophysical data (seismic, gravity, EM) it is possible to re-process and selectively sample aspects of existing data to target direct detection of CO_2.

The specific case of surface deformation measurements, either by satellite or ground based methods, as a way to map the CO_2 plume migration in the reservoir will be explored in order to assess its applicability and limitations.

Early detection of CO_2 migration through the first caprock layers

As far as the integrity of the storage is concerned, it is of primary interest to continuously control at affordable costs, specific weak areas in the nearest caprock layers indicated by the risk analysis. This kind of monitoring aims at providing early alerts for remediation actions.

Hence, high-resolution techniques such as well active and passive seismics can be deployed for this goal. In particular, the use of passive seismic, merging surface and downhole data, will be explored in order to characterize reservoir and cap rock integrity.

The aim of this activity can also be dedicated to defining other physical or chemical measurements able to detect very small flow rates of free or dissolved CO_2.

This will be done through the combined use of experimental measurements and modelling, in order to establish the detection threshold and spatial extent of the detectability for the different measurements, and define an optimal array for a long-term monitoring at relatively low costs.

Induced microseismicity

The injection of CO_2 requires the formation pressure to be exceeded, as the injected fluid needs to displace or compress the existing fluid or compress the rock. Therefore, deep well injection may trigger seismic or microseismic activity. Microseismic monitoring can be used to detect accidental over-pressurization of the formation as it is likely to allow for real-time adjustment of injection pressures.

<u>Objectives four year program</u>

- Develop or improve methods to detect and quantify CO_2 in or near the reservoir
- Improve the knowledge of the options for and limitations to combining monitoring techniques to improve the imaging and quantification of CO_2 in or near the reservoir

<u>Milestones for first 24 month period</u>

Milestone	**Measurable Objectives**	**Project Month**
M 1.2.1	Develop or test new methods of processing seismic data to image and quantify CO_2 in the reservoir	12, 24
M 1.2.2	Exchange with the EERA program on Geothermal Energy on induced seismicity	12
M 1.2.3	Deploy passive seismic instruments over an active storage site	24

<u>Participants</u>

BGS, BRGM, ETHZ, IFPEN, KIT, LNEG, OGS, TNO, UK-Bristol, UK-SCCS, University of Evora.

SP 1.3 Wellbore system

<u>Background</u>

A well forms a penetration of the caprock and therefore is a potential migration pathway to shallower formations or even the atmosphere. In order to detect the onset and magnitude of any possible migration along the well, the wellbore system needs to be monitored. Several tools already exist which can monitor specific properties of the wellbore system. Most of these have been developed and applied in the oil and gas industry.

For wells in CO_2 storage reservoirs there is the need for specific tools and strategies that take into account the specific characteristics of geological storage of CO_2. This includes tools suitable for downhole placement over prolonged periods of time, investigating the applicability of existing tools (alone or in combination) and developing strategies how to effectively deploy them. Of special interest are previously abandoned wells, which generally are more difficult to monitor. Especially older abandoned wells pose an increased risk as technology and regulations at the time of abandonment may have been of lower standards.

<u>Description of work</u>

The following R&D directions can be envisaged.

Sensitivity analysis of tools

Review current wellbore logging tools, possibly improving current detection tools to increase ability to detect micro annuli damages and establish measuring strategy (tool selection & measurement frequency).

Determining the sensitivity and accuracy of logging tools and permanent sensors with respect to CO_2 migration along boreholes.

Laboratory experiments to evaluate the chemical (kinetic), mechanical and sealing behaviour of wellbore system components under the influence of aqueous and supercritical CO_2 at in-situ reservoir conditions (pressure, temperature, impurities and possibly microbial induced corrosion) and validation against available data and cement-steel-rock samples from field cases.

Monitoring strategies

Develop general strategies to monitor the wellbore system based on specific potential migration mechanisms, using state-of-the-art methods applicable to a wide variety of materials.

Develop applications possibly combining multiple techniques to evaluate their individual and joint value in monitoring well integrity.

Monitoring strategies for abandoned wells. Abandoned wells pose an extra challenge in that entering such a well with logging/monitoring tools is often difficult, expensive or simply impossible. For each storage location it is of utmost importance that the integrity is assured. In order to evaluate the integrity of abandoned wells, specific monitoring strategies will be developed.

Prevention and remediation. The application of suitable corrosion monitoring and control techniques in combination with advanced materials and (surface) treatments for the well bore after abandonment and during mitigation.

Permanent tools

In order to have continuous monitoring data and not having to mobilize extensive and complicated logging/monitoring surveys, the development of downhole sensor systems to verify both short- and long-term well integrity will be investigated.

In order to provide well integrity data during the post closure phase, the applicability of a sensor system will also be investigated.

Modelling the well system

Development of numerical models describing the effects of chemical degradation of well materials and of associated coupled processes (mechanics, chemistry, thermal, multi-phase flow) on the wellbore system scale. This will improve the quantitative understanding of the wellbore system behaviour. Validation of field, monitoring and experimental data will build confidence and is part of the EU directive.

<u>Objectives four year program</u>

- Develop or improve methods to detect and quantify CO_2 in or near the well
- Better understand the effect of CO_2 on the wellbore system
- Propose strategies to deal with improperly abandoned wells

<u>Milestones for first 24 month period</u>

Milestone	Measurable Objectives	Project Month
M 1.3.1	Perform and analyse the results of long-term (>5 years) laboratory experiments on the effect of CO_2 on casing and cement	24

M 1.3.2	Measure the integrity of wells at active injection sites	24
M 1.3.3	Assess the feasibility of permanent downhole geochemical tools	24

Participants

BGS, BRGM, EMEPC, IFPEN, KIT, LNEG, MERG-Imperial, RSE, TNO, University of Rome.

SP 1.4 Integrated closed-loop monitoring and modelling

Background

The previous SPs are aimed at improving the techniques for monitoring the various compartments of the storage site (reservoir, cap-rock, overburden up to the surface) and the most critical components (wells) for potential migration paths. These techniques have to be tailored to the specific storage sites, in order to be effective and, at the same time, efficient in terms of costs and comparables in terms of produced results. Guidelines have, thus, to be developed and verified in real situations.

This SP aims at:

- developing guidelines or methods for constructing a monitoring system (strategy) for specific storage sites;
- developing algorithms and methods for assessing the data from monitoring systems;
- applying monitoring techniques in a realistic storage site where CO_2 is leaked on purpose.

Description of work

The following R&D directions can be envisaged:

Ranking monitoring techniques and designing monitoring strategies

Monitoring a CO_2 storage site must be performance and risk based, i.e., the starting point should be an analysis of the storage performance to meet contractual obligations towards agreed injection rates and volumes and of the risks of the system not behaving as expected. A risk analysis will highlight those areas of the storage system that need to be monitored. Applicable monitoring techniques for different areas of the storage complex are then to be ranked, based on their detection potential derived from pilot tests and modelling, and with external factors such as accessibility of the site and its surroundings and cost to determine the final choice of techniques. There is as yet little experience in determining the efficacy and suitability of a particular monitoring strategy. In addition, different phases of injection require different monitoring intensity, possibly resulting in changes in the choice of monitoring techniques.

Link between monitoring system and data and storage complex models

The main aim of monitoring is to prove safe and secure storage of CO_2, by verifying that the storage site behaves as expected. This can only be done by comparing monitoring data with predictions from models of the storage complex and assessing whether differences should be identified as ‘significant irregularities’ [EU Directive on CO_2 Storage], in which case corrective measures should be initiated. Best results are expected by joint inversion or interpretation of data from multiple sources, using techniques such as data assimilation.

This activity aims at developing guidelines and algorithms, to optimize monitoring strategies.

Field tests of monitoring techniques and strategies at a realistic storage site

Field tests are an essential part of developing new monitoring techniques and methods. The field lab currently planned in Norway will provide important data from monitoring techniques applied in the upper part of a realistic storage environment. At this site, monitoring techniques will be used to detect CO_2 migrating through the subsurface and, ultimately, to the atmosphere.

Controlled release experiments in glacial sand/moraine clay sequence are planned at GEUS in the framework of a nationally funded project. Detection methods for surface flux and location of surface release (focussed/disseminated) could be tested on this site. A controlled release experiment is also planned in a Scottish near-shore shallow marine setting.

Where real storage sites are expected never to fail (leak), resulting in absence of significant irregularities in the monitoring data, a real, leaking storage site offers the possibility of testing all elements of the monitoring system, including the link with storage complex models.

Objectives four year program

- Establishing monitoring protocols for the different phases of a storage site
- Establishing the method(s) for selecting or ranking monitoring techniques, based on the characteristics of the storage complex and the required level (intensity) of monitoring
- To develop methods to understand and interpret the mismatch between predictions from storage complex models and monitoring measurements
- To test these methods in a real or realistic storage site where CO_2 is purposely migrating from its storage location into the overburden

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 1.4.1	Create an inventory of current guidelines for the design of monitoring plans	12
M 1.4.2	Participate in a field test of CO_2 leakage	24
M 1.4.3	Link with SP2 and SP3 to establish modelling uncertainties, and define methods to assess uncertainties in monitoring data	12, 24

Participants

BGS, BRGM, EMEPC, GEUS, IFPEN, NIVA, RSE, TNO, UK-SCCS, University of Rome.

SP2 Static modelling

Background

To allow a widespread use of CCS technologies in the coming years, a very large number of suitable and secure geological formations have to be screened in Europe, characterised and verified to match the needed storage capacities.

Deep saline formations provide by far the largest potential volumes for geological storage of CO_2: the chief advantage is their widespread nature, the drawback is that they are generally poorly explored. Specific gaps include a lack of regional and site-specific knowledge about reservoir formation depth, volume and characteristics, trapping mechanisms and efficiency of storage, pressure control and variations, CO_2 migration pathways, rate and effect of geochemical interaction, pressure building and consequences on other activities using the same aquifer.

Indications on how to tackle these issues are given also by the European Directive on CCS, that emphasizes the importance of: 1) collecting sufficient data of the storage site and storage complex (including cap rock, surrounding areas and hydraulically connected areas), 2) build a three-dimensional static geological model, or a set of such models, of the candidate storage complex by using computer reservoir simulators, 3) characterise the storage dynamic behaviour.

So, in this process, the so-called “static modelling” plays a key role and provides data to the “dynamic modelling”. In reality the interaction between the two is not one-way only: discrepancies in the dynamic modelling could require to revise the static models and, in the future, history matching techniques could bring to a better tuning of the dynamic models and, moreover, to a revision of the static ones and even to start additional exploration activities. Nevertheless, an operative distinction between static and dynamic modelling is generally accepted and we have decided to keep this distinction in the EERA CCS Programme, also if the involved stakeholders largely correspond and deep interactions between the two topics exist.

Objectives

The research activities are aimed at increasing geological knowledge and modelling performance for:

- further defining reservoir and cap-rock characteristics that are relevant to injectivity, capacity and storage integrity;
- providing means for predicting spatial characteristics of the reservoir and storage complex, while assessing their uncertainties;
- defining a robust storage potential assessment methodology.

The overall Static Modelling work program is organised in five parts:

- geological structure of the storage complex;
- petrophysical, geomechanical and geochemical characteristics of the storage complex;
- storage potential estimation;
- uncertainties management;
- alternative geological storage solutions.

SP 2.1 Geological structure of the storage complex

Background

To ensure long term CO_2 storage, it is necessary to determine and characterize the structure of the reservoir, the cap rock and the other surrounding formations, at local and regional scales.

Potential reservoirs need to fulfil some criteria, such as large volume of permeable rocks with sufficient capacity to store large amounts of CO_2, overlain by good quality cap rocks at depths in excess of 800 m. Characterizing the geological structure of the basins will enable the identification of good geological traps, such as folds and faults, as well as the geometry of open saline formations suitable to store CO_2 by dissolution and residual saturation.

Most suitable traps include more or less complex dome shape structures, with upwards closure, outlined by a continuous impermeable layer. Anticlines can be good structural traps as long as impermeable layers are preserved and can act as permeability barriers. To better characterize the general geology of the physical trap and to identify the flow barriers and flow drains, sedimentological analysis are taken into account. This method studies the sedimentary processes to build the 3D static model and the petrophysical characterization.

Other structures such as faults, can have a major role in defining suitable storage sites: they can act as permeability barriers in some circumstances and as preferential pathways for fluid flow in other circumstances. Therefore, the study of faults will allow the identification of traps for storage or elucidate on possible leakage pathways that compromise reservoir integrity. The aim is to develop methodologies to better define the hydraulic, geochemical and geomechanical characteristics of faults and fractures as well as of any human-made pathways, in particular of old deep drill holes.

Description of work

The following R&D directions can be envisaged.

Areal and vertical extent of the reservoir

Defining the areal extent ("footprint") of the storage site is important to determine the storage potential of a site and for storage licensing and monitoring. Storage sites comprising vertically elongated structures will define small "footprint" areas, whereas more open aquifers with gently dipping limits will define larger "footprint" areas. Defining the vertical extent of the reservoir is important since it is generally accepted that thicker reservoirs are better to store considerable amounts of CO_2 and make economically viable a CO_2 storage project. Reservoirs with large areal extent, will define a large "footprint" area, which can be difficult to fully characterise in detail and have constraints for licensing and monitoring over larger areas. The definition of the storage complex extent is hence important to "move to the top of the resource-reserve pyramid" where the practical capacity has to be evaluated by considering also socio-economic and environmental constraints.

The aim of this activity is to collect and share experiences on how this issue has been considered in a series of real situations and to deduct from these some guidelines.

Fracture system characterisation

Fractures can act as preferential pathways for fluid flow. Therefore, it is necessary to determine their directions, size, density and orientation. The fracture networks may increase the reservoir permeability and storage capacity, possibly defining preferential flow pathways. However, fluid migration through and along fractures and microfractures networks, can lead to leakages and escape of CO_2 from the reservoir. Our goal is to develop guidelines on how to characterize the fracture systems in order to be able to consider them for the overall storage potential estimation.

Fracture systems are also relevant to understand the long-term fate of CO_2, namely the diffusive behaviour between fractures and rock matrix. They influence the dissolution and mineralisation of CO_2 and the occurrence of anomalous dispersion due to channeling along fractures.

It is difficult to solve this problem with deterministic methods, because of the quantity and quality of data and the scale of study. Probabilistic and stochastic methods, based on geostatistical algorithms, are more accurate to characterize fracture networks. These will need to be scaled up appropriately from the detailed data source to represent the reservoir or regional features. Different methods may be needed for silicate or carbonate rocks.

Moreover, fracture characterisation methodologies may be integrated with dynamic models for short- and long-term assessment.

Faults characteristics

Determining the nature of faults requires field studies and analysis of geophysical data to determine the local stress fields and establish whether the particular stress regime facilitates the reactivation of a fault either as compressive, or extensional or strike-slip.

The dynamic constrains to the faults reactivation is essential to determine if the CO_2 will move towards the fault surface converting the fault in a pathway for the percolation of CO_2 or if the fault will act as a seal. This assessment should be done to large-scale brittle structures independent of their geometric relations to the stress field, since the presence of fluids also contributes significantly to the reactivation even for fault planes with unfavourable orientations.

The faults have to be fully characterized also because they play a key role in the determination of the pressure footprint of the storage activity and that requires some drill holes interpretations like logs and well testing. There is a strong difference if faults are or are not permeable and if they are hydraulically connected or disconnected to the various compartments of the reservoir and if or if not they connect the reservoir with the surrounding formations. The aim of this activity is to progress towards a better definition of the faults characteristics. Information may be gained from surface and subsurface examples and statistically scaled to enable modelling of fluid flux rates up, down, or across faults. Orientation to local stress fields is important and can be simulated for quantitative analysis.

Characteristics of existing boreholes

It is generally accepted that depleted hydrocarbon fields may be very suitable storage sites. Not only because they guaranteed the containment of fluids and a good capacity of CO_2 dissolution for thousands of years, but because they have been widely explored and characterized and are, hence, generally very well known. A drawback may be the generally large number of drill holes, many of them being old and closed with methods that were not aimed at assuring durability versus potential CO_2 leakages. To check and eventually rework them could be costly and time consuming. The aim of this activity is to define the best practices for characterize pre-storage boreholes.

Objectives four year program

- Develop guidelines to describe and characterize the storage complex
- Establish protocols for fracture networks and fault characterisation and evaluate their influence in the performance of the storage complex
- Develop a methodology to verify and characterize existing boreholes

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 2.1.1	Identify problems and pitfalls on reservoir characterisation from real situations experience	24
M 2.1.2	Compilation of existing CO_2 experience on fractures and faults	24
M 2.1.3	Assess methods and workflows from other industries to evaluate fractures and faults and its applicability to CO_2 storage	24
M 2.1.4	Evaluation of existing experience and data on EU borehole leakage	24
M 2.1.5	Develop stochastic methods to characterise fractures and faults and their connectivity in the storage complex	12

Participants

BGS, BRGM, EMEPC, IFPEN, IRIS, KIT, LNEG, MERG-Imperial, OGS, RSE, TNO, UK-SCCS, University of Evora, University of Rome.

SP 2.2 Petrophysical, geomechanical and geochemical characteristics of the storage complex

Background

Petrophysical, geomechanical and geochemical characteristics are key elements for defining the dynamic behaviour of the reservoir and storage complex during and after the injection of CO_2. They are also interconnected and have to be carefully assessed and analysed to verify if the overall static model is congruent and appropriate.

Description of work

The following R&D directions can be envisaged.

Petrophysical property distribution (porosity, permeability, sedimentary model, lithofacies, etc …)

Porosity and permeability are the petrophysical parameters that ensure enough pore space available to store CO_2 and that it is easy to inject it in the reservoir, respectively. They decrease with increasing depth, due to diagenetic effects, and this constrains the reservoirs storage capacity and injection effectiveness. Permeability influences the fluid flow characteristics, and it is accepted that suitable storage reservoirs should have sufficient permeability to guarantee good injectivity.

The porosity gives an indication of the reservoir void space. The effective porosity of the reservoir, measures the volume where fluid flow takes place. The pore space that can be effectively filled defines the storage efficiency of the reservoir. Lateral facies variations are common within sequential stratigraphic sequences of sedimentary basins, requiring detailed studies of lateral facies distribution, to ensure the petrophysical characteristics of the formations are maintained for distances great enough to define a suitable reservoir. Therefore, the lateral continuity of the seal and reservoir rocks properties has to be defined, in order to characterize in 3D the potential volume of storage but also to diminish the risk of CO_2 leakage.

Definition of a sedimentary model for the sequence that hosts the reservoir, will determine the depositional environment in which it was formed, and predict the abundance and proportion of impermeable and porous rocks in the sedimentary sequence, since these relations are known for different sedimentary environments. It is important that these pore-scale and fracture features are converted to petrophysical rock properties, and have a statistically valid population through the reservoir, and through the seals. This will enable accurate simulation during short and long timescales.

The aim of this activity is to analyse these parameters from the various available data sets, in order to better define which are the more suitable techniques to "infer" them, and how they may be integrated to calculate the reservoir storage potential.

Moreover, methodologies may be developed for assessing and defining reservoir/caprock heterogeneities with a view to integrating these with dynamic models for short- and long-term performance assessment.

Geomechanical, geochemical and flow properties of the reservoir, overburden (caprock, seals, porous and permeable horizons) and surrounding formations

Geomechanical, geochemical and flow properties need to be gathered and compiled for subsequent analysis and modelling of the CO_2 behaviour in the storage site and its surroundings.

The seal is important to effectively guarantee the CO_2 storage. It should have low permeability, a sufficient thickness to guarantee its integrity, and not be disrupted by permeable faults, in order to prevent CO_2 migration from the storage site. Geomechanical properties are measured using triaxial cells, simulating in situ reservoir conditions (stress and pressure) at depth. Geochemical analysis of rocks and fluids will establish concentrations and distribution of most reactive elements, which are involved in dissolution and precipitation reactions that can compromise the seal integrity or injectivity and storage efficiency of the reservoir. Flow properties are conditioned by porosity and permeability. The aim of this activity is to assess a protocol for guaranteeing that all the data needed for the following dynamic modelling of the reservoir and storage complex are defined in a proper and coherent way.

Baseline fluid distribution and characterization

Hydrochemical baseline assessment is not only necessary to evaluate potential impact on storage, but also on adjacent/connected freshwater bodies. One risk of CCS is the migration of brines/deep saline waters under the modified pressure gradients and flow fields. Mixing might occur with freshwaters and the hydrochemical/geochemical baseline of the deep reservoir fulfils two functions:

- to evidence and quantify mixing, by defining the hydrochemical characteristics of the two mixing end members;
- to assess the risks related to such mixing, addressing the salinity and geogenic contaminants (mainly As, F, Se, B, heavy metals), in order to evaluate conflicts with regulation, e.g. on drinking water or irrigation use.

For both purposes, full chemical characterisation is needed (major and trace elements, including rare earth elements) together with isotope fingerprinting, which refines and confirms mixing calculations and the identification even of small quantities of brine input in freshwater aquifers (reservoir-specific fingerprints).

Objectives four year program

- Derive guidelines for establishing the distribution of petrophysical parameters and its integration in static models
- Define a protocol to gather the necessary data that will be delivered to SP3

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 2.2.1	Defining the achievable inputs from petrophysical, geomechanical and geochemical features to SP3 – Dynamic modelling	24
M 2.2.2	Review the existing models to describe petrophysical parameter variation and heterogeneity	24

Participants

BGS, BRGM, EMEPC, GEUS, IFPEN, IRIS, KIT, LNEG, MERG-Imperial, OGS, RSE, TNO, UK-Bristol, UK-SCCS, University of Evora, University of Rome, RC Rez

SP 2.3 Storage potential estimation

Background

An accepted concept is that CO_2 geological storage may contribute to reduce climate changes only if deployed at large scale. This will be possible only if sufficient storage capacities are available in various parts of the world and if very large quantities of CO_2, in the order of 1-10 Mt/year, can be safely and permanently store per project. The estimation of storage capacities is, hence, a pre-requisite to start large-scale industrial projects, as highlighted also by the EC Directive on CCS. This Directive states that Member States that intend to allow geological storage of CO_2 in their territory shall undertake an assessment of the storage capacity available in parts or in the whole of their territory.

Whilst the methodologies to evaluate storage capacity in depleted hydrocarbon fields come from the gas and oil industry experiences and may be considered sufficiently known, those that have to be applied to large saline aquifers are still a matter of debate, due to a general lack of data and because the experiences are still limited.

Description of work

The following R&D directions can be envisaged.

Assessment of effective storage capacity

Determination of storage capacity depends greatly on the scale of assessment and the level of considered factors. To overcome this complexity, the Carbon Sequestration Leadership Forum has proposed the so-called “resource-reserve techno-economic pyramid” concept.

It defines the theoretical capacity as the maximum total pore volume that could be available for storage and the effective capacity as the fraction of the previous one that may be occupied by the injected CO_2, when considering technical factors.

Regional storage assessments are estimated by analytical evaluation of theoretical or effective storage capacities. The theoretical capacities can be converted to effective capacities by applying a storage coefficient (also termed the efficiency factor). This coefficient needs to be better constrained for several geological settings and assessment scales, by integrating all of the different types of data. The petrophysical properties and their distribution will greatly control the reservoir storage potential. The storage potential will also be affected by chemical heterogeneities in the reservoir, areal extent and thickness of the reservoir, the structure of the trap, the tectonic regime, which will have influence on faults and fractures. Besides, the use of those properties and geological constrains to test simplified simulations of injection process can improve the efficient factor and reduce the range of values for the storage capacities. The aim of this activity is to understand and assess how to better evaluate and constrain the efficiency factor by considering the various characteristics of the reservoir and options for reservoir management.

Fluid pressure limitation on the storage capacity

Of particular relevance is the use of pressure simulation to constrain volumes of injection locally around the boreholes, and regionally within the reservoir. This pressure depends on the enclosing sediments whether the aquifer is open, semi-open or closed. Engineered injection, or production, to mitigate pressure can greatly enhance the storage efficiency coefficient, and needs much greater investigation. Pressure interactions with other uses for the same formations, such as hydrocarbon and/or geothermal exploitation needs to be addressed.

Towards an European Atlas

To move forwards now, the members contributing to EERA agree on the necessity of coordinate efforts to compile data towards a European Atlas of the national reservoir locations and their storage capacity. This Atlas will provide information on the geographical location and main characteristics of potential reservoirs and a first estimation of their CO_2 storage capacity. Having been involved in the storage evaluation in their countries within the European projects GESTCO and GEOCAPACITY (5^{th} and 6^{th} FP), and because the members intend to mutualise past experiences, methods and software tools, they can start an action aimed at assessing the methodology for the European Atlas.

Objectives four year program

- Methods to improve the application of storage efficiency factor
- Methods to address pressure limitation and management

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 2.3.1	Compare existing approaches for application of storage efficiency factor	24
M 2.3.2	Compile existing engineering techniques for pressure limitation management	24
M 2.3.3	Agree on a standardized methodology for Atlas calculations	24

Participants

BGS, BRGM, EMEPC, GEUS, IFPEN, IRIS, LNEG, MERG-Imperial, OGS, TNO, UK-SCCS, University of Evora.

SP 2.4 Uncertainties management

Background

Uncertainties associated with model parameters and assumptions have to be considered and can be accounted for by analysis models. It has to be stressed that there is a cyclic interaction between static modelling and dynamic modelling. Some apparent inconsistencies that can emerge during the dynamic modelling, may find their explanation in a better interpretation of the static modelling, as well as the results of the dynamic modelling may result in a re-consideration of some parameters included in the static model. A fine uncertainty assessment can contribute to better evaluate the results of the dynamic modelling and assess their ranges.

Description of work

The following R&D directions can be envisaged.

Uncertainties assessment

These models will contribute to improve the confidence to predict the evolution of the storage complex in response to fluid injection and the storage performance of the system with time. These models will be designed for short and long term predictions and will help to preserve the storage site efficiency and safety.

Uncertainties assessment for the static modelling sub-programme is linked with the modelling process. Static models provide an estimation of uncertainties at each step of the process:

- structural modelling: estimation of confidence intervals for the faults' traces and shifts coordinates values;
- lithological and stratigraphical horizons modelling: creation of 2D uncertainties maps on the isobath and isopach values;
- properties modelling: computation of 3D probability maps given by stochastic methods;
- upscaling process and deterioration of quality: assessment of the loss of geological accuracy.

It is also possible to reduce the gap of uncertainties and to update models by an increasing number of data and by using results from dynamic models and simulation processes. The aim of this activity is to provide a global confidence interval on static models, which is taken into account in the scenarios of risk during the injection processes.

Scenarios building and confidence limits estimation

Different scenarios will be modelled to provide data and parameter ranges for determining the response and evolution of the storage complex in response to different situations. Models to predict the system performance and evaluate the impacts of injecting CO_2 in the storage complex and in particular the characteristics and extent of impacts that may result from the potential leakage of CO_2 need to be built. Other scenarios to be considered include the impact and fate of CO_2 in the subsurface environment, in the groundwater, CO_2 leakage or abnormal fluid displacement combined with the economic feasibility of the projects.

Therefore, during injection any deviation from the predicted scenario can be adjusted and corrected. The different scenarios will help to define guidelines to correct any system deviation to the predicted scenario during operation and provide safe storage.

The aim of this activity is to provide some guidelines for scenario building.

<u>Objectives four year program</u>

- Define guidelines for scenario building
- Workflow for including uncertainties in static models

<u>Milestones for first 24 month period</u>

Milestone	Measurable Objectives	Project Month
M 2.4.1	Define a list of scenarios to address routinely in CO_2 storage	24
M 2.4.2	Develop stochastic methods to consider matrix properties and fracture distribution uncertainty in static models	12

<u>Participants</u>

BGS, BRGM, GEUS, IFPEN, IRIS, LNEG, MERG-Imperial, TNO, UK-SCCS, RC Rez

SP 2.5 Alternative geological storage solutions

Background

All the members contributing to the CCS part of the EERA initiative, fully acknowledge the relevance of the GeoCapacity project that, for the first time, has assessed a common methodology to evaluate the storage capacity in many European countries, both in depleted hydrocarbon reservoirs, deep saline aquifers and unmineable coal beds. Therefore, we think it is needed to integrate the distribution and potential of alternative geological storage solutions to the work presented in this program.

Description of work

The following R&D directions can be envisaged.

Alternative geological storage solutions

Deep saline aquifers are recognised to be the best option for large scale underground storage of CO_2. However, countries with small or without sedimentary basins will have to find different manners for geological storage of CO_2. Studies have been conducted in many parts of the world to assess the possibility of using mafic and ultra-mafic rocks, such as basalts to store CO_2, taking advantage of the enhanced in-situ mineralisation linked to geochemical features of those rocks. Pilot injection projects such as CARBFIX in Iceland can retrieve important conclusions about the actual possibility of storing CO_2 in basalts.

Other potential solutions relate to storage in deep-sea sediments as CO_2 hydrates, a methodology that should be addressed since, if feasible, it could provide a considerable storage capacity to countries with deep-offshore conditions near to coastal regions. This storage solution could eventually be combined with storage in deep-saline aquifers, providing added security to the storage complex.

In addition, unmineable coal beds may also serve as large potential CO_2 sink in several European countries. This storage could be associated to CH_4 extraction in some areas to improve the economic value of the storage but not only. A specific methodology must be applied to these alternative sites to estimate the storage potential and feasibility.

The aim of this activity is to assess the economic/technical feasibility of using alternative geological formations for storing CO_2, to identify the regions that could be of interest and to define the challenges to overcome in those alternative solutions.

Objectives four year program

- Ranking the viability of alternative reservoirs
- Develop methodologies for quantifying storage capacity associated with these solutions

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 2.5.1	Organize a workshop with players working for other geological solutions	24
M 2.5.2	State of the art of the research conducted in alternative storage solutions	24
M 2.5.3	Identify the EU regions where such alternatives may be appropriate	24

Participants

BGS, BRGM, EMEPC, ETHZ, GEUS, IFPEN, LNEG, RSE, TNO, University of Evora, VITO.

SP3 Dynamic modelling

Background

Research and development programs in the field of storage of CO_2 in geological formations have been run over the last 15 years and are currently being intensified due to the large role that CO_2 capture and storage could play as a climate change mitigation option. In the context of geological storage of CO_2, numerical simulators, both on a reservoir and a basin scale, play a crucial role since they are the practical tools that mimic the physical processes involved in CO_2 injection and that allow to evaluate a priori the underground behaviour of the injected CO_2, in particular the long term stability and security of storage. More generally, numerical simulation is playing a key role to answer economic safety and environmental issues.

The challenge of CO_2 storage simulation lies today on two elements. First, many different temporal and spatial scales have to be considered. Second, many physical and chemical processes are involved and have to be integrated in a consistent way, taking into account the complex interactions between the different processes. Therefore a joint research program, bringing together the main European players with their specific skills, will allow the actors to share experience, to pool resources and thus to increase the pace for reaching our common objective: deliver to the industry and to the society at large reliable tools for predicting the performance and the integrity of a subsurface CO_2 storage site.

The results obtained by a simulation software depend on several components: the constitutive laws used (the different physical and chemical laws and their associated interactions), the numerical methods used (e.g. mesh construction, mathematical/numerical precision, etc…), and the input data (e.g. injection pressure, chemical composition of the CO_2 stream, stress constraints, etc…). Up to now, simulation results are evaluated on a case-by-case basis through a fit to experimental or analytical solutions. One of the objectives of a joint R&D program should be the design of common validation procedures and standards that should allow the software developers to insure the proper functioning of their tools.

Objectives

The aim of this sub-program is to improve and certify dynamic modelling that will be used to manage and control the CO_2 geological storage process and to estimate risk and potential impacts of CO_2 migration outside of the storage complex and mechanical damage of the rock formations. Until now different simulation studies were performed to evaluate on one hand the CO_2 storage capacity in deep aquifers and on the other hand the induced over pressure, by taking into account coupled physical models. Such benchmark studies showed that if each software was parameterised in the same way the results were sensitive to the gridding and the boundary conditions. Physical modelling is based on Representative Elementary Volume (REV), thus the numerical mesh must respect this volume to assure that the numerical results will be good, both qualitatively and quantitatively. Another problem is the boundary conditions. Most simulations fix the pressure at the border of the computational zone but this condition could constraint the simulation if the domain is too small. The modelling of the CO_2 migration in porous media with gravity and capillary effects is well-known but the large scale CO_2 storage simulation for the injection and post-injection phases requires the development of complex and reliable models able to take into account very different phenomena such as rock fluid interactions, petrophysical changes, mechanical effects on fault or seals due to pressure build up, thermodynamic effects. A different approach to the modelling of CO_2 migration is the use of basin scale simulators. These simulators can cover large scales without being too time consuming. Thus they are suitable for risk assessment.

Finally, the modelling of carbonate cycle and interactions in the marine environment, under leakage is to be implemented by coupling existing hydrodynamic models of bubble behaviour in the marine environment, hydrodynamic conditions, biogeochemical processes and ecosystem functioning in the bottom boundary layer.

A joint program in the field of dynamic modelling for CO_2 storage could be set-up around the following topics:

- adaption / implementation of constitutive laws, geochemical databases, coupling / interaction approaches;
- computational / numerical approaches to improve large space and time scales;
- workflow design methodology and validation.

SP 3.1 Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches

Background

The aim of this work package is to bring together the current knowledge of various institutes relating to rock-fluid interactions, with special attention on enhancing the capacity of numerical models to predict accurately.

Geochemical effects of CO_2 storage are very important. Currently there is a lack of reliable and complete thermodynamic and kinetics databases for mineral reactions, especially for clay minerals and cement phases, but also for complex gas compositions. In particular, while the kinetics parameters determine the timing of the different processes, the reaction paths are mainly controlled by thermodynamic properties of chemical system components.

Obtaining an internally consistent thermodynamic database, accounting for different types of constrains (calorimetry, bracketings, density, etc...), guaranties the accuracy of phase diagrams. The other gaps in the database are related to dissolution and, more dramatically, precipitation kinetics of minerals. A more extensive and consistent database that is fully accepted and shared by all partners would make possible to do more realistic reactive transport simulations for predicting the fate of CO_2 after injection into the subsurface.

Following injection, the effect of pressure changes on the mechanical stresses needs to be considered. Beside short time behaviour (poro-elasticity) long time behaviour (rheology) has to be taken into account to assess the performance of the storage system.

Description of work

The following aspects will be considered.

Construction of internally consistent thermodynamic model

In the petrology domain during the eighties, researchers have proven the unreliability of the compilation of thermodynamic database, leading the phase diagram to major inconsistencies. To face this problem, a new experimental approach has been developed (bracketing of equilibria) together with different mathematical approaches allowing to consider different sources of constrains (calorimetric, bracketing, natural observations, ab initio ...) to better constrain thermodynamic data. This approach leads to the concept of "internally consistent database". This part aims at developing this approach to the low temperature ($T<350°C$) and low pressure ($P<3000$ bars) domain in order to get better predictable fluid-rock interaction models.

Overall reaction kinetics inversion methods

By studying natural occurrences of CO_2, the long-term rates of mineral-CO_2 interaction can be determined. Experimental simulations in the lab are ideal comparisons to determine short-term reaction rate kinetics.

Reactivity impact on permeability-porosity constitutive laws and mechanical properties

Numerous porosity/permeability laws are able to describe transport in porous and dense structures. Rock-fluid-gas interactions caused by reactive minerals will have an impact on the porosity, the permeability and hence the mechanical properties of the structure. In this activity, optimization of the porosity/permeability constitutive laws will be studied taking into account the reactivity of the rock or structure towards CO_2. Different constitutive laws might be relevant for concrete, clay and other rock minerals.

The aim of this activity is to further adapt the permeability-porosity constitutive laws taking into account the reactivity of the rock or structure.

A critical unknown in fluid flow models is the relative permeability to CO_2. Laboratory experiments can produce tightly specified measurement results for carefully chosen field samples.

Effects of impurities on CO_2 stream and fluid rock interactions

Impurities present in the gas stream will have an impact on the CO_2-rock interactions also resulting in mechanical property changes. This activity will investigate the effect that impurities might have on the geochemical and geomechanical effects due to CO_2 rock interactions. Impurities, such as N_2, SOx, H_2 and others occur in industrial flue gases and might have an impact on both the type and the rate of the geochemical reactions that occur during CO_2-rock interactions.

Clogging effects, due to mineral reactions in reservoirs and gas-hydrate formation in depleted gas fields; these effects influence the porosity and permeability and therefore overall injectivity

During the injection period, the thermodynamical conditions evolution as increase pressure could induce gas-hydrate formation. These physical processes will change the injectivity and then might plug the well. To simulate and predict such phenomena, modelling has to take into account thermodynamics, geochemistry and geomechanical coupling and the effects on porosity and permeability.

In the same case, this activity could study the plug well effect due to salt deposit.

Objectives four year program

- Produce an updated fluid-rock interaction model
- Develop porosity/permeability constitutive laws for CO_2 storage system condition
- Develop models of injectivity evolution due to salt and hydrate precipitation

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 3.1.1	First thermodynamic database for reservoir mineralogy	24
M 3.1.2	Porosity/permeability constitutive laws for pure CO_2	24
M 3.1.3	Comparison results of injectivity studies	24

Participants

BGS, BRGM, IFPEN, IRIS, KIT, MERG-Imperial, SINTEF, TNO, UK-Bristol, UK-SCCS, UK-UNOTT, VITO.

SP 3.2 Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling

Background

Large scale modelling of massive injection of CO_2 into saline aquifer is needed to provide estimates of the migration of the gas plume, the displacement of brine, and also over pressurization of the whole system. The modelling can be carried out using either simulators on a reservoir or a basin scale.

The translation of the different models and couplings into numerical methods is a non-trivial activity and may by itself impact the validity of the obtained results. Thus, work on numerical approaches as e.g. dynamic mesh handling, dynamic local time stepping and physical up scaling approaches, porosity permeability evolution and simulation updating as well as analytical codes, is included in the joint R&D program. Moreover, it is important to combine simplified models (e.g. without reactive fluid flow in the site screening phase) to very detailed or tailor-made calculations (e.g. injection problem at a specific well) during permitting or operational phase. Finally the precision of the simulated results is influenced by uncertainty on fluid, rock and gas properties and the heterogeneity of the storage system modelled.

Basin scale simulators are based on other techniques and can be well suited for large scale modelling of CO_2 migration. Short simulation time can make this approach well suited for (statistical) sensitivity analysis, and results can be compared with the outcome of reservoir simulators.

Description of work

The following R&D directions can be envisaged.

Physical and numerical techniques to update diffusion and dissolution-reaction processes up-scaling techniques

Particularly at long term, the diffusion, dissolution and reaction processes are the major mechanisms to take into account in the CO_2 storage modelling. The numerical schemes used to simulate these phenomena are often not adapted to large scale modelling. Furthermore, the entire dissolution models existing in the reservoir software are based on the local equilibrium hypothesis. This hypothesis may induce kinetic errors on the position and the size of the CO_2 plume if we use a basin grid size (1km x 1km x 0,5km). Finally, the reactive flow model is too complex (i.e. a lot of species and minerals, local front) to be used at a large scale. The aim of this activity is to develop technique to improve the simulation of the diffusion, dissolution and reaction modelling at large scale.

Methodologies for calibration, verification and sensitivity analysis of large scale simulations

CO_2 storage in deep saline aquifers will need to be conducted resorting to much less information about the existing hydrodynamic in the reservoir than, for instance, in hydrocarbon reservoirs and freshwater aquifers. This limited amount of information will pose challenges to the calibration of the numerical models, which traditionally resort measurement of pressure in multiple points and along time series. The process of verification of the models will suffer from the same problem, since it also relies on the existence of observations in space and time. The process of calibration and verification are essential for asserting the reliability of dynamic modelling and to raise credibility for the forecast of long-term behaviour of CO_2. Moreover, various sources of uncertainties are associated with the large-scale models. In this context, sensitivity analysis as component of analyses for complex systems is essential from a risk management perspective, where sensitivity analysis designates the determination of the contributions of individual uncertain analysis inputs to the uncertainty in analysis results.

It is worth noting that the need for measuring the influence of these sources of uncertainties for an appropriate decision for risk management has been recently outlined in the EU Directive on CO_2 Storage (Annex I Step 3.2 Sensitivity characterization).

It has to be noted that numerical models can become extremely computer time consuming (from a few hours to several days) reducing considerably the feasibility of multiple runs required by sensitivity analysis (based on Monte-Carlo, geostatistical simulations and Bayesian methods for instance). Methods to overcome this problem including response surface and adaptive gridding methods will be considered.

Analytical and/or numerical simplified model

The classical numerical modelling could be time consuming especially for simulation at large spatial scale and might be impractical especially in a screening phase for licensing and permitting of the storage projects or for designing monitoring plans. As alternatives, low computer time consuming analytical and/or numerical simplified models can be very useful for safety and effectiveness assessment in such a pre- analysis phase of the storage project.

Methodologies for quantification of potentially leaked CO_2 in the marine and atmospheric environments

Integrated marine modelling of hydrodynamics (transport, current, diffusion), bubble migration (from gas to Dissolved Inorganic Carbon, DIC) and biogeochemical processes (carbonate system, update by living organisms, buffer effect) is necessary in order to quantify the volume of seeping CO_2 that could potentially reach the sea surface and diffuse to the atmosphere. Such modelling tools are under development in the consortium and will give the capacity to simulate behaviour of CO_2 leaks in the marine environment.

Objectives four year program

- Develop simplified model (numerical and analytical)
- Define up scaling methods from reservoir to basin scale
- Develop methodologies to characterise and propagate uncertainties
- Develop numerical tools to simulate and quantify CO_2 leaking into marine and atmospheric environment

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 3.2.1	Simplify model to study leakage system	24
M 3.2.2	Diffusion/dissolution up scaling	24
M 3.2.3	Comparative assessment of input data and modelling uncertainty	24

Participants

BGS, BRGM, ETHZ, GEUS, IFPEN, IRIS, MERG-Imperial, NIVA, SINTEF, TNO, UK-SCCS, University of Evora, RC Rez

SP 3.3 Workflow design methodology and validation

Background

In general, and at least for the coming years, different software tools will be in use for different dedicated parts of a CO_2 storage workflow. It will thus be important to define practical workflows and coupling strategies (including associated tools), allowing the storage operators to perform all the different studies that will be required for permitting, operation and closure of a storage site. These workflows for dynamic modelling should be strongly connected with the monitoring workflows and the static modelling.

Description of work

The following R&D directions can be envisaged.

Design of validation procedures and standards

One of the objectives of a joint R&D program will be the design of case studies allowing the validation of specific pieces of software or of the overall performance of a simulation tool or workflow.

From monitoring to modelling of long-term fate of CO_2

Monitoring techniques often detect the fate of CO_2 indirectly. The prediction of the numerical models will have to be routinely crosschecked against the results of indirect monitoring to improve and verify the quality of the dynamic modelling. Methodologies for using the indirect monitoring observations as constrains to the numerical modelling predictions, and for the parameter estimation techniques are required, as the existing ones rely mostly on direct observations of variables such as pressure or concentration.

The aim of this activity is to define methodologies to constrain and update the simulation of numerical models using the indirect monitoring observations.

Objectives four year program

- Define use cases to validate dynamic modelling
- Methodologies to constrain and update the simulation

Milestones for first 24 month period

Milestone	Measurable Objectives	Project Month
M 3.3.1	Benchmark on reactive transport	24

Participants

BGS, BRGM, IFPEN, IRIS, MERG-Imperial, RSE, TNO, UK-SCCS, University of Evora, RC Rez

4. Participants and yearly commitment (in man years)

Participant / Associate	BGS	BRGM	EMEPC	GEUS	GFZ	IFPEN	IRIS	LNEG	MERG	NIVA	OGS	RSE	SINTEF	TNO	UK-Bristol	UK-SCCS	UK-UNOTT	UN. Evora	UN.Rome	VITO	KIT	RC REZ	ETHZ
Country	UK	FR	PT	DK	DE	FR	NO	PT	UK	NO	IT	IT	NO	NL	UK	UK	UK	PT	IT	BE	DE	CZ	CH
SP1 Monitoring												**Persons/year**											
SP 1.1 Surface and near-surface	1,6	1,0	0,1			0,15		0,7	0,5	0,3	2,0	1,0		0,2		1,0	1,0	0,1	0,5	1,0			
SP 1.2 Reservoir and overburden	0,8	1,0			0,1	0,35		0,3			2,0			0,3	1,0	1,0		1,5			1,25		1,5
SP 1.3 Wellbore system	0,4	0,5	0,1		0,25	0,15		0,2	1,0			1,5		0,2					0,5		0,5		
SP 1.4 Integrated closed-loop monitoring and	0,1	0,5	0,25	0,5	0,15	0,35				0,3		1,5		0,5		1,0			1,0				
SP2 Static modelling												**Persons/year**											
SP 2.1 Geological structure of the storage	0,5	1,0	0,25			0,2	0,25	1	0,5		1,0	0,5		0,2		1,0		1,3	1,0		1,5		
SP 2.2 Petrophysical, geomec. and geochem charact. of the storage complex	0,5	1,0	0,05	0,5		0,2	0,25	0,5	1,25		0,5	0,5		0,3	1,0	0,5		0,7	0,5		1,25	1,2	
SP 2.3 Storage potential estimation	0,5	1,0	0,15	0,5		0,2	0,3	1	0,5		1,0			0,2		0,5		1,3					
SP 2.4 Uncertainties management	0,1	0,5		0,5		0,2	0,2	0,3	0,75					0,2		0,75						1,1	
SP 2.5 Alternative geological storage solutions	0,3	0,5	0,1	0,5		0,2		1				2,0		0,2				1,7		1,0			1,0

Pag. 390

Participant / Associate	BGS	BRGM	EMEPC	GEUS	GFZ	IFPEN	IRIS	LNEG	MERG	NIVA	OGS	RSE	SINTEF	TNO	UK-Bristol	UK-SCCS	UK-UNOTT	UN. Evora	UN.Rome	VITO	KIT	RC REZ	ETHZ
SP3 Dynamic modelling	**Persons/year**																						
SP 3.1 Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches	0,8	1,0			0,5	0,25	0,5		1,5				0,4	0,3	1,0	1,0	1,5			2,7	3,25		
SP 3.2 Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling	0,7	1,0		1,0	0,5	1,0	0,8		1,5	0,4			0,4	0,2		0,5		0,25				0,9	1,0
SP 3.3 Workflow design methodology and validation	0,3	1,0				0,75	0,2		1,5			3,0		0,2		0,25		0,25				0,8	
TOTAL	6,6	10,0	1,0	3,5	1,5	4,0	2,5	5,0	9,0	1,0	6,5	10,0	0,8	3,0	3,0	7,5	2,5	7,1	3,5	4,7	7,75	4,0	3,5

The total human resource commitment of the sub-programme members arises to 107,95 person years / year.

Pag. 390

5. Participants contacts

Participant / Associate	Country	Contact	E-mail
BGS	UK	Gary Kirby	gak@bgs.ac.uk
BRGM	France	Isabelle Czernichowski	i.czernichowski@brgm.fr
EMEPC	Portugal	Nuno Lourenço	nlourenco@emepc-portugal.org
ETHZ	Switzerland	Marco Mazotti	marco.mazotti@ipe.mavt.ethz.ch
GEUS	Denmark	Lars Henrik Nielsen	LHN@geus.dk
GFZ	Germany	Michael Kühn	mkuehn@gfz-potsdam.de
IFP Energies nouvelles	France	Hervé Quinquis Laurent Trenty	Herve.Quinquis@ifpenergiesnouvelles.fr Laurent.Trenty@ifpenergiesnouvelles.fr
IRIS	Norway	Dimitrios Hatzignatiou	Dimitrios.Hatzignatiou@iris.no
KIT	Germany	Thomas Mutschler	thomas.mutschler@kit.edu
LNEG	Portugal	Carlos Rosa	carlos.rosa@lneg.pt
MERG_Imperial	UK	Anna Korre	a.korre@imperial.ac.uk
NIVA	Norway	Dominique Durand	dominique.durand@niva.no
OGS	Italy	Sergio Persoglia	spersoglia@ogs.trieste.it
RC Rez	Czech Republic	Vaclava Havloca	hvl@ujv.cz
RSE	Italy	Fabio Moia Valter Martinotti	fabio.moia@erse-web.it valter.martinotti@erse-web.it
SINTEF	Norway	Joachim Rinna	Joachim.Rinna@sintef.no
TNO	Netherlands	Filip Neele Vincent Vandeweijer	filip.neele@tno.nl vincent.vandemeijer@tno.nl
UK-Bristol	UK	James Verdon	gljpv@bristol.ac.uk
UK-SCCS	UK	Stuart Haszeldine	s.haszeldine@ed.ac.uk
UK-UNOTT	UK	Mercedes Maroto-Valer	Mercedes.Maroto-Valer@nottingham.ac.uk
University of Evora	Portugal	Julio Carneiro	jcarneiro@uevora.pt
University of Rome	Italy	Salvatore Lombardi	salvatore.lombardi@gmail.com
VITO	Belgium	Virginie Harcouët-Menou	virginie.harcouet-menou@vito.be

6. Infrastructures and facilities

Participant / Associate	Facilities
BGS	• **Hydrothermal Laboratory** The Hydrothermal Laboratory is used to study fluid-rock interactions and processes over a range of temperatures and pressures typical of the upper few kilometres of the Earth's crust. • **Transport Properties Research Laboratory** Particular expertise relates to the characterisation low permeability materials such as reservoir seals, well bore cements and reservoir traps (e.g. fault bounded formations). Laboratory experiments are performed under simulated in situ conditions of stress, pore pressure, temperature and chemical environment. • **Geomicrobiology Laboratory** The Geomicrobiology Laboratory is well equipped and placed to undertake detailed work to understand the biological processes involved in the safe long-term storage of CO_2. It has wide experience in the understanding of biological processes involved in the transport of contaminants in a variety of rock types using the developed Biological Flow Apparatus (BFA) and is the first centre in Europe to be able to provide quantitative information in realistic conditions. • **Rock Engineering Laboratory** Characterization of Rock Properties is an area of research that has had a long history at BGS. For the last 20 years a systematic programme of research, has been investigating and characterising the rock properties of various bedrock formations across the UK. The Rock Engineering laboratory has played an active part in this programme of research and has undertaken specialist advanced geotechnical rock engineering and geomechanical testing, measuring the strength, deformability, geophysical properties and density of rock samples. • **Mineralogy, Petrology & Biostratigraphy Laboratories, MPB** MPB possess a full range of state-of-the-art mineralogical and petrographical laboratories. • **Hydrates Laboratory** The Hydrates Laboratory has many similarities to the Hydrothermal Laboratory in terms of equipment, but is used to conduct experiments under the high pressure/low temperature conditions found on the bed of deep oceans or under permafrost.
BRGM	• Monitoring equipment: geophysical (shallow seismic, CSEM, gravity, passive surface seismic) and geochemical (soil gas and fluid sampling, down hole geochemical logging tool) • Laboratories for geochemical analysis and microbiological studies • Grid computing architecture for massively parallel simulations
EMEPC	• **Equipment used in Oceanographic missions** ROV (capacity to dive up to 6000 mbd) equipped with: CTD, CO_2 sensor, methane sensor, DVL;,4 water bottles. • **Stand alone equipments** Rosette with 11 Niskin bottles to sample up to 5l water each and extra CTD, portable UCTD, Ocean Bottom Seismometers (OBS), 5 marine Magneto-Telluric instruments, magnetometer, gravimeter, professional rigid inflatable boat (RIB). • **EMEPC Facilities** ROV LAB with capacity for training and maintenance Basic Geolab

	Basic microbiological LAB Oracle based DBMS and ARCGIS based Information Systems. • **Access to ship time**. Platform is equipped with: ADCP EM120 and EM710 Multibeam systems Biological probe Dynamic Positioning System
GEUS	• Core analysis laboratory for flooding experiments with supercritical CO_2 • Geochemical analysis laboratory • Software for geological and geophysical data interpretation • Software for geological 3D model building • Flow simulation software (Eclipse100) • GIS system and database for storage sites and capacity estimates
GFZ	• CO_2 storage test site at Ketzin • Permanently installed monitoring equipment at Ketzin (DTS, ERT, etc.) • Geophysical Instrument Pool Potsdam (GIPP) for joint geophysical experiments • Geochemical and petrophysical laboratories • Software for geological 3D model building (e.g. Petrel) • Flow simulation software (Eclipse100, Eclipse300, TOUGH2-MP, OpenGeoSys, MUFTE-UG, $DuMu^X$, PFLOTRAN)
IFP Energies nouvelles	• **Petrophysical lab.** (Kr, Pc, degraded sample tests) IFPEN is equipped with advanced devices and interpretation tools to study rock/fluid interactions and mechanisms involved within CO_2 storage: rock characterization laboratories (CT-scanner, Microscanner, NMR, HPMI...), acid alteration laboratories to reproduce CO_2 attack on rocks, HPHT core flood laboratories for flow experiments with reactive or non reactive fluids (Kr, Pc, Resistivity Indices, CO_2 injections, WAG injections), low K laboratories to characterize caprocks, Pore Network Model which can be used to study the impact of flow regimes on pore structure. • **Geomecanical lab.** (triaxial tests, uniaxial tests, special cells for tests on shales) Several equipments are available to characterize the geomechanical parameters (poroelastic parameters, failure strength) and petroacoustical properties (Vp, Vs, dynamic elastic moduli) and their evolution in the context of CO_2 storage or of shale gas production. The mechanical experiments performed on reservoir rocks or on caprocks benefits of the analysis equipments of the petrophysical laboratories. • **Geochemical monitoring lab.** (including determination of gas composition, stable isotope of gas species (carbon and hydrogen) as well as noble gas compositional and isotopic quantification, flux chambers, sample probing...). • **Mineral reactivity lab.** (including experimental equipment ranging from 50°C to 600°C at pressures up to 5000 bars and reaction volumes from 100 µL to 500 mL and analytical tools like XRD, FTIR, SEM with EDS detection, AEM, TEM, oven and flame AAS. • Cells to analyse long term behaviour in CO_2 media for steel and polymers • Hyro-mechanical coupling software for reservoir simulation and geomechanical analysis • Rock mechanics modelling (plasticity, failure, homogenization, etc...) • IFP Energies nouvelles software COORES™ and ARXIM CO_2 storage dedicated software PumaFlow™ reservoir simulator and TemisFmow™ basin simulator Sensitivity analysis software COUGAR™
IRIS	• Geomechanical laboratory (triaxial tests, uniaxial tests, etc.) • Rock properties estimation laboratory (reservoir conditions permeability,

	porosity, relative permeability curves, capillary pressure curves, core flooding, etc.) • Static and dynamic modelling of multiphase flow in underground strata (commercial and in-house software tools) • Geochemistry public domain and in-house modelling software tools
KIT	**FOCO2S**: Research group on CO2-Storage in geological formations to which belong 6 KIT-institutes: o AGW - Institute for Applied Geosciences - o GPI - Geophysical Institute – o IBF - Institute for Soil Mechanics and Rock Mechanics o IMB - Institute of Concrete Structures and Building Materials o IMG - Institute for Mineralogy and Geochemistry o CMM - Center of Competence for Material Moisture **FOCO2S** is well grounded in large expertise and capacity of testing, analytics, monitoring and numerical simulation of diverse processes connected to CO_2storage. • Testing: o Geomechanical laboratory for soils, rocks and rock masses (sort- and long-term testing, temperature controlled testing, large-scale testing, permeability measurements) o Field equipment for sampling o Experimental simulation of rock alteration processes including faults o Structural testing laboratory (testing facilities up to 15000 kN under compression, variable testing facilities up to 10000 kN under compression and 8000 kN under tension, large scale testing, static and dynamic testing, creep and shrinkage measurements) o Autoclave system for corrosion experiments (2 x 1 liter, up to 150 °C and 300 bar, $CO_{2,}$sc) o Climatic cambers (standard chambers 18-25 °C/40-70 % r. H.; special chambers T = -20 °C to +100 °C, freely adjustable humidity) o Borehole simulator system for simulation of CO_2-boreholes and wellbores with d_{max} = 510 mm, h_{max} = 10 m, p_{max} = 80 bar, T_{max} = 60 °C including cementing and borehole monitoring equipment o Water/CO_2/rock/rock discontinuities-interactions o Underground sealing-systems (abandonment) • Analytics: o Chemical laboratory (AAS, FTIR, CSA) o Physical laboratory (mercury intrusion porosimetry MIP, BET, XRD (Bruker AXS-D8), DTA-TG, optical microscopy with image analysis software, rheological measurements at high p-T conditions combined with ultrasonic measurement of the zeta-potential and particle size distribution, calorimeter, laser granulometer, determination of transport parameters) o Mineralogical Laboratories for (XRD, DTA/TG, SEM, TEM), and geochemical analytics (AAS, ICP-OES, ICP-MS, CSA, XRF) o Stable isotope laboratory (IR-MS, CRDS) and microanalytics (µRFA) o Clay mineralogical analyses (caprocks o Electron microscopy (SEM and ESEM) • Monitoring:

	o 4D time lapse reservoir monitoring (localization and source mechanisms of induced seismicity) o Seismic tomography o Seismic interferometry o Development of induced seismicity: probabilistic analysis o KArlsruhe BroadBand Array (KABBA consists of 42 high precision broad-band seismometers that can be used for the above purposes) o Monitoring of material moisture content (TDR - Time Domain Reflectometry) • Modeling and numerical simulation: o Development of innovative constitutive laws for geomaterials o Modeling and numerical simulations of underground processes including safety analysis o Numerical modeling of underground stress fields including of pore pressures (e.g. investigation of load change effects during injection). o Stability assessment for bounding faults, caprocks and wellbores
LNEG	• Geological, geophysical, geochemical instruments and laboratories • Geological, geophysical and hydrogeological database of Portugal • Core storage • Sample (slabbing, gridding sieving) and thin sections preparation lab; • XRD, EPMAand XRF labs • Reference laboratory for water analysis and petrography • Sedimentology, Micropaleontology and biogeochemistry laboratories • Marine geology laboratory (seismic, bathimetry and side scan sonar data processing) • Software packages: GMS; TOUGH; Promax; SPW; Radexpro; IXRefrax; Seisworks (LandMark); OpendTect (DGb); GoCad • In addition, we also have drilling rigs (maximum capacity of 600 m) and mobile equipment to conduct geophysical surveys (gravimetric; magnetics; seismic reflection down to 500 m and refraction down to 200 m; induced polarization; resistivity; radiometry; multiparametric geophysical borehole logs down to 600 m)
MERG-Imperial	• Geomechanics laboratory with servo controlled electrohydraulic rock testing rig for multistage traxial testing, simulating reservoir pressures and stresses and flow characteristics for geomechanical and flow characterisation • Petrophysics laboratory for reservoir properties characterisation (porosity, permeability, relative permeability, BET). Specialist rigs for core flooding at controlled temperature and pressures • Software for static and dynamic modelling of reservoir behaviour, including flow, coupled gemechanics, geochemistry, etc…
NIVA	• Benthic chamber lander for in-situ experiment of ecosystem response to CO_2 exposure • Marine research station at Solbergstrand in Oslofjord. Mesocosm experiments on impacts from CO2 exposure in controlled environment • Deep-sea camera to map offshore benthic habitats • Sediment profiling Imagery to assess the status of the top-layer seabed • Micro-profiling of contaminants and heavy metals in seabed top-layer • Model for simulating carbon cycle and biogeochemical processes in the marine environment • Coupled hydrodynamic/biogeochemical model to simulate spreading, dissolution and biogeochemical impacts of CO_2/CH_4 seeps into the marine environment.

OGS	• Research vessel OGS-Explora (73 m long, ice-class) for geophysical, oceanographic and marine biology surveys • Telemetric seismic recorders for deep and high-resolution 2D and 3D seismic surveys (high number of active channels) • Seisbit, a patented system for reverse VSPs • Microgravimeters and seismological recorders • Multispectral cameras and LIDAR mounted on an airplane for remote sensing surveys • Proprietary software for subsurface direct and inverse modelling (also for parallel computers) • Database with all the geophysical data available to the public in Italy (wells and seismic profiles) supplemented by the data collected by OGS (CROP project and Mediterranean Seismic Lines) • Calibration laboratory for oceanographic instruments • Microbiology Laboratory • Primary Productivity Laboratory • Molecular Biology Laboratory • Biogeochemistry Laboratory to study C, N, P, Si cycles • Work-in-cool rooms for protists cultures • Oceanographic probes (CTD, bio-optical probes) • Sampling devices (carousel sampler equipped with Nikin bottles, phyto-zooplankton nets, grabs)
RSE	• Database on petrophysical properties of rock in Italy • Database on geological data for a relevant set of deep wells (>2000 data) • Benthic chambers for shallow depth • Benthic Lander for high depth • Analytical instrumentation for carbonate system • Analytical laboratories • Software tools for CO_2 fluidodynamic, geochemical and geomechanical numerical modelling • Software tools to create accurate 3D mesh with Voronoi methodology • Laboratory facilities to study the chemical reaction of minerals at CO_2 reservoir conditions and degradation of cement wells • Numerical modelling of Italian potential reservoirs in saline aquifers: n.3 onshore and n.1 offshore
SINTEF	• Own basin modelling software package SEMI, capable to model migration behaviour of non-aqueous phases and pressure.
TNO	• Expertise in the following areas: • Storage capacity estimation, on basin scale as well as on reservoir level • Reservoir simulation and engineering • Geochemical modelling of interaction between CO_2 and matrix • Geomechanical analyses of storage complex • Monitoring • Risk analysis • Economic modelling of the CCS chain • Extensive experience in performing storage site feasibility studies, being involved in all national activities, as well as in most site feasibility studies in the framework of European-funded projects • Software tools for the economic analysis of CCS projects, both one-on-one and many-on-many scenarios • Quantitative risk analysis methods and risk / mitigation database • Database of national subsurface properties • Expertise in data assimilation and reservoir optimisation

	• Access to national laboratories, to perform geomechanical and geochemical experiments
UK-BRISTOL	• **Bristol Interface Analysis Centre** Material science and surface analysis laboratory, with facilities for X-ray diffraction, Electron backscattering, Raman spectroscopy, SEm, TEM, Focused Ion-Beam probes, mass spectroscopy, etc… These techniques are mainly used to image CO_2 reaction effects on rock fabrics. • Group also has access to most geophysical data (particularly microseismics) from both Weyburn and In Salah CCS sites.
UK-SCCS	**EDINBURGH UNIVERSITY** • **Geochemical laboratory (UoE)** A full suite of micro-analytical instrumentation, equal to any in Europe. Complete with dedicated technical support and sample preparation equipment. Suitable for analysis of the Rowntree and textures before during and after experimentation, or from natural analogues sites. • **Experimental geoscience (UoE)** UK National community facility, comprising high-pressure experimental laboratories, specializing in first of a kind and difficult to measure experimentation. Some CO_2 specific equipment. Experienced interaction with EU collaboration. Also includes an optically fat bench for fine resolution x-ray CT scanning of matrix facility, or fracture systems. • **Seismic research (UoE)** Edinburgh Seismic Research - ESR - is the UK's largest group of academic scientists in exploration and monitoring geophysics. Particular experise exists in fracture flow, time-lapse, and 3D anisotropy. ESR focuses in three main areas of application: Oil and gas, hydrates, CO_2. • **CO_2 flow laboratory (UoE)** New facility dedicated to CO_2 supercritical flow experiments through matrix paucity and fractured court material. Ability to alternate brine and CO_2. Also possible to geochemistry sample before during and after run times. • **Microbiology laboratory (UoE)** This enables growth of bacterial cultures, separation of cells from supernatant solution is, and surface characterization. Bio- reactor for control Eh pH temperature experiments. Includes access to facilities within the University for DNA and RNA gene sequencing. • **Computational seismic and simulation laboratory (UoE)** Seismic imaging and analysis laboratory, running Kingdom, GeoFrame and Petrel software. Central computing facilities include the most modern parallel processing powerful systems, equal to any in the EU. • **Common Data Access (UoE)** It provides Web-based access to all records for the UK offshore enabling data rich analysis of hydrocarbon fields and CO_2 storage formations. • **Remote sensing survey aircraft (UoE)** The aeroplane enables us to make measurements of trace gas concentrations up to about 10,000 feet asl and to take images of the Earth's surface using sensors similar to those carried onboard satellites. We are also able to directly measure the exchange of gases between the earth’s vegetation and the atmosphere while flying low above the ground, which is a vital tool in understanding the effect of natural processes on human emissions in the atmosphere (and vice versa). • **Field spectroscopy facility (UoE)** This is a UK national facility, containing a full and comprehensive suite of remote sensing equipment. This is state of the art in all areas and involves meeting the demands of users. These instruments find application in surveying of stressed vegetation, contaminated land mineral surveying or waste. • **Isotope geoscience (UoE)**

	Facilities at SUERC contain a cluster of European quality isotope analysis systems for a comprehensive suite of all geological applications. This hosts five UK national facilities. These enable the qualitative evaluation of mineralogical effects at natural sites and laboratory experimentation. Also includes a 14C accelerator dating facility. **• Extreme Conditions experimentation and analysis (UoE)** This is a multi-disciplinary Centre at The University of Edinburgh designed to promote the study of materials at extremes of pressure and temperature, and in electromagnetic fields, using both in-house and synchrotron and neutron techniques. **• Joseph Black laboratory for CO2 chemistry (UoE)** Brings together chemists, chemical engineers, and geologists in studying both new catalytic methods of conversion of CO_2 into value-added chemicals, and understanding the chemical processes involved in maintaining safe geological storage sites. **• Mechanical Workshops (UoE)** Machine tools and skilled staff capable of manufacturing fluid flow, and extremely high-pressure vessels, to unique specifications. Assisted by established electronics design and control workshops capable of any geophysical laboratory technique. **HERIOT-WATT UNIVERSITY** **Institute of Petroleum Engineering** **• Environmental Scanning Electron Microscopy (H-WU)** Facility with flexibility to physically examine virtually any substance, including liquids. The ESEM is also equipped with a full energy dispersive x-ray analysis package (EDX), which is available in all modes. This is particularly useful to examine hydrated oily or sensitive samples in their natural state. Application in the interaction of oil and CO2 in porous rocks. **• Rock Mechanics Laboratory (H-WU)** Measurement of Rock Properties under true triaxial stresses, using a new test cell, producing stress-sensitive petrophysical and rock property data. Testing of rock failure modes and fault reactivation. Testing of dry, wet and CO2 saturated cores. Includes fully coupled flow/geomechanics simulation capability. Underground Coal Gasification. **• Gas hydrate research (H-WU)** CO2 storage in subsurface and the role of gas hydrates. Flow assurance in the oil/gas industry (hydrates, wax, salt, asphaltene precipitation problems), gas hydrates in the natural environment (e.g. geohazards, potential as an energy resource), and positive applications of hydrates (e.g. gas separation, storage and transportation). **• PVT & Reservoir Fluids (H-WU)** One of the few international centres active in the laboratory measurement and theoretical modelling of phase behaviour and properties of petroleum reservoir fluids. Work includes reservoir fluid analysis, multiphase equilibria VVT element, at a density viscosity and interfacial tension measurement, fluid contact miscibility. These can be undertaken at pressures up to 30,000 psi and 200°C. PVT and phase behaviour and properties of CO_2-rich systems, dehydration requirement for CO2-rich systems, acoustic properties of CO2-rich systems in bulk conditions and in porous media, together with all relevant thermodynamic modelling. **• Hydrocarbon Recovery Mechanisms Laboratory (H-WU)** CO2 Enhanced Oil recovery (EOR) testing. Novel method for improving cold production of heavy oils by combining water and CO2 injection. Carbonated Water Injection (CWI): CO_2-enriched water flooding. Measurements of CO_2 relative permeabilities.

	• **Production Chemistry Laboratory (H-WU)** CO_2 interactions with brine and porous media, especially mineral reactions (dissolution/precipitation). Formation damage testing. ICP and wet chemical analysis of brines. Mineral scale inhibition testing. Includes thermodynamic modelling of mineral reactions and mineral inhibition treatments. Prevention of CO_2 leakage from reservoirs. • **Equipment Manufacture (H-WU)** Mechanical workshop capable of manufacturing equipment that can withstand pressures of 30,000 psia and temperatures of 200 C to study properties of CO_2, and flow of CO_2 through porous media. • **Computational Multi-Scale Modelling Laboratory (H-WU)** Pore-scale flow modelling of near-miscible CO_2 injection for sequestration and enhanced oil recovery. Pore-scale reactive transport simulation of petrophysical property changes due to CO_2 injection. Field scale flow modelling, including fully coupled geomechanics and geochemistry. Quantification of flow through cap rock and fault seals. • **Computational Seismic Laboratory (H-WU)** Modelling 3D and 4D seismic responses from geological and flow simulation models. Incorporates realistic fluid flow compositional simulation for reservoirs with range of geological conditions. Linking seismic response to geological, petrophysical and fluid domains for CO2 monitoring. • **Computational Carbonate Reservoir Simulation Laboratory (H-WU)** CMG supply standard oil industry software products used in many CO_2 and CO_2EOR studies. Development of software for CO2 studies in carbonate reservoirs.
UK-UNOTT	• Oil gassing facility (ASGARD) that simulates the elevated soil CO_2 concentrations caused by a CCS leak. The 75 m2 measurement programme includes routine carbon isotope soil gas analysis, plant stress in grass and cereal crop growth samples, and regular monitoring of spectral reflectance to validate satellite data
University of Évora	• Permanent and portable Broadband seismological stations (10) • Seismic acquisition system (24 channels, 4.5 Hz (vertical components) and 10 Hz (horizontal components) • Computer cluster (28 nodes) and TOUGH2/ECO2N modelling software • Geothermal Paleoclimatology Platform, field laboratory to study energy transfer processes between the ground and the atmosphere (air- ground coupling) • Mineralogy and Petrology laboratory equipped with SEM-EDS (Scanning Electron microscopy with X-ray microanalysis), Raman microscope, and standard equipment for mineralogical and petrographical analysis. • Laboratory of geochemical analysis of porous materials, equipped with Atomic absorption spectrometer with flame and Hydric, Atomic absorption spectrometer (AAS) with Hydride generator system and graphite furnace; UV-visible spectrometer (UV-Vis); Total organic carbon analyser (TOC); Portable infrared mineral analyser; Elemental Analyser for CHNS-O; Infrared spectrometer (FTIR); Laser sedimentometer; Benchtop conductivity/pH/Ion/DO meter; Benchtop centrifuge refrigerated + high capacity swing-out rotor) • Laboratory of stable isotope analysis, equipped with GC with TCD and FID detector • Experimental tectonics laboratory, associated with the Laboratory on Investigation in Industrial and Ornamental Rocks, where simulation with analogical models is performed
University of Rome	• Equipment for shallow subsurface and surface gas measurements, including probes, sampling canisters, instruments for in situ gas analysis (CO_2, H_2S,

	H_2, Rn, etc.), instruments for CO_2 flux measurements • Equipment for shallow groundwater sampling and monitoring, including manual piezometer installation tools, pumps, and down-hole sensors for monitoring major chemical species, water-level, etc… • Equipment for surface water sampling and monitoring, including a mini-ROV (capacity to dive up to 50 m water depth) equipped with video capabilities • Gas Geochemistry Laboratory for analysis of gas and dissolved gas samples, including multiple gas chromatographs and helium mass spectrometers • Aqueous Geochemistry Laboratory for analysis of groundwater and surface water samples, including ion chromatographs for major ions and an ICPMS for minor and trace element analysis • Sensors Research Group – actively involved in the development, testing, and deployment of gas and dissolved gas-monitoring systems for mapping applications or permanent in situ installation. Recently completed deployment of new generation of CO_2 and CH_4 soil gas and atmospheric gas analysis station for real-time monitoring via the internet of gas concentrations and in situ meteorological conditions, and a second system for monitoring dissolved CO_2 and CH_4 in seawater • Structural Geology Research Group – actively involved in modelling of secondary permeability distribution (fractures and faults) based on real-world sites and associated gas flow and migration • Development of and access to a series of natural test sites where geologically produced CO_2 is leaking at surface - sites used to test monitoring and site assessment tools, study the processes that control gas migration, and assess the potential impact and risk of CO_2 leakage at ground surface. These sites include, but are not limited to, the terrestrial sites of Latera and San Vittorino, and the marine site of Panarea • Soil gas and gas flux database of Italian territory.
VITO	• Geological database on the Belgian subsurface • Databases for subsurface applications in Flanders-Belgium (the databases are used to collect and handle data that is used in geological and thematic mapping projects and for the development of reservoir models. These models are used in resource calculations and for reservoir development) • Methodology to calculate the CO_2 storage potential and associated CH_4-extraction potential in coal beds • CO_2 sink inventory for CO_2-storage in saline aquifers in Flanders • High P and T reactor equipment to study CO_2 rock interactions • Carbonation unit equipped to study in situ reaction kinetics • Geochemical and petrographic laboratory • Research lab on bioaugmentation and the use of specific micro-organisms to degrade specific compounds

7. Contact Point for the Sub-Programme on CO_2 storage

Dr. Sergio Persoglia
OGS – Italian National Institute of Oceanography and Experimental Geophysics
Borgo Grotta Gigante, 42/C
34010 Sgonico (TS)
Italy

Phone: +39 040 2140 229
Fax: +39 040 327307
e-mail: spersoglia@ogs.trieste.it

Reference for SP1 Monitoring

Dr. F.P. Neele
TNO - Netherlands Organization for Applied Scientific Research
Princetonlaan 6
3584CB Utrecht
Netherlands
Phone: +31 30 256 4859
Fax: +3130 256 46 05
e-mail: filip.neele@tno.nl

Reference for SP2 Static modelling

Dr. Carlos Rosa
LNEG - Laboratório Nacional de Energia e Geologia, I.P
Estrada da Portela, Bairro do Zambujal – Alfragide
Apartado 7586 - 2720-866 Amadora
Portugal
Phone: +351 214 705 458 (dir.)
Fax: +351 217 160901
e-mail: carlos.rosa@lneg.pt

Reference for SP3 Dynamic modelling

Dr. Laurent Trenty
IFP Energies nouvelles
1 et 4 Avenue de Bois Préau
92852 Rueil Malmaison CEDEX
France
Phone: +33 1 4752 7259
Fax: +33 1 4752 7022
e-mail: Laurent.TRENTY@ifpenergiesnouvelles.fr

--- +++ ---

Pag. 402

EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

CO_2 capture and storage (CCS)

Version: *2.1*
Last modification date: *January 7, 2011*
Contact person: *Andreas Ehinger – andreas.ehinger@ifpenergiesnouvelles.fr*

Pag. 402

Page intentionally left blank

Pag. 404

SUMMARY OF THE JOINT PROGRAMME ON CCS

The Carbon Capture and Storage Joint Programme (CCS-JP) involves over 30 members from more than 12 countries who have committed more than 270 person years /year to carry out joint R&D activities.

The CCS-JP is completely dedicated to reaching the objectives that the international community has identified as necessary enablers for large scale deployment of CCS and thus for holding its promise to contribute a very significant part to the required world-wide CO_2 emissions reduction :

- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ confidence in storage technologies, based on subsurface knowledge and understanding;

The program is thus structured in two sub-programmes corresponding to the two mayor steps in the CCS chain: CO_2 capture and CO_2 storage. In the future, and depending on the dynamics of the programme, it is expected that other research themes, e.g. CO_2 transport, may become part of the programme.

In CO_2 capture, collaborative R&D will take place on pre- and post-combustion capture as well as on oxyfuel capture. Technologies that will be investigated include CO_2 solvents and sorbents, polymeric, metallic and ceramic membranes, solid looping processes, and advanced gas turbines. Also several cross-cutting issues will be addressed. These include integration of CO_2 capture in power plants, CCS in industry and Bio CCS.
The general objectives of the CO_2 capture sub-programme are to:

- develop more energy efficient and more cost efficient CO_2 capture technologies with a low environmental impact.
- develop more efficient designs for integration of CO_2 capture technologies in new and existing power plants and other industrial facilities (steel, cement, refineries, biofuels production, etc.).

In CO_2 storage, the R&D activity will focus on static and dynamic modelling of the subsurface and its interaction with injected CO_2 and on associated monitoring methods. The general objective of this programme is to produce significant advancements on the issues that are recognised as key elements for a safe and wide deployment of geological CO_2 storage:

- identification and characterization of suitable geologic complexes that may be used for storing CO_2, with no interference with other human activities, no impact on the ecosystem, having capacities that match the sources and that guarantee safe conditions for the whole period of storage operations, closure and post closure;
- development of tools that allow better understanding and evaluation of the behaviour at different time scales of the injected CO_2 and its interactions with the storage complex and the surrounding formations up to the surface;
- further development and integration of a large set of currently-available monitoring techniques and the definition of recognised protocols for their use in a variety of geological, environmental and operative contexts.

The CCS-JP management will be particularly attentive to efficient interfacing with other initiatives in the field of CCS research, in particular the ZEP technology platform, the CCS-EII, the ESFRI-listed ECCSEL project, etc. It will also seek contact with the European Commission and with Member States in order to streamline R&D priorities.

Pag. 404

Pag. 405

Page intentionally left blank

Pag. 405

Pag. 406

Contents

Pag. 406

Pag. 407

Page intentionally left blank

Pag. 407

1. Background

CO_2 capture and storage (CCS) is potentially one of the major technology solutions for reducing man made greenhouse gas emissions. The important role that can be played by CCS in the battle against climate change has been recognized by many international bodies like the International Energy Agency, the Carbon Sequestration Leadership Forum or the Global Carbon Capture and Storage Institute. In its latest documents, the International Energy Agency estimates that CCS could contribute as much as 20% of the total emissions reduction required by 2050 in order to maintain global warming below 2°C. Quite naturally, CCS is thus one of the key technologies mentioned in the Strategic Energy Technologies (SET) Plan that the European Commission has published in 2008.

In Europe, the European Commission has actively supported CCS research since the 1990s through its R&D framework programs. Furthermore, in 2005, European CCS RD&D got a large impulse through the launch of the European Technology Platform on Zero Emission Fossil Fuels Power Plants (ETP-ZEP). This platform brings together stakeholders from industry, public R&D and NGOs and is very active in all aspects related to CCS. Concerning R&D, ZEP has published in September 2006 a Strategic Research Agenda and in 2009 its "Recommendations for research within EU and national programs in support of deployment of CCS in Europe beyond 2020".

During the last years, CCS research has already achieved significant progress permitting today to conceive, build and run first large scale CCS pilot and demonstration projects. The first six European projects, funded by the European Economic Recovery package, cooperate within the framework of the CCS project network set up by the European Commission, and the European Industrial Initiative (EII) launched in June 2010 is dedicated to setting up a complete, comprehensive CCS demonstration program.

However, for economic reasons, the currently available technologies used for the first demonstration plants will not allow the large scale deployment of CCS and we will thus fall behind the exploitation of the full potential contribution of CCS in the climate change battle. Moreover, the public acceptance of CO_2 storage has still to be gained. We need thus to intensify the R&D activities in order to develop

- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ public confidence in storage technologies, based on subsurface knowledge and understanding.

While a number of collaborative R&D projects are on-going in Europe, both in the framework of FP7 funding and national funding, the advent of EERA will allow the main public R&D organisations active in this area to further intensify their cooperation. Indeed, the overarching objectives of the EERA CCS Joint Programme (CCS-JP) are to ensure that short, medium and long term R&D challenges are recognized, translated into R&D programs and met through the joint execution of R&D projects by the CCS-JP members. Industry relevance of this research will be guaranteed by a close coordination both with the ZEP platform and with the EII on CCS.

In order to maximize the added value of cooperative research, the CCS-JP will also be very attentive to interfacing with existing and future bodies and activities, like for example the CO_2GeoNet association in the field of geological storage of CO_2 or the ESFRI-labelled ECCSEL project aiming at setting up a pan-European research infrastructure for CCS.

2. Value added

The EERA Joint Programme on Carbon Capture and Storage provides added value through the enhanced coordination and cooperation of the activities of the major European R&D players in CCS.

Strategic leadership

Strategic leadership builds upon a vision of the future and of the transition pathways to reach that future. Bringing together the major European R&D players in a Joint Programme will allow to share individual visions and to gradually build a common one, providing true strategic leadership on a global scale. Communication, information exchange, mutual understanding, trust building, through meetings and effective collaborations, in the framework of an efficient governance, and strongly interfaced with industrial and other players, will be key for reaching this goal.

Speeding up the realization of SET-plan goals

The SET-Plan aims at accelerating the development and deployment of new energy technologies in response to the climate change challenge. Joint R&D planning and programming, knowledge sharing, grouping of resources, joint execution of R&D projects are the means to achieve this acceleration. The CCS-JP is completely focused on the efficient implementation of these means: organisation of meetings and workshops, elaboration of shared program documents, joint execution of projects, coordination with other initiatives.

The CCS-JP will also contribute to the acceleration of the realisation of the SET-Plan goals through its role as an open alliance bringing together all relevant R&D players. Indeed, there exists a number of European structures dedicated to CCS research, with restricted memberships, and the coordination between those structures will be facilitated as all the involved actors will meet, exchange and cooperate in the framework of the CCS-JP.

3. Objectives

The massive deployment of CCS after 2020 requires that three essential points will have been achieved until then:
- ✓ cost competitive and energy efficient CO_2 capture methods and processes;
- ✓ confidence in storage technologies, based on subsurface knowledge and understanding;
- ✓ first successful demonstrations of the full CCS chain, including capture, transport and storage

The latter point is currently being addressed in the recently awarded CCS demonstration projects under the EU Economic Recovery Program and will be further pursued by the European Industrial Initiative on CCS. The EERA CCS-JP aims at the first two points.

CO_2 Capture
Several capture technologies are currently being investigates. It is important to continue the investigation of all of them since none of them has emerged yet as superior to the others. Moreover, the different technologies do not cover necessarily the same time horizons, in other words the short/medium term improvements of known technologies have to be researched simultaneously with the next generation, medium/long term technologies.

The main R&D objectives in the area of CO_2 capture are
- ✓ improved CO_2 separation technologies (solvents, sorbents, membranes);
- ✓ improved fuel firing systems (hydrogen gas turbines, oxy-boilers);
- ✓ new processes (carbonate cycles, chemical looping combustion).

Pag. 410

CO_2 storage

Safe CO_2 storage requires good knowledge of the subsurface conditions and of the dynamic interaction of injected CO_2 with the subsurface environment. The basic approach for achieving this aim is the coupling of predictive modelling with experimental observation.

The main R&D objectives in the area of CO_2 storage are

- ✓ improved capacity to characterize the subsurface;
- ✓ improved methods for predicting the fate of injected CO_2;
- ✓ enhanced capabilities to monitor all components of the CO_2 storage complex.

4. Description of foreseen activities

General program activities

A number of general program activities will be performed to make the CCS-JP become a reality. In particular, the CCS-JP will

- set up a mechanism to identify and to include under the CCS-JP umbrella ongoing and new projects performed by CCS-JP members, including those funded under FP7
- help CCS-JP members to discuss common R&D interests and to prepare joint projects (funded by external sources or by own resources), e.g. through the organisation of topical workshops
- establish relationships with the European Commission and with Members States, in particular in the context of future financial support
- formalize links with different organisations / structures in Europe in order to insure coordination and overall coherence of European R&D activities in the field of CCS:
    - EIT/KICs (InnoEnergy and Climate)
    - Zero Emissions Platform ZEP
    - European industrial initiative EII-CSS
    - Pan-European CCS infrastructure project ECCSEL
    - Association of CO_2 storage R&D organisations CO_2GeoNet
    - ...
- establish contacts with other EERA JPs that may have some intersection with the CCS-JP, e.g.
    - Biomass JP - CO_2 capture by algae
    - Biomass JP – use of biochar as CO_2 capture and storage option
    - Geothermal Energy JP – coupling of CO_2 geological storage and geothermal energy recovery
    - Basic science for energy

R&D activities in the sub-programmes

The EERA CCS Joint Programme is currently organized into two sub-programmes:

- CO_2 capture
- CO_2 storage

This "natural" structuring has been adopted for the time being and will allow efficient management of the JP activities. In the future, new sub-programmes may be added (e.g. a sub-programme on CO_2 transport) or the two existing sub-programmes may be split in view of the volume of activities. The guiding ideas for the structuring of the JP into sub-programmes are and will be thematic coherence and organisational efficiency. Interfacing between sub-programmes will be achieved in a general way at JP meetings (e.g. executive board meeting) or in a detailed way by inter-project cooperation or, in some cases, by cross-sub-programme projects.

Pag. 410

 Pag. 411

It has to be noted that this first description of work (DoW) of the EERA CCS-JP does not pretend to be a comprehensive document covering all R&D aspects related to CCS. It is rather a document presenting a first set of identifies subjects the program members wish to work on in a collaborative way. Thus the DoW of the CCS-JP is expected to evolve over time to include more subjects.

The two sub-programmes are structures into several R&D areas. For each area the program members have identified key objectives and they have defined dedicated work packages in order to further structure the R&D activity. Below is a summary of these objectives and work packages; for more details, please refer to the sub-programme descriptions (Annexes of this document).

CO_2 Capture sub-programme

The Sub-programme on CO_2 capture is broken down in four areas with specific objectives and work program structures.

- **Post-combustion CO_2 capture**
  - Objectives
    - Develop second generation solvent systems and processes with improved performance (energy requirement, costs, environmental impact) compared to the first generation solvent systems and processes.
    - Develop proper control schemes and improved online analysers for large scale integrated capture facilities.
    - Develop improved methods for avoidance of emission of species (amines, degradation and by-products), which could be harmful to the environment
    - Investigate and develop solid sorbents and carbonate looping cycles for more efficient post-combustion capture.
    - Development of polymeric and ceramic membranes with improved separation properties
    - Developing advanced techniques for monitoring and abatements of CO_2 contaminants as NOx, hydrocarbons, and particulate for allowing efficient and safe CO_2 capture.
  - The Work program is structured around the three main technologies for post combustion capture:
    - CO_2 solvent systems
    - CO_2 sorbent systems
    - CO_2 selective membranes

- **Pre-combustion CO_2 capture**
  - Objectives
    - Development of high-temperature membrane materials, membrane modules, and membrane reactors, testing them at realistic conditions and designing schemes for integration of membrane systems in power plants.
    - Development of high-capacity CO_2 sorbents for combined CO_2 and sulphur removal, for sorption-enhanced reforming and sorption-enhanced water-gas shift. Designing schemes for integration of sorption systems in power plants.
    - Investigate and develop hydrogen-fired gas turbines, including CFD models, and the use of membranes in the combustion chamber.
  - The Work program addresses separation methods (membranes, sorbents) as well as dedicated gas turbine technology:
    - Hydrogen selective membranes
    - CO_2 sorbent systems
    - Hydrogen fired gas turbines

- **Oxyfuel CO_2 capture**
  - Objectives

 Pag. 411

Pag. 412

  - Study the implication of using pure oxygen in coal combustion in boilers and fluidized beds, develop CFD models, and investigate CO_2 purification.
  - Develop mixed ionic electronic conducting materials and thin film membranes for O2/N2 separation
  - Develop chemical looping combustion technology: design reactors, develop oxygen carriers for both gaseous and solid fuels.
  - Investigate and develop oxyfuel gas turbines, including CFD models
- The Work program comprises 4 work packages:
  - Oxy-combustion
  - Oxygen selective membranes
  - Chemical looping combustion
  - Oxyfuel gas turbines

➢ **Cross-cutting issues**
- Objectives
  - Define common starting points and boundary conditions for modelling and economic evaluation of all the technologies to be used in the CO_2 capture sub-programme.
  - Developing proper steady state and dynamic models of CO_2 capture installations integrated in power plants and compare technologies on an equal basis. Study the possibilities for CO_2 capture technologies in biomass conversion schemes, such as the production of biofuels, aiming to achieve negative CO_2 emissions.
  - Investigate the possibilities and technological challenges for CO_2 capture in non-power applications like the steel, chemical and cement industries and refineries.
- The Work program is composed as follows:
  - Benchmarking, process simulation, and economic evaluation
  - Bio CCS
  - CO_2 capture from other sources

CO_2 Storage sub-programme

The Sub-programme on CO_2 geological storage is broken down in three areas with specific objectives and work program structures.

➢ **Monitoring**
- Objectives
  - Developing passive, long-term monitoring techniques (these may include autonomous active techniques, such as ERT or seismic measurements with permanent source-receiver deployment...).
  - Establishing or improving methods to detect and quantify CO_2 in different parts of the storage complex.
  - Preparing for a field test of a suite of monitoring techniques.
  - Developing a method for constructing monitoring scenarios (monitoring plans).
- The Work program comprises three work packages with respect to the sub-systems to be monitored and one work package dedicated to the monitoring-modelling integration:
  - Surface and near-surface
  - Reservoir and overburden
  - Wellbore system
  - Integrated closed-loop monitoring and modelling

➢ **Static modelling**
- Objectives
  - Further defining reservoir and cap-rock characteristics that are relevant to injectivity, capacity and storage integrity.
  - Providing means for predicting spatial characteristics of the reservoir and storage complex, while assessing their uncertainties.

Pag. 412

- Defining a robust storage potential assessment methodology.
- The Work program comprises five work packages:
  - Geological structure of the storage complex
  - Petrophysical, geomechanical and geochemical characteristics of the storage complex
  - Storage potential estimation
  - Uncertainties management
  - Alternative geological storage solutions

➢ **Dynamic modelling**
- Objectives
  - improve and certify dynamic modelling approaches
  - enable large scale, coupled modelling
- The Work program is structured in three work packages:
  - Development / improvement of constitutive laws, geochemical databases, coupling / interaction approaches
  - Computational / numerical approaches to improve large space and time scales design for hydrodynamic and chemical modelling
  - Workflow design methodology and validation.

5. Milestones

not public information

6. Participants and Human Resources

Membership to the CCS-JP is to be formalized by signing a general "EERA Declaration of support" and a CCS-JP specific "Letter of intent". As of today, no such signatures have been requested from the organisations that have contributed to the elaboration of the programme. Thus, the below "membership" statistics and tables refer to those organisations that have committed themselves informally during the process of writing this document.

General structure of membership and human resources commitment (in person years / year (py/y)):

Total number of JP members	34
Number of participants	24
Number of named associates (some participants have already consolidated their numbers with those of some non-named associates)	10
Number of members in capture sub-programme	19
Number of members in storage sub-programme	23
Number of members present in both sub-programmes	8
Total human resource commitment (py/y)	275
Human resources committed to capture sub-programme (py/y)	167
Human resources committed to storage sub-programme (py/y)	108

7. Infrastructures and facilities

Most of the programme members have at their disposal R&D infrastructures that they will use for the purpose of the programme. These infrastructures are described in the corresponding sub-programmes.

The investigation of the possibilities for putting in place a joint European CCS research infrastructure is the purpose of the upcoming ECCSEL project. ECCSEL, the European Carbon Dioxide Capture and Storage Laboratory, is part of the ESFRI roadmap and has recently been the subject of an FP7 call concerning a so-called Preparatory Phase Project (PPP). This project, expected to run from 2011 to 2013, has as objective to design ECCSEL in all its aspects, including technical (which infrastructures will make up ECCSEL?), contractual (who will have access under which conditions?) and financial (who will pay?) issues. The ECCSEL PPP is headed by Trondheim University (NTNU) and it involves all major European CCS R&D organisations and in particular those present in the CCS-JP. Thus there is an automatic, inherent connection between the CCS-JP and ECCSEL through the presence of the same actors in both structures. In addition, a more formal relationship will be established between the CCS-JP and ECCSEL.

In summary, the CCS-JP will not work on the subject of infrastructure sharing but will seek a close integration of ECCSEL and the CCS-JP, e.g. in the sense that CCS-JP projects will be able to use ECCSEL infrastructures.

8. Management of the Joint Programme

Interaction with existing and emerging initiatives

In the field of carbon capture and storage there exists a wide variety of initiatives, organisations and structures. The EERA CCS-JP will establish close contacts with the most prominent ones:

- Zero Emissions Technology Platform (ZEP), in particular with the Technology Task Force of the ZEP
- European Industrial Initiative on CCS
- CO_2GeoNet – Association of European R&D centres in the field of CO_2 geological storage
- ECCSEL –European ESFRI infrastructure in CCS

Furthermore, contacts will be established with the two EIT/KICs working on CCS, the InnoEnergy KIC and the Climate KIC.

Interaction between the CCS-JP and the other initiatives will consist in formal and informal meetings and in reciprocal participation as observers in governance structures. The short term objective of the interaction will be to make sure that information on strategic work (e.g. roadmaps) and on R&D activities flows seamlessly between the different initiatives.

EERA internal communication will be established with those JPs that might have some intersection with the CCS-JP (Biomass, Geothermal Energy, Basic science for energy).

Governance structure

The EERA CCS Joint Programme is currently organized into two sub-programmes, CO_2 capture and CO_2 storage. This "natural" structuring has been adopted for the time being and will allow efficient management of the JP activities. In the future, new sub-programmes may be added (e.g. a sub-programme on CO_2 transport) or the two existing sub-programmes may be split in view of the volume of activities. The guiding principles for the structuring of the JP into sub-programmes are and will be thematic coherence and organisational efficiency.

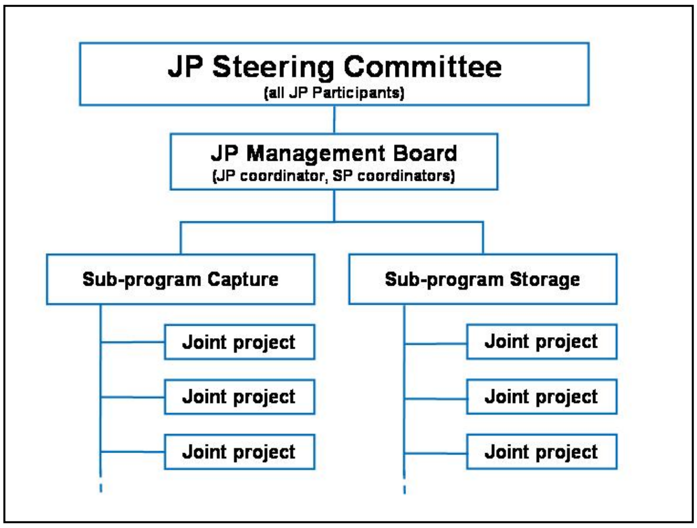
The governance structure of the CCS-JP is set-up following the relevant EERA guideline.

<u>JP membership</u>
Publicly funded R&D organisations or private companies recognized as R&D organisations by the European Commission can joint the program as ***participants*** if they commit more than 5

person years/year (py/y) to the program. Other organisations or those committing less than 5 py/y to the program can join as ***associates***. The contributions of an associate, both in terms of human resources and R&D work, are consolidated with those of the participant that the associates has chosen. Several small members may associate and name one of them as representative, becoming a program participant if the consolidated contribution surpasses 5 py/y.
JP membership (either as participant or as associate) is formalized by signing a general "EERA letter of support" and a program specific "letter of intent".

JP Steering Committee
The JP Steering Committee is composed of one representative of each JP participant. The JP Steering Committee

- selects the Joint Programme Coordinator
- selects the Sub-programme coordinators
- reviews the progress and achievements of the JP
- provides strategic guidance to the management board
- approves new JP members (participants or associates)
- approves updates of the Description of Work of the JP.



The JP Steering Committee is chaired by the JP Coordinator; the sub-programme coordinators participate as observers in the Committee. It convenes twice a year.
The JP coordinator and the sub-programme coordinators cannot act as representatives of their respective R&D organisation in the Steering Committee.

JP Management Board
The JP Management Board is the executive body of the JP and is composed of the JP Coordinator (chair) and the sub-programme coordinators.
Tasks and responsibilities:

- Financial management of the JP budget (if applicable)
- Contractual oversight
- IP (intellectual property) oversight
- Scientific co-ordination, progress control, planning on programme and sub-programme level
- JP internal communication
- External communication with other organisations (European Commission, ZEP, EII, ...)
- Reporting to Steering Committee and EERA ExCo

The JP Management board meets four times a year.

Sub-programme execution team
The Sub-programme execution team is the coordinating body on the sub-programme level. It is composed of the sub-programme coordinator (chair) and the leaders of the projects within the sub-programme. It meets on request.

JP Coordinator
The JP Coordinator (JPC) is selected by the JP steering committee for a mandate of two years. The mandate can be renewed. The JPC chairs the Steering Committee and the Management Board.
Tasks and responsibilities

- Co-ordination of the scientific activities in the joint programme and communication with the EERA ExCo and the EERA secretariat.
- Monitoring progress in achieving the sub-programmes deliverables and milestones.

- Reporting scientific progress and unexpected developments to the EERA ExCo.
- Propose and coordinate scientific sub-programmes for the joint programme.
- Coordinate the overall planning process and progress reporting.

Sub-programme coordinator
The Sub-programme coordinators are selected by the JP steering committee for a mandate of two years. The mandate can be renewed. The sub-programme coordinator takes part in Steering Committee meetings, is a member of the management board and chairs the sub-programme execution team.
Tasks and responsibilities
- Oversee the sub-programme projects
- Co-ordination of the scientific activities in the sub-programme to be carried out by the participants according to the agreed commitment. The SPC communicates with the contact persons to be assigned by each participant.
- Monitoring progress in achieving the sub-programmes deliverables and milestones.
- Reporting progress to joint programme coordinator
- Propose and coordinate scientific actions for the sub-programme
- Monitor scientific progress and report unexpected developments

Project leaders
The joint activities will be performed in the form of projects that are expected to be set-up in variable configurations (in terms of project members) and in the framework of project specific contracts. The project leaders are responsible for the execution of their projects; they are members of the sub-programme execution team.

9. Risks

The most important risk concerns the effective set-up of joint R&D activities (i.e. projects). This will in general require the detailed definition of a work program, a consortium and a legal contract. If the EERA project is to be proposed for external funding (e.g. FP7) the corresponding procedures and rules commonly used by the programme members will be applied. However, in the case of a non-externally-funded activity there exists a risk concerning the effective engagement of the actors. It will be the task of the JP coordinator and the sub-programme coordinators to minimize this risk.

10. Intellectual Property Rights

It is expected that the projects, e.g. the R&D work performed by the program, will be subject to individual project contracts (consortium agreement). This implies that the CCS-JP members freely decide on the composition of any given project consortium. So, while the CCS-JP is open to all R&D organisations provided they commit themselves to a substantial contribution to the program, any given project will be run as a consortium with its agreed-on mechanisms for including new members. Concerning IPR, it is expected that the projects follow the EERA IPR policy.

11. Contact Point

Andreas Ehinger andreas.ehinger@ifpenergiesnouvelles.fr
IFP Energies nouvelles T: +33 14752 6744
1&4 avenue de Bois-Préau F: +33 14752 7026
92852 Rueil-Malmaison M: +33 68016 4716
France

 Pag. 417

Allegato 7.

Partecipazione alla delegazione europea nella visita in Australia per cooperazione sulle CCS

report finale sulla vista

elenco esperti che costituiscono la delegazione, oltre ai funzionari EC

programma degli incontri

presentazione agli australiani delle attività di EERA

 Pag. 417

Pag. 418

Report from EU CCS fact finding mission to Australia 5-9 December 2011

Nils A.Røkke, Rob Arts, Sandrine Decarre, Guiseppe Girardi, Jonathan Pearce, Claudia Tomescu and Marjolein de Best Waldhober

12/22/2011

This report gives facts and considerations for co-operation between EU and Australia within CCS. It isbasee

Pag. 418

Mission:

The objective of the delegation was to:

- Understand Australian CCS policies
- Resource base and power structure (utilities)
- Frame the conditions for R&D co-operation between EU and Australia within CCS including
  - Support system for R&D within the topic in Australia
  - Key scientific organisations (universities, R&D institutes), industrial players and governmental agencies and bodies
  - Identify topics for R&D co-operation in future calls in FP7
- Initiate a dialogue between the parties to enhance co-operation and follow-up activities

EU delegation:

The delegation was headed by Wiktor Raldow and Vassilios Kougnias of the commission with the support from 7 nominated EU experts:

Name	Area of expertise	Affiliation
Dr. Rob Arts	Storage	TNO, NL
Dr. Sandrine Decarre	Transport	IFP Energie Nouvelle, Fr
Dr. Guiseppe Girardi	Representing EERA	ENEA, It
Dr. Jonathan Pearce	Storage	BGS, Uk
Dr. Nils A. Røkke	Capture, also representing ZEP, **Rapporteur**	SINTEF, NO
Dr. Claudia Tomescu	Representing CCS Demo projects	ISPE, RO
Dr. Marjolein de Best Waldhober	Social sciences in CCS	ECN, NL

Visits to CCS projects in Australia

A number of sites were visited relevant in particular to capture and storage of CO_2. This facilitated a better understanding of Australian activities and priorities. The sites were located in:

- Victoria drawing upon a large reserve of brown coal (lignite) and a world class pilot storage project in Otway operated by CO2CRC[1].
- New South Wales with capture pilots in CSIRO[2] (Newcastle, outside Sydney)
- PV, CSP and wind pilots including energy storage which was provided by Australia to give background information on renewable developments in Australia.

Overall impression- framework for CCS in Australia

Australia is a continent and one country with a low population and a high carbon footprint per capita. Total emissions in 2010 in Australia amounted to near 500 million tons of CO_2 equivalents. With a population of 22 million this gives a footprint of near 22Mt CO_2/capita which is only exceeded by Qatar and UAE on a global basis (EU average 14,5 MtCO_2/capita). This is due to the industrial

[1] CO2CRC is a Co-operative Research Centre (CRC) within CO_2 with funding from companies and partnering with universities and institutes. Operated since 1999.
[2] CSIRO employs 6500 people in research within energy, environment, social sciences and general engineering, mainly funded by government (>60%).

structure of Australia, the way electricity is produced, the energy mix and the general low prices of energy.

- Australia is the world's largest exporter of hard coal (mainly to Asia) and a major exporter of minerals and raw materials.
- Electricity is mainly produced by brown and hard coal (80%) with an aged fleet of generators
- The energy mix is extremely fossil based
- The low prices of coal have dictated low energy prices and few incentives for energy efficiency and renewable phase in.
- Large distances and low populated areas means transport emissions are high

Australia has passed a law for introducing a carbon tax of 23$[3]/ton CO_2 effective from July 2012. It encompasses the country's 500 top emitters. Special conditions apply for industries which are subject to "carbon leakage" like paper and pulp, aluminium smelters and cement. Australian framework for reductions is regulated by the current Kyoto protocol and the targets on a national level are:

- 5% reductions by 2020 relative to 2000 level (note base year[4])
- 20% renewables by 2020
- 80% reduction by 2050
- 50% coal electricity generation by 2030 (80% now)

From these targets it is evident that CCS will have to play a role in achieving these.

Albeit Australia has vast resources of renewables it is not well developed, the introduction being hampered by the low price of coal. Power production is operated by private companies (some of European control like GDF-Suez) based on long term contracts for coal resources. In Victoria there are vast deposits of lignite, notably in the Latrobe valley about 150 km's from Melbourne. The lignite is low in ash, sulphur and fuel bound nitrogen, however the moisture is 65-70%. The fuel price is on the order of 1$/GJ which is low by any standards (European level 1.5-2€/GJ). The coal is mined in open pits and the power plants sit on top of the deposits with conveyors transporting the coal to the power plants. The coal is deposited in layers up to 180 metres thick with an overburden of only 10 metres.

The power plants visited (Loy Yang and Hazelwood) are plants based on technology from the 1970's and 80's. Hazelwood is ranked as the least fuel efficient power plant in the OECD. The low efficiency (26-27%) is due to the moisture content of the coal, old technology for the power plant (steam conditions) and no incentives for improvement due to low coal prices. State of the art efficiency for lignite plants in Europe is 40-43%, whereas hard coal plants reach 45-46%. There are no DESOX or DENOX requirements in Australia, meaning that any capture equipment will be complicated by the need for introducing such additional cleaning. Solvents for capture have low resistance towards NOx and SOx. Retail costs for electricity is on the order of 10 cents/kWh, generating costs are on the order of 3-6 cents/kWh.

Australia has among the best conditions in the world for solar energy due to high irradiation intensity. It also has very good wind resources with efficiency factors of 35-40% being achieved onshore. Grid parity is however hard to achieve giving the low electricity prices. Green certificates are in operation

[3] $ is Australian $ in this report if not otherwise noted
[44] Most countries base this on 1990 figures, this target is thus less ambitious as most countries had growth in emissions between 1990 and year 2000.

 Pag. 421

with an incentive on the order of 5-6cents/kWh. Given the retail price it means that renewables will have to compete at 10-11 cents/kWh which is not commercially feasible at present.

Due to the aging generation fleet of electricity in Australia with predominantly low efficiencies it is not easy to envisage retrofit capture plants to be realised which further reduces efficiencies of 8-10% points. A revamp of the fleet is needed to envisage this.

A counterpart of the ZEP can be found in Australia by the National CCS council, the main difference is that the NCCSC is appointed by the government and is led by the government. ZEP is industry led and employs all stakeholder sectors in Europe.

Storage potential in Australia

Australia has sizeable storage possibilities offshore especially in the Northern Territory, in Victoria (Gippsland) and the western part of Australia. Onshore storage is also feasible but mainly in the central and unpopulated areas without emission sources. Queensland has large emission sources and limited storage potential. An issue here is the transport distances which could be 500-600 km's.

Plans for large scale CCS deployment in Australia

The Gorgon project in west Australia is under construction and will separate CO_2 from natural gas containing 15-18% CO_2 in a LNG development. The project is operated by Chevron with Shell as another major partner. When in operation (2014) it will separate 3.5 Mt CO_2/yr. and store this in an aquifer. Legislation has been put in place to accommodate this. It will be the largest operating CCS project in the world in 2014.

Carbonnet is planning for a large scale CCS plant in Victoria, it is however not determined which source it will use for this. Storage will be in the Gippsland basin. Bids have been put in place to make use of the governmental $2Bn call for tenders[5] for CCS plants.

There are also plans for the Collie hub CCS initiative which will create a trunk line for transport of CCS in a highly industrialised area also employing cement and aluminium industry.

In Europe the EEPR and NER300 arrangements are seeking to leverage large scale integrated projects in CCS. The possible interaction and sharing between EU CCS project network and other proposed CCS demo projects in Europe with the existing or future Australian projects would be in the benefit of CCS deployment. Lessons learned regarding how to implement a demo project, to develop a business, to obtain permits, to minimize the risks and to increase the public awareness can be shared to avoid making the same mistakes and shorten the time for its realisation.

The possible interaction and sharing between Australia and the EU on project level should be explored further, the new CCS project network which is led by the GCCSI could be a good basis for this.

[5] Fund has been truncated to $1.5Bn after the floods in the Brisbane area in 2010.

 Pag. 421

Pag. 422

CCS pilots in Australia

Capture

There are PCC[6] pilots installed at Hazelwood and Loy Yang in Victoria and in NSW for the Delta power plant. The PCC pilots are comparable to pilots in Europe as regards size, the largest being at Hazelwood operating at 25 ton CO_2/day. This is similar to the Esbjerg plant in Europe. Work has been directed towards co-capture of CO2 and SOx as no DESOx is required in Australia. Amines has been developed and some new developments using secondary concentrated amines (piperazine). World class laboratories for measuring atmospheric reactions of amines can be found in CSIRO's premises at Lucas Heights close to Sydney. CSIRO is advanced as regards methods and understanding of HSE risks related to solvent use in PCC plants. Some work has also been conducted in oxy-fuel combustion (Callide), Europe is operating the largest plant in operation in the world for oxy-fuel in the Schwarze pumpe operation in Cottbus, Germany (Vattenfall). Callide will however when in operation become a comparable project. The project is supported by Air Liquide.

Storage

The Otway storage pilot is comparable to the Ketzin pilot in Europe in the sense that it is small scale (~65 ktonnes injected so far) with a large focus on dedicated research and less on operations. The Otway project consists of two phases, of which the first phase has been concluded in 2009 consisting of injection in a depleted gas field at 2000 m depth. The second phase, about to start, consists of injection in a shallower aquifer at above the gas field. A well has been drilled in 2010 up to a depth of 1565 meters. One of the main aims is to investigate residual saturation behaviour in the aquifer reservoir through a huff-and-puff injection field test combined with an extensive dedicated monitoring program. Furthermore a variety of monitoring tools including seismic are tested for their suitability to monitor the processes in the reservoir. Determination of seismic detectability through demonstration is considered an important topic in the CO2RC project.

Framework for co-operation

It would seem that the Australian funding arrangements are flexible in terms of adapting to co-operation possibilities. A sizeable portfolio of funds have been made available to a variety of partners from the government, through R&D Institutes and Universities and PPP's like the Carbonnet and the Brown Coal Innovation Australia (BCI) initiative. Twinning arrangements can be foreseen to be successful if the topics for co-operation can be agreed on a reasonable level.

Australia also established the Global CCS Institute (GCCSI) in 2008, this is still active and has established offices in various places around the world also in EU (Paris). GCCSI is a global organisation drawing upon a fund of 400 million $ made available from the government of Australia. Main mission is to promote large scale demonstration, it employs about 30 people. The operation of the GCCSI is extended two years to 2016 although with no additional funding.

Australia has been involved in a number of CCS R&D projects in the FP6 and 7, among these projects is ICap and they will operate the CCS network secretariat through the GCCSI from early 2012 with the support of 3 partners (IFP, TNO and SINTEF).

The EERA, an alliance of leading organizations in the field of energy research, also represents a

[6] Post Combustion Capture

Pag. 422

possibility for further co-operation. EERA aims to strengthen, expand and optimize EU energy research capabilities through the sharing of world-class national facilities in Europe and the joint realization of pan-European research programmes (EERA **Joint Programmes**), and it's open to international cooperation.

The Joint Programme on **Carbon Capture and Storage** was launched at the SET-Plan Conference in Brussels in November 2011 where the work (DoW) has been presented. It is structured into two sub-programmes - capture and storage - dedicated to reaching the objectives identified as necessary enablers for large scale deployment of CCS: a) cost competitive and energy efficient CO_2 capture methods and processes; b) confidence in storage technologies, based on subsurface knowledge and understanding.

The JP members are currently engaged in the organisation of a number of focus workshops. These workshops bring together those programme members that are interested in setting up collaborative projects on specific topics identified in the DoW. These projects may be funded either by own resources or they may be submitted to funding agencies for support.

In this phase of growth of JP on CCS, a possible cooperation with australian research institutions within EERA context could be analysed quickly and efficiently, starting by organising a joint meeting - to be held soon in the first months of 2012 - aimed to integrate the contribution of Australia in the existing WP's and/or to define new WP's.

Added value of EU- Australia co-operation within CCS

Australia has been pioneering legislation for CCS (for Gorgon) and has been pushing hard for realisation of plants. Limited success has so far been achieved for realization of integrated large scale plants, this is however not different from other countries or economies.

Australia is willing to promote CCS as their need for emission cuts cannot be met without this technology. It is as such a valuable allied for the deployment of CCS. Australia is among the team of willing for CCS on a global scale.

Australia has made sizeable investments in R&D and pilots for CCS. Knowledge sharing and complementarity can be established and found between EU and Australia. Global co-operation within R&D for CCS is crucial to leverage the limited funds available in each country, region or economy so that progress can be made and avoid unnecessary overlap of work.

The range of fuels explored for CCS in Australia is also relevant for Europe- some of the lignite deposits in Australia resembles for instance Greek resources and same applies for hard coal. Australia will also develop shale gas which is of importance for Europe as well for the utilisation with CCS.

Strengthening links within storage experiences and development of protocols, standards and methods will be of great interest as storage is at present the main obstacle for CCS deployment on the larger scale.

Pag. 424

Identified topics for further CCS R&D co-operation with Australia

The following list represents the first iteration of topics of mutual interest between EU and Australia and should be further discussed with the Australian counterparts especially as regards details of the headline subject.

1. Capture: **Third generation solvents and/or high capacity sorbents for capture of CO_2.** The topic includes R&D into high potential novel systems of capture of CO_2 based on solids or liquids or a combination of these such as enzyme based systems, biomimicking systems or MOF's (Metal Organic Frameworks). Environmentally benign systems should be pursued. The topic relates to both post- and pre combustion capture systems.

2. Capture: **Methods, systems and standards for measuring potential harmful emissions from CCS plants.** Amine based capture systems need to be better characterised in terms of the environmental footprint and more specifically to develop methods and standards for measuring substances of HSE concern. R&D should be directed towards developing such methods, testing and validation for the most used and prospective solvent types in CO_2 capture.

3. Transport: **Integrity of large scale CCS infrastructures.** Large scale infrastructures for CO_2 will need to be operated safely and with a no-leak philosophy. Such infrastructures will include many components that are possible sources of leaks such as valves, flanges and seals, compressors, pumps and measuring devices. The R&D work should be directed towards characterisation of current practices and experiences, materials selection and characterisation and development and testing of materials and components to be used in large scale infrastructures for CO_2 transport.

4. Storage: **Monitoring, mitigation and remediation in CO_2 storage**. A key element for stewardship of CO_2 storage is good methods for monitoring, mitigation and remediation. Limited work has so far been conducted on remediation methods and strategies. The R&D work should focus on the effective remediation strategies and methods and the required monitoring techniques and systems for realising this. Field tests and experience from operating pilots and plants should be pursued.

5. Communication and social aspects: **Energy awareness for CCS.** There is in general a low awareness in the society for the importance of energy, it's origin, production and distribution and the implication of energy usage in terms of security, the environment and climate change. Energy awareness especially directed towards CCS is a topic of interest and should be directed towards understanding the perception of energy in the society, what are the barriers for improving the knowledge and designing measures to improve the general knowledge of these issues especially for CCS. CCS can play a powerful role in mitigation emissions of CO_2 but will not be deployed unless there is a better understanding of the facts of energy and the role different technologies must play in a carbon restrained world.

It should also be noted that there exist possibilities for co-operation in current open calls in FP7, notably for the two stage call which closes in it's second stage in April 2012. These topics include "Sizeable storage pilots" and "Impacts of impurities in CO_2 for transport and the storage complex". These calls have however not been particularly designed for EU-Australian co-operation but relevant and good quality co-operation from other countries are always welcome.

Pag. 424

Pag. 425

No	Name	Company/Organization	Projects involved
1	**Mr Jonathan Pierce**	British Geological Survey (UK) –CO2 storage expert	SiteChar; http://www.sitechar-co2.eu/ CO2Care: http://www.co2care.org/ CGS EUROPE: http://www.cgseurope.net/ RISCS: information on CORDIS http://www.euussciencetechnology.eu/inventory/show/id/317
2	**Ms Claudia Tomescu**	ISPE (Romania)	GETICA-Turceni CCS power plant Romania http://www.co2club.ro/en/getica-ccs.html
3	**Ms Sandrine Decarre**	IFP Energies Nouvelles (FR)-CO2 transport expert	Coordinator :COCATE : http://projet.ifpen.fr/Projet/jcms/c_7831/cocate
4	**Ms Marjolein De Best-Waldhober**	ECN Policy Studies (NL)-CCS Public Awareness	Coordinator :NearCO2 http://www.communicationnearco2.eu/home/
5	**Mr Nils Rokke**	SINTEF (NO) – CO2 capture, , ZEP AC member	DECARBIT; http://www.decarbit.com/ EERA : http://www.eera-set.eu/index.php?index=34 ZEP: http://www.zeroemissionsplatform.eu
6	**Mr Rob Arts**	TNO (NL)-CO2 storage expert	CO2REMOVE; http://www.co2remove.eu/
7	**Mr Giuseppe Girardi**	ENEA (Italy)	Representing EERA http://www.eera-set.eu/

List of participants - European CCS experts for Australia visit 5-9 December 2011

Pag. 425

Visit of European Union Delegation on Energy Research to Australia
3 -10 December 2011

European Delegation

No	Name	Organisation	Projects involved
1	Dr Wiktor Raldow *Head of Unit*	DG for Research, Energy Conversion and Distribution Systems	
2	Dr Vassilios Kougionas		
3	Mr Jonathan Pearce	British Geological Survey (UK) – CO2 storage expert	SiteChar: http://www.sitechar-co2.eu/ CO2Care: http://www.co2care.org/ CGS EUROPE: http://www.cgseurope.net/ RISCS: information on CORDIS http://www.euussciencetechnology.eu/inventory/show/id/317
4	Ms Claudia Tomescu	Institute for Studies and Power Engineering – ISPE (Romania)	GETICA-Turceni CCS power plant Romania http://www.co2club.ro/en/getica-ccs.html
5	Ms Sandrine Decarre	IFP Energies Nouvelles (France) - CO2 transport expert	Coordinator: COCATE http://projet.ifpen.fr/Projet/jcms/c_7831/cocate
6	Ms Marjolein De Best-Waldhober	Energy research Centre of the Netherlands (ECN): Policy Studies - CCS Public Awareness	Coordinator: NearCO2 http://www.communicationnearco2.eu/home/
7	Mr Nils Rokke	SINTEF (Norway) – CO2 capture, EERA, ZEP AC member	DECARBIT: http://www.decarbit.com/ EERA: http://www.eera-set.eu/index.php?index=34 ZEP: http://www.zeroemissionsplatform.eu
8	Mr Rob Arts	TNO (Netherlands) – CO2 storage expert	CO2REMOVE: http://www.co2remove.eu/
9	Mr Giuseppe Girardi	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	Representing European Energy Research Alliance (EERA) http://www.eera-set.eu/
10	Ms Nikki-Lynne Hunter	Delegation of the EU to Australia and New Zealand (Canberra)	

Friday, 2 December – Brussels -Melbourne
- EU Energy Research Delegation departs Brussels

Saturday, 3 December - Melbourne
- EU Energy Research Delegation arrives in Melbourne
- Make own way from airport to Hotel Lindrum (http://www.hotellindrum.com.au)

Sunday, 4 December – Melbourne
- Rest day
- Ms Hunter and Mr Sean Hannan (RET, International CCS) arrive in Melbourne, check into Hotel Lindrum

Monday 5 December, Melbourne – Otway (Group 1) & Melbourne – Hazelwood / Loy Yang (Group 2)

Group 1	Group 2
European participants 1. Mr Pearce 2. Mr Arts 3. Ms Best-Waldhober 4. Ms Decarre 5. Ms Hunter Australian Participants 6. Dr Matthias Raab, Manager Storage Program, CO2CRC 7. Mr Hannan, RET	European Participants 1. Dr Raldow, European Commission 2. Dr Kougionas, European Commission 3. Ms Tomescu, 4. Mr Rokke, 5. Mr Girardi Australian Participants 6. Mr Manjula Antony, Manager Brown Coal Technologies, Victorian Government (Department of Primary Industries - DPI) 7. Dr Phil Gurney, CEO, Brown Coal Innovation Australia 8. CO2CRC (transport not required)
0800 Check out, bus leaves Hotel Lindrum Drive to Otway Project - *Rest stop at either*	**0800** Bus leaves Hotel Lindrum **1030** Arrive at Powerworks, Latrobe Valley

Winchelsea or Colac **1130** Otway Project tour **1330** Lunch: Boggy Creek Pub - 10 minutes from Otway **1430** Travel to TRUenergy Iona gas storage facility **1500** Tour of Iona Gas storage facility **1700** Travel to Port Campbell via Twelve Apostles **1800** Check into Portside Motel http://www.portsidemotel.com.au/ **1900** Dinner: 12 Rocks Cafe **Otway Project** Australia's first demonstration of deep geological storage of CO2 project provides technical information on geosequestration processes, technologies and monitoring and verification regimes that will help inform public policy and industry decision-makers while also providing assurance to the community **www.co2crc.com.au/otway**	**1100** Tour of CSIRO/Loy Yang Power PCC pilot plant **1330** Lunch, Powerworks **1430** Tour of CO2CRC/Hazelwood Power Station H3 Capture Project **1630** Depart for Melbourne **1830** Arrive Hotel Lindrum **Evening free** **Latrobe Valley site visits** Full day visit including Power Works complex, Hazelwood Power Station and Loy Yang Mine. Will include a tour of the post combustion capture pilot plant, mineral carbonation plant, and algae trials. **www.powerworks.com.au**

Tuesday 6 December, Otway/Hazelwood – Melbourne - Sydney

Group 1	Group 2
0830 Check out of Portside Motel **0900** Drive to Melbourne Airport (~3 ½ hrs) **1230** Arrive Melbourne Airport	**0830** Check out of Hotel Lindrum **0850** Meet with Victorian Government *Level 16, Room 16.01, 1 Spring Street, Melbourne* 1. Dr Peter Redlich, Director Energy Technology Innovation, DPI 2. Mr Manjula Antony, Manager Brown Coal Technologies, DPI 3. Mr Richard Brookie, Director, CarbonNet Project, DPI 4. Dr Phil Gurney, CEO, Brown Coal Innovation Australia 5. Professor Klaus Hein, Research Leader Fellow, BCIA **0900** Welcome to Victoria (Dr Redlich) **0910** Introduction of the Delegation (Dr Raldow) **0930** Victorian CCS Policy **0950** Victoria's CarbonNet Project (Richard Brookie) **1010** Victoria's Energy Technology Innovation Strategy (Dr Redlich) **1030** Brown Coal Innovation Australia (Dr Gurney) **1100** Discussion **1130** Meeting Close **1130** Taxis to airport for flight to Sydney
Group 1 and Group 2	
Flight from Melbourne to Sydney (1 ½ hrs duration) All participants to book this flight QANTAS AIRWAYS - QF 438 TUE 06DEC MELBOURNE SYDNEY 1400 1525 **1400** Depart Melbourne for Sydney **1525** Arrive in Sydney. Taxi's from airport to Four Seasons Hotel. **1630** Check in **http://www.fourseasons.com/sydney** **Evening free**	

Wednesday 7 December, Sydney – Newcastle - Sydney

0800 Bus departs Four Seasons Hotel for Newcastle (~2hours)
1030 Arrive at reception, CSIRO Energy Research Centre **http://www.csiro.au/places/Newcastle.html**
1035 Overview of CSIRO energy research – Jim Smitham**coffee and tea available for refreshment*, Boardroom
1100 Overview of CSIRO Carbon Capture & Storage research – Paul Feron, Boardroom
1130 Tour of PCC test rig – Leigh Wardhaugh (lead by Paul Feron) - Process Bay
1200 Tour of PCC lab, 3rd floor lab wing
1230 Lunch, Boardroom
1300 Energy-related social research – Peta Ashworth. Boardroom

1330 Demand side energy management/energy efficiency. smart grids & storage – Glenn Platt, Renewable Energy Integration Facility – Process Bay
1430-1510 National Solar Energy Centre – Wes Stein, Solar field
1515 Concluding comments – Jim Smitham/Peter Mayfield, Boardroom
1530 Bus departs Newcastle for Sydney
1800 Arrive Four Seasons Hotel
Evening Free

Thursday 8 December – Sydney – Hampton - Canberra

0800 Check out. Bus departs Four Seasons Hotel for Ultra battery Demonstration site – Hampton - (1MW/MWhr scale system) (~2½ hours – Very close to the village of Hampton) *Directions TBA*
1130 Site tour - Dr Peter Coppin CSIRO.
Meet on site. Facility Manager, Chris Price and John Wood (CEO Ecoult)
1430 Drive to Canberra – (~3.5 hours)
1800 Arrive at Novotel Hotel Canberra. Check in http://www.novotelcanberra.com.au/
1900 - 2200 Ottoman Restaurant, Hosted by the Delegation of the EU to Australia and New Zealand Office
Corner of Broughton & Blackall Streets, Barton ACT

Friday 9 December, Canberra - Sydney

0830 Check out of the Novotel Hotel. Taxi to office of European Delegation in Australia (Drop off luggage)
0940 Taxi to RET *51 Allara Street, Canberra*
1000 Arrive RET - sign in (*meetings on Level 5, Room A & B)*
1015 Meeting with Mr Dick Wells, Chair of the Australian National CCS Council
1030 ANLEC R&D meeting with Mr Noel Simento, Managing Director http://www.anlecrd.com.au/
1145 Lunch

1230 Meet with Australian Government and stakeholders - Welcome (Ms Sewell)
1235 Energy White Paper (Mr Wilson)
1250 Low Emissions Coal Policy and Implementation in Australia (Ms Sewell)
1300 European CCS policy, projects and opportunities for collaboration

1) European Commission initiatives (presented by the EC, Wiktor Raldow , Vassilios Kougionas)
2) EU research on CO2 storage (Jonathan Pearce and Rob Arts)
3) EU research on CO2 transport (Sandrine Decarre)
4) EU research on CO2 capture and ZEP platform (Nills Rokke)
5) CCS Public acceptance (Marjolein Best-Waldhober)
6) CCS demonstration in the EU (Claudia Tomescu)
7) EERA (Giussepe Girardi)

1400 Support for Australian-European S&T collaboration (Ms Finlay)
1415 CSIRO developments and EU linkages (Dr Carras)
1420 CO2CRC developments and EU linkages (Dr Aldous)
1425 GCCSI support for EU linkages (Dr Henderson)
1430 Discussion
1500 Meeting concludes, taxi's to office of the European Union Delegation in Australia
1600 EU delegation meeting with EU Ambassador David Daly
1700 Taxi's to Canberra airport for flight to Sydney
1830 Depart Canberra for Sydney (QANTAS AIRWAYS - QF 806)
FRI 09DEC CANBERRA SYDNEY 1830 1925
1925 Arrive Sydney, taxi's to the Four Seasons Hotel

Saturday, 10 December, Sydney - Brussels
EU Energy Research Delegation departs Sydney for Brussels

Sunday, 11 December, Brussels
EU Energy Research Delegation arrives in Brussels

Pag. 429

Acronyms

ANLEC R& D = Australian Low Emission Coal Research and Development - http://www.anlecrd.com.au/
CO2CRC = The Cooperative Research Centre for Greenhouse Gas Technologies -
http://www.co2crc.com.au/about/
CSIRO – Commonwealth Scientific and Industrial Research Organisation -
http://www.csiro.au/org/EnergyTransformedFlagship.html
DIISR = Department of Innovation, Industry Science and Research -
http://www.innovation.gov.au/SCIENCE/INTERNATIONALCOLLABORATION/Pages/default.aspx
DPI = Department of Primary Industries (Victorian State Government) -
http://new.dpi.vic.gov.au/energy/policy/greenhouse-challenge/near-zero-emissions
DTI = Department of Trade and Investment (New South Wales Government) –
http://www.dpi.nsw.gov.au/minerals/resources/low-emissions-coal/nsw-clean-coal-fund-research-projects
Energy Pipeline CRC –
https://www.epcrc.com.au/index.php?stm_a=23&m=281
GA = Geoscience Australia –
http://ga.gov.au/ghg.html
GCCSI = Global CCS Institute
http://www.globalccsinstitute.com/
RET = Department of Resources, Energy and Tourism
http://www.ret.gov.au/energy/clean_energy_technologies/Pages/CleanEnergyTechnologies.aspx

Pag. 429

Pag. 430

EU mission to Australia

EERA Joint Programme
Carbon capture and storage (CCS)

JP Co-ordinator

Andreas Ehinger
IFP Energies nouvelles

Giuseppe Girardi
ENEA

www.eera-set.eu

Pag. 430

Pag. 431

What is EERA

Cooperation of Energy Research Organisations

- ***15 partners***
  - responsible for EERA culture and governance
  - launch and review of EERA Joint Programmes
  - partnership reviewed biannually, first time in 2012

- ***More than 70 participating organisations***
  - responsible for EERA Joint Programmes

- ***More than 1000 professionals full time equivalent***
  - make it happen

Pag. 431

EUROPEAN COMMISSION
Community research
Pag. 432

Vision CCS-JP

The EERA CCS Joint Programme is dedicated to reaching the objectives that the international community has identified as necessary <u>enablers for large scale deployment</u> of CCS and thus for holding its promise to contribute a very significant part to the required world-wide CO_2 emissions reduction

- ✓ **cost competitive and energy efficient CO_2 capture methods and processes**
- ✓ **confidence in storage technologies, based on subsurface knowledge and understanding**

EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE
Pag. 432

EUROPEAN COMMISSION
Community research

Pag. 433

Membership and resources

Programme launched at last SET-Plan conference (Nov. 2010)

34 program members

- *24 participants*
- *10 associates*
- *12 countries*

HR commitment

270 py/y

Several new applications

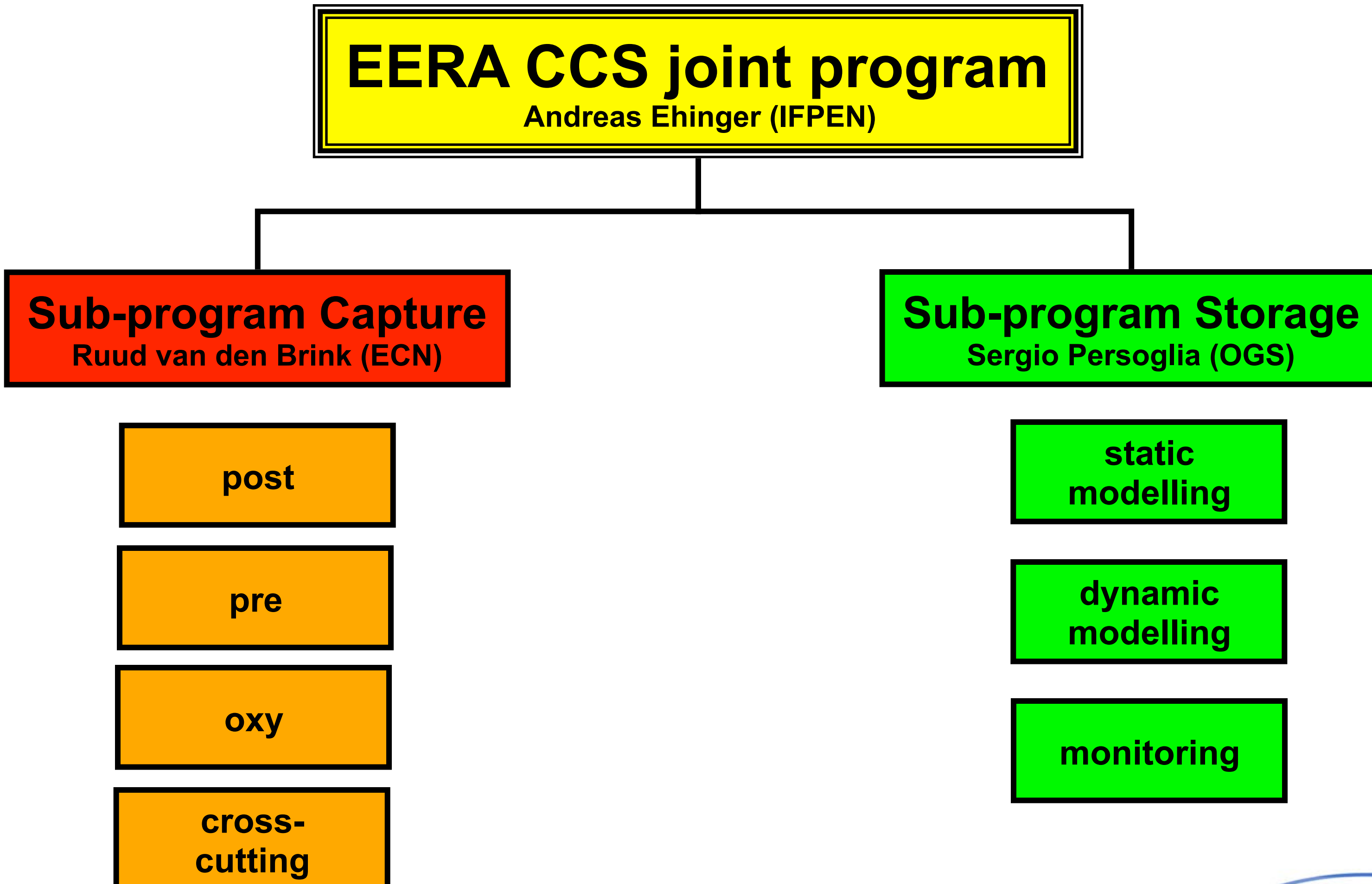
EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 433

EUROPEAN COMMISSION
Community research

Pag. 434

Program structure



EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 434

EUROPEAN COMMISSION
Community research

Pag. 435

Objectives and activities

CO_2 capture

R&D areas (structuring of sub-programme)

- post-combustion capture (solvents, sorbents, membranes)
- pre-combustion capture (sorbents, membranes, H_2 turbines)
- oxyfuel (combustion, membranes, CLC, oxyfuel turbines)
- cross-cutting issues (benchmarking, BioCCS, other emitters)

R&D objectives

- improved CO_2 separation technologies (solvents, sorbents, membranes, ...);
- improved fuel firing systems (hydrogen gas turbines, oxy-boilers, ...);
- new processes (carbonate cycles, chemical looping, ...)

Detailed objectives are identified in each R&D area

EERA
European Energy Research Alliance
Pag. 435
CARBON CAPTURE AND STORAGE

EUROPEAN COMMISSION
Community research

Pag. 436

Objectives and activities

CO_2 storage

- ***R&D areas (structuring of sub-programme)***
  - monitoring
  - static modelling
  - dynamic modelling
- ***R&D objectives***
  - improved capacity to characterize the subsurface
  - improved methods for predicting the fate of injected CO_2
  - enhanced capabilities to monitor all components of the CO_2 storage complex
- ***Detailed objectives are identified in each R&D area***

EUROPEAN COMMISSION
Community research

Pag. 437

Latest developments

- *Focus workshops*
- *CCS Research Infrastructures*
  EERA-CCS – ECCSEL relationship
- *Interfaces with other EERA-JPs*
- *International cooperation*

Pag. 437

Pag. 438

Latest developments

Focus workshops

- encourage JP members to take initiative
- focus on a scientific fields
- few, committed participants
- objective: set-up joint R&D activity

- several workshops have been organized during 2011
- low temperature sorbents
- H2/O2 membranes
- process simulation
- ...

➨ several new projects are being proposed

Pag. 438

EUROPEAN COMMISSION
Community research

Pag. 439

Latest developments

CCS Research Infrastructures
EERA-CCS – ECCSEL relationship

- Research infrastructures of critical importance
- ECCSEL
  - ESFRI project
  - in its preparatory phase (FP7 funding)

- EERA-CCS JP invited as observer to ECCSEL Steering Board
- ECCSEL invited as observer to CCS JP Steering Committee

➡ coordination and cooperation between Research Programme and Research Infrastructures

EUROPEAN COMMISSION
Community research

Pag. 440

Latest developments

Interfaces with other EERA-JPs

- Biomass JP - CO_2 capture by algae
- Biomass JP – use of biochar as CO_2 capture and storage option
- Geothermal Energy JP – coupling of CO_2 geological storage and geothermal energy recovery
- Advanced Materials and Processes for Energy Applications JP

EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 440

EUROPEAN COMMISSION
Community research

Pag. 441

Latest developments

International cooperation

- started
- participation in this mission is an important step

- EERA CCS-JP interested in evaluating possibilities for cooperation with Australian R&D organisations

EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 442

EERA
European Energy Research Alliance
CARBON CAPTURE AND STORAGE

EU mission to Australia

Thanks for your attention

Giuseppe Girardi
giuseppe.girardi@enea.it

www.eera-set.eu
Pag. 442

EUROPEAN COMMISSION
Community research

Pag. 443

Present status

COMMERCIAL-IN-CONFIDENCE

EERA
European Energy Research Alliance

EERA
EUROPEAN ENERGY RESEARCH ALLIANCE

CO_2 capture and storage (CCS)

Version: *2.1*
Last modification date: *January 7, 2011*
Contact person: *Andreas Ehinger – andreas.ehinger@ifpenergiesnouvelles.fr*

EERA European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 443

Pag. 444

EERA mission

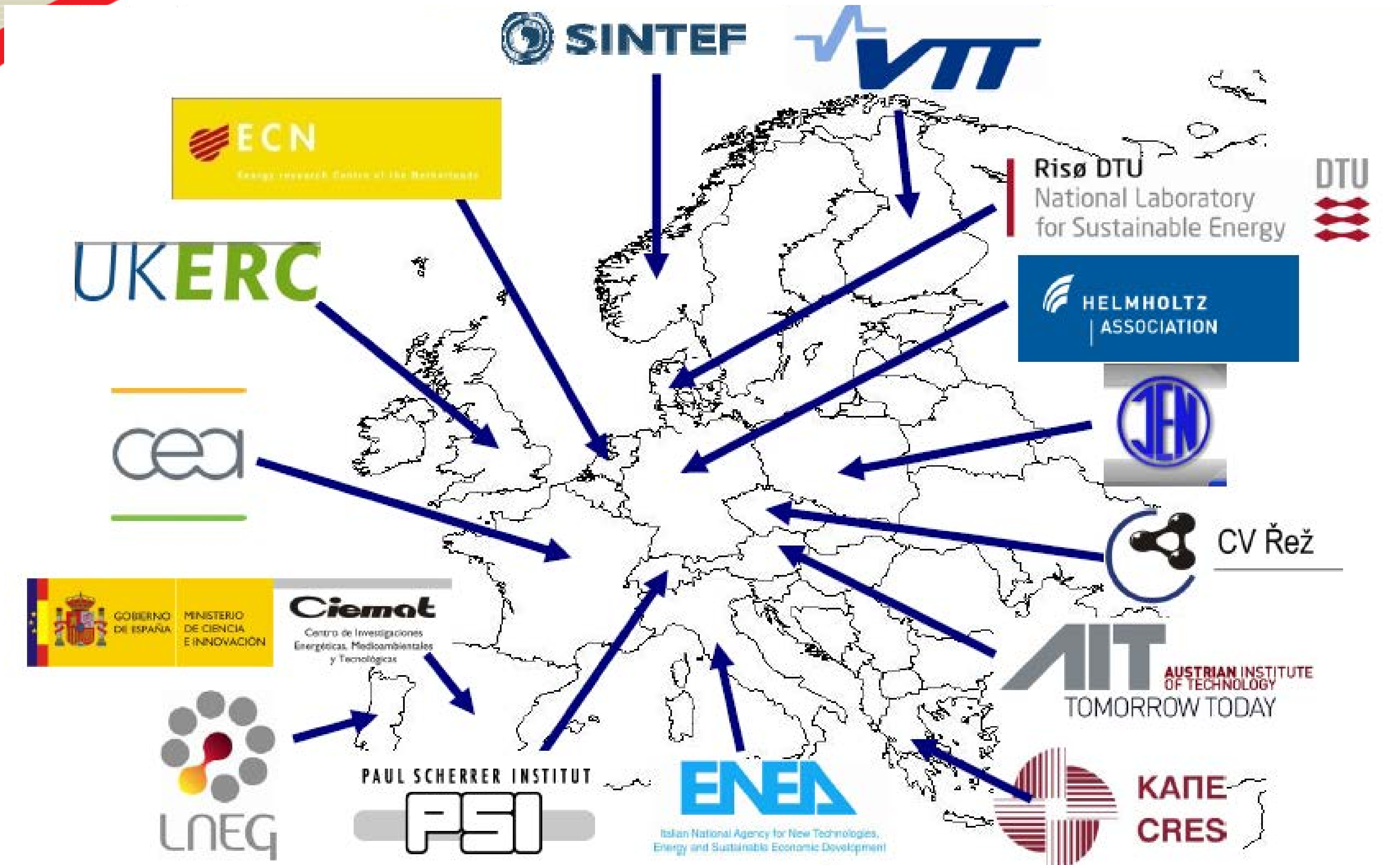
- ***Through energy research***
  - deliver on the objectives of the SET Plan
  - accelerate development of new energy technologies

!

- ***In energy research***
  - improve coordination and cooperation
  - reduce duplication and fill gaps
  - increase efficiency and effectiveness

Pag. 445
EUROPEAN COMMISSION
Community research

Current EERA partners



Pag. 445
Pag. 445
EERA
European Energy Research Alliance
CARBON CAPTURE AND STORAGE

Pag. 446

Backup – general EERA slides

Pag. 446

Pag. 447

Allegato 8.

Iniziative progettuali internazionali

presentazione delle attività in Italia per una collaborazione con Cina ed ENEL

presentazione delle attività in Italia per una collaborazione con SINTEF

progetto ECCSEL

progetto ECRI

Pag. 447

Pag. 448

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel

ENERGY IN TUNE WITH YOU.

Preliminary Agenda

SINO – ITALY COOPERATION ON CLEAN COAL TECHNOLOGIES (CCTS), INCLUDING CARBON CAPTURE AND STORAGE AND ULTRA SUPER CRITICAL COAL FIRED POWER PLANT TECHNOLOGIES

2nd Sino – Italian Scientific Meeting
Recommendations to Design and Operate a Coal-Fired Power Plant Integrated with CC Unit and CO_2 Transport

About the Scientific Meeting

The 2nd Scientific Meeting focuses on design and operation guidelines and recommendations in retrofitting coal-fired power plants with CCS

The greenhouse gas most commonly produced by our activities is carbon dioxide (CO_2) that is responsible for 63% of man-made global warming. One of the main sources of CO_2 in the atmosphere is the combustion of fossil fuels - coal, oil and gas. Since the Industrial Revolution, the concentration of CO_2 in the atmosphere has increased by around 37%, and it continues to rise. The European Union has long been committed to robust policy-making at home. At European level a comprehensive package of policy measures to reduce greenhouse gas emissions has been initiated through the European Climate Change Program (ECCP). Each of the EU Member States has also put in place its own domestic actions that build on the ECCP measures or complement them.

IEA forecasts that by 2050, Carbon Capture and Storage (CCS) could become the biggest contribution to emissions reduction technology among single technologies.
To help fulfill the potential of CCS, the European Commission is sponsoring and coordinating the world's first network of demonstration projects, all of which are aiming to be operational by 2015. The goal is to create a prominent community of projects united in the goal of achieving commercially viable CCS by 2020.
The CCS Project Network fosters knowledge sharing amongst the demonstration projects and leverage this new body of knowledge to raise public understanding of the potential of CCS.

This accelerates learning and ensures that we can assist CCS to safely fulfill its potential, both in the EU and in cooperation with global partners and within this framework ENEL Group also is strongly engaged.

Pag. 448

 Pag. 449

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel
ENERGY IN TUNE WITH YOU.

As a big consumer of thermal power and coal, energy strategies and environmental protection by the government is crucial, but it's also vital to the interests of China where Carbon Capture, Use and Storage(CCUS) technology is considered as an important technology option for clean coal utilization in China. CCUS's potential contribution rate to emissions reduction has been gradually recognized by more and more people.

Chinese Government has defined clearer energy strategies to face the increasingly serious energy and environmental issues, by setting out reduction targets as intensity of carbon emissions per capita GDP reduced by 40%-45% by 2020 compared to 2005 values.
China's 2011-2015 Plan aims to reduce carbon emissions intensity by 16%-17% through the development and implementation of a series of energy saving programs.
Recognizing the huge CO2 emissions reduction potential, while bearing in mind the challenges of high cost, high energy penalty and the risks related to environment and long-term safety, policy researchers, government officials and business managers are not sure about whether CCUS should develop or how to develop and the answers to the issues are still relatively lacking.

MOST (CHINA), IMELS(Italy) and ENEL, within the framework of 2009 agreement on CCS and CCTS, are organizing the 2nd scientific Meeting focused on design and operation guidelines and recommendations in retrofitting coal-fired power plants to CCS to promote a comprehensive discussion of CCUS problems among experts from both Countries.
This conference follows the first SISM held in Beijing on May 11th and it will contribute to explore preliminarily the technical aspects inherently design and operation guidelines and recommendations in retrofitting coal-fired power plants to CCS. This SISM will lead to a comparison among China and Italy activities as well as technological advances will be presented because R&D on environmental-friendly coal use is crucial for the future where coal will remain a major energy source during the 21st century and fulfill its function in a clean and efficiently way.
Features, design and operation plant criteria for CCS technology will be mainly discussed by analyzing its pros and cons, and the meeting report will offer specific descriptions to better understand and apply this technology.

In the meeting experts from both China and Italy will presents the development of their studies on CCS, they will describe the development of the research activities on CCUS (carbon capture, use and storage) technology in China and Italy. This discussion will be the basis to define a list of possible future activities, that could be established within a further phase of cooperation.

MEETING PLACE	
November , 22th-23rd ,2011	**November , 24th-25th ,2011**
Brindisi -ENEL – Ricerca Center **Strada provinciale 87-Cerano Lido**	**Roma - sede Enel di Villa Lazzaroni,** **Viale Tor di Quinto 58.**

 Pag. 449

 Pag. 450

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部
The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel ENERGY IN TUNE WITH YOU.

Monday, November 21st, Rome-Brindisi

17.50	*Arrival of Chinese delegation to Rome FCO, flight CA939 from Beijing*	
22.40	*Arrival to Brindisi airport, flight AZ1625 from Rome FCO*	
23.00	*Transfer to the hotel Grande Albergo Internazionale in Brindisi (hotel TBC).*	

Tuesday, November 22nd, Brindisi

(participation restricted to the Projects' partners)

10.15	*Transfer from hotel to Enel's Research Centre*	
10:40–11:15		**Welcome coffee**
11:15–11:30	**G. Belz** Engineering & Innovation Division, Enel	**Enel's welcome**
11:30–13:00	**G.Belz** Engineering & Innovation Division, Enel	**R&D activities in Enel's Brindisi Research Centre**
13:00–14:00		**Lunch**
14:00–15:30	**Labs visit, Q&A**	
15:30–17:30	**SICCS Project 1st phase** **1. Discussion of interim reports** **2. Interim reports status and deliverables review**	
17:30–18:00	**Conclusions**	
18.00	*Transfer from hotel to Enel's Research Centre*	
19.30	*Transfer to the restaurant (TBD)*	
20:00–22:00		**Dinner**
22.00	*Transfer to the hotel*	

 Pag. 450

 Pag. 451

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel ENERGY IN TUNE WITH YOU.

Wednesday, November 23rd, Brindisi
(participation restricted to the Projects' partners)

08.30	*Transfer from hotel to Enel's Research Centre*	
09:00–09:15		**Welcome coffee**
09:15–09:30	**M. Graziadio** Engineering & Innovation Division, Enel	**Keynotes on** **Post combustion capture**
09:30–10:00	**A. Mangiaracina** Engineering & Innovation Division, Enel	**Enel's 10,000 Ncm/h** **CO2 capture**
10.05	*Transfer from Research Centre To PCC pilot plant*	
10:20–12:00	**Visit to Enel's CO2 capture plant and Brindisi Federico II power plant**	
12.05	*Transfer from PCC pilot plant to Research Centre*	
12:20–13:30	**Question time on PCC (ALL)**	**Pilot plant's main features and R&D activities on Post combustion capture**
13:30–14:30		**Lunch**
14:30–16:00	**SICCS Project 1st phase** **1. Discussion of interim reports open points** **2. Action plan to complete SICCS Project 1st phase**	
16:00–17:00	**SICCS Project 2st phase** **1. Phase 2: hypothesis for contents** **2. Future steps**	
17:00–17:30	**Meeting wrap-up**	
17.30	*Transfer to Brindisi airport.*	
19.20	*Frlight AZ1626 Brindisi-Rome FCO*	
20.45	*Transfer to Claridge hotel (TBD)*	
22.00		**Dinner at the hotel**

 Pag. 451

Pag. 452

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部
The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel
ENERGY IN TUNE WITH YOU.

Thursday Morning , November 24th, Rome

08.00 *Transfer from to Villa Lazzaroni (Chinese Delegation only)*

08:30–09:00 **Welcome coffee**

09.00-10.00 **Opening session**

L. Vido
Enel
Peng Sizhen
MOST-ACCA21
SPEAKER FROM Ministero ESTERI
MAE
Speaker from Italian Institution
Senato della Repubblica
Associazione parlamentare Amici della Cina

10.00-11.00 **Session 1. Research projects in the field of CCS in Italy and China**

Moderator: S. Serra (TBC)
MATTM

Speaker from GCCSI — **Topic TBD**
GCCSI

G. Girardi — **CCS-CCUS pecularity of Italian Projects within EU framework**
Italian CSLF representative

Speaker from ACCA21 — **CCUS R&D activities and technology roadmap in China**
ACCA21

DELEGATE MiSE — **.......**
MiSE

11:00–11:30 **Coffee Break**

Pag. 452

 Pag. 453

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel ENERGY IN TUNE WITH YOU.

Thursday Morning , November 24th, Rome

11.30-12.45 **Session 2. Technology qualification and process design of post combustion CCS systems**

Moderator: S. Malloggi
Enel

Gao Lin IET	**System modelling & Retrofit of Post**
C. La Marca Enel	**Technology qualification of post-combustion CCU**
Wang Shujuan Tsinghua University	**Heat integration of ammonia based capturing system in power plants**
M. Toschi Enel	**Post Combustion Capture plants: process design criteria**
Q&A	

12:45–13:45 **Lunch**

 Pag. 453

 Pag. 454

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel
ENERGY IN TUNE WITH YOU.

Thursday Afternoon , November 24th, Rome

13.45-15.00 **Session 3. Design and construction criteria for CCS and its integration in coal-fired power plants**

Moderator: G. Valenti
Enel

Wang Jinyi Huaneng Clean Energy Research Institute	**CCU Construction Experiences in China**
G.Belotti Enel	**Constructability approach to CCU**
Wang Jinyi Huaneng Clean Energy Research Institute	**CCU Construction Experiences in China**
L. Santarcangelo Enel	**CCU Integration to coal-fired power plant**
Zhang Xiaosong IET	**Optimization of CO2 compression & transportation**

Q&A

 Pag. 454

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部

The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel

ENERGY IN TUNE WITH YOU.

Thursday Afternoon , November 24th, Rome

15.00-17.15 **Session 4. Environmental impact assessment of CCS and CO2 Storage**

Moderators: From ENEL –ACCA21

F. Venezia IET	**Approach to health, safety and environmental issues**
Wang Shujuan Tsinghua University	**Corrosion problem of CO2 Capture system**
S.Cainer Tsinghua University	**CCS: Environmental Directives and Permitting**
Wang Jinyi Huaneng CERI	**Health, safety and environmental requirements in China**
S.Persoglia OGS	**Storage Safety Criteria and Monitoring System**
Zhang Xiaosong IET	**Possibility for CO2 Utilization for Tongchuan power plant**
C. Spinelli ENI	**CO2 pipeline design criteria and CO2 standard requirements**
J. Ballestreros Endesa	**Feasibility Study for CO2 geological storage**

Q&A

17.15 *Rome guided tour (Chinese delegation only)*

20:00–22:00 **Dinner**

 Pag. 456

2nd Sino Italian Scientific Meeting

Brindisi-Rome

21-25 November 2011

中华人民共和国科学技术部
The Ministry of Science and Technology of the People's Republic of China

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Enel
ENERGY IN TUNE WITH YOU.

Friday, November 25th, Rome

08.30	*Transfer from Hotel to Villa Lazzaroni (Chinese delegation only)*

09:00–09:30 **Welcome coffee**

09.30-11.30 **Round Table. The future of CCS in China and western Countries: a challenge to be won**

Moderator: From ENEL
Enel
Representative from MATTM
MATTM
Representative from MOST
MOST
Representative from SDF
Sustainable Development Foundation
Representative from MiSE
MiSE
Representative from ACCA21
ACCA 21
China Huaneng representative
China Huaneng Group: Clean Energy Research Institute

11.30-12.30 **Concluding remarks: the future of Sino-Italy cooperation on CCS.**
S. Pasini
Enel
Representative China Huaneng Group
China Huaneng Group

12:30–14:30 **Lunch & Networking**

14.30	*Transfer to Hotel and Fiumicino airport (Chinese Delegation only)*
20.55	*Flight CA940 Rome FCO-Beijing*

 Pag. 456

Pag. 457

2nd Sino Italian Scientific Meeting

CCS in Italy within EU frame work: EERA Joint Programme and Industrial Initiative

Giuseppe Girardi

ENEA
Sustainable fossil fuels and CCS

SOTACARBO
vicePresident

giuseppe.girardi@enea.it

14 – 15 December 2011, Rome

Pag. 457

Pag. 458

ENEA research centres and Sotacarbo

ENEA activities

- R/D/D
- Support/advice for MSE and Government
- European context: EII, EERA, ZEP, FP7

2nd Sino Italian Scientific Meeting

Pag. 458

CCS: a key solution for the EU

Pag. 459

Greater energy efficiency + Growth in renewables + Other + CCS

CCS needs to deliver **20%** of the required global GHG cuts by 2050!

2nd Sino Italian Scientific Meeting

Pag. 459

CCS: the italian policy

Pag. 460

Law n.99 on "Regulations for the development and internationalization of enterprises and on the subject of energy:

- allowing the implementation of demonstrative projects on CO2 capture, and permanent storage of CO2 into suitable deep geological formations;
- realizing a coal fired with CCS demo plant in Sardinia region
- R/D Plan for industrial innovation

Other national initiatives

- Funds to Sotacarbo and Carbosulcis for common project with ENEA
- R&D national programs – on CCS - for the next four years
- Strong demonstration initiatives
  - ENEL/ENI
  - Sulcis integrated project - feasibility by ENEA/Sotacarbo
  - Sotacarbo/ENEA, firstly pilot

2nd Sino Italian Scientific Meeting

Pag. 460

Transposition of Directive 2009/31

Pag. 461

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

- **Transposition has been done** (decree n. 162, Sptember 2011) after a wide consultation with stakeholders, mainly regional governments and local administrations: now Italy is one of the two members States in Europa that have approved a national transposition law.
- **A national committee** will manage CO2 storage activities.
- Ministry of Economic Development will store and manage all the data concerning exploitation and storage activities of CO2.

2nd Sino Italian Scientific Meeting

Pag. 461

Italian programme on CCS

Pag. 462

	project/ responsible	NATION. FUND: Electr. System	NATION. FUND: Energy Strategy	NATION. FUND: R&D Progr.	REGIONAL FUND (Sardinia)	EC FUND
DEMO	**Porto Tolle** ENEL-ENI					NER 300 other
	Sulcis 400 MWe Sotacarbo/ENEA				X	NER 300 other
PILOT	**Precomb (and coal-to-liquid)** Sotacarbo/ENEA	X			X	other
	CBM-ECBM in Sulcis basin Carbosulcis-Sotacarbo-ENEA	X			X	other
	Brindisi post comb ENEL					other
	Oxycomb ITEA - ENEA					other
R&D	**pre-comb** ENEA-Sotacarbo-ERSE	X			X	X
	post-comb ERSE-ENEA-ENEL	X			X	X
	oxy-comb ENEA-ITEA-Sotacarbo-CNR				X	X
	ECBM-wells-aquifers ENI-Carbosulcis-OGS-Univ., ENEA,..	X			X	X

Pag. 462

EIIs: European Industrial Initiatives

- To strenghten Research and industrial innovation in the energy sector
- To decrease costs and improve performances

Iniziative already started:

- European Wind Initiative
- Solar Europe Initiative (sia fotovoltaico che termodinamico)
- European electricity grid initiative
- Sustainable bio-energy Europe Initiative
- **CO2 capture, transport and storage**
- Sustainable nuclear fission initiative
- Fuel cells and hydrogen
- Energy efficiency
- Smart Cities initiative

EERA CCS - JP

Pag. 464

ENEA AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Objectives

- Lower costs and higher efficiency
- public awareness and acceptance

Programme launched at last SET-Plan conference (Nov. 2010)

34 program members

- *24 participants*
- *10 associates*
- *12 countries*

HR commitment

270 py/y

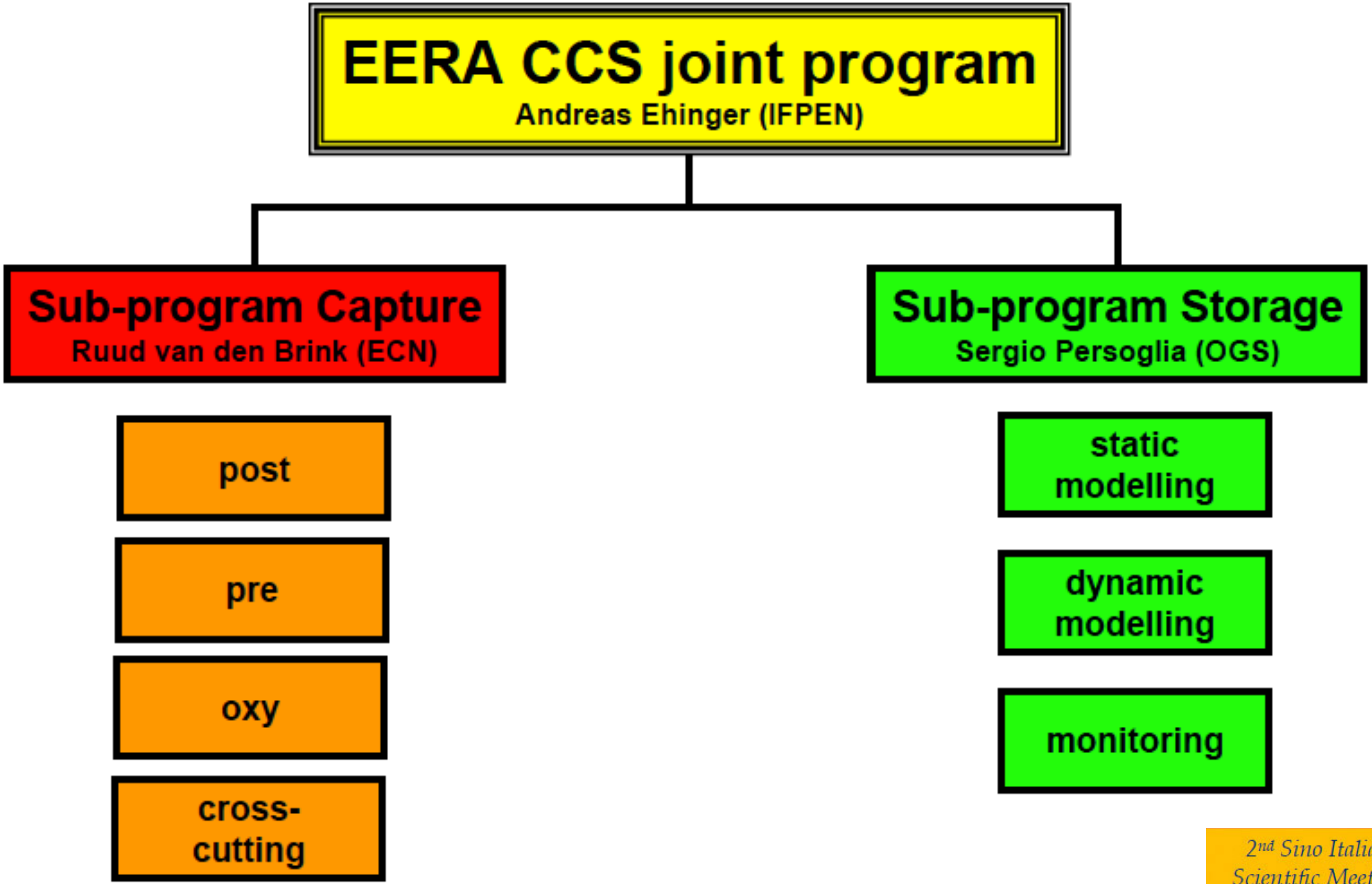
Several new ap

2nd Sino Italian Scientific Meeting

Pag. 464

Pag. 465

Program structure



Pag. 465

FP7

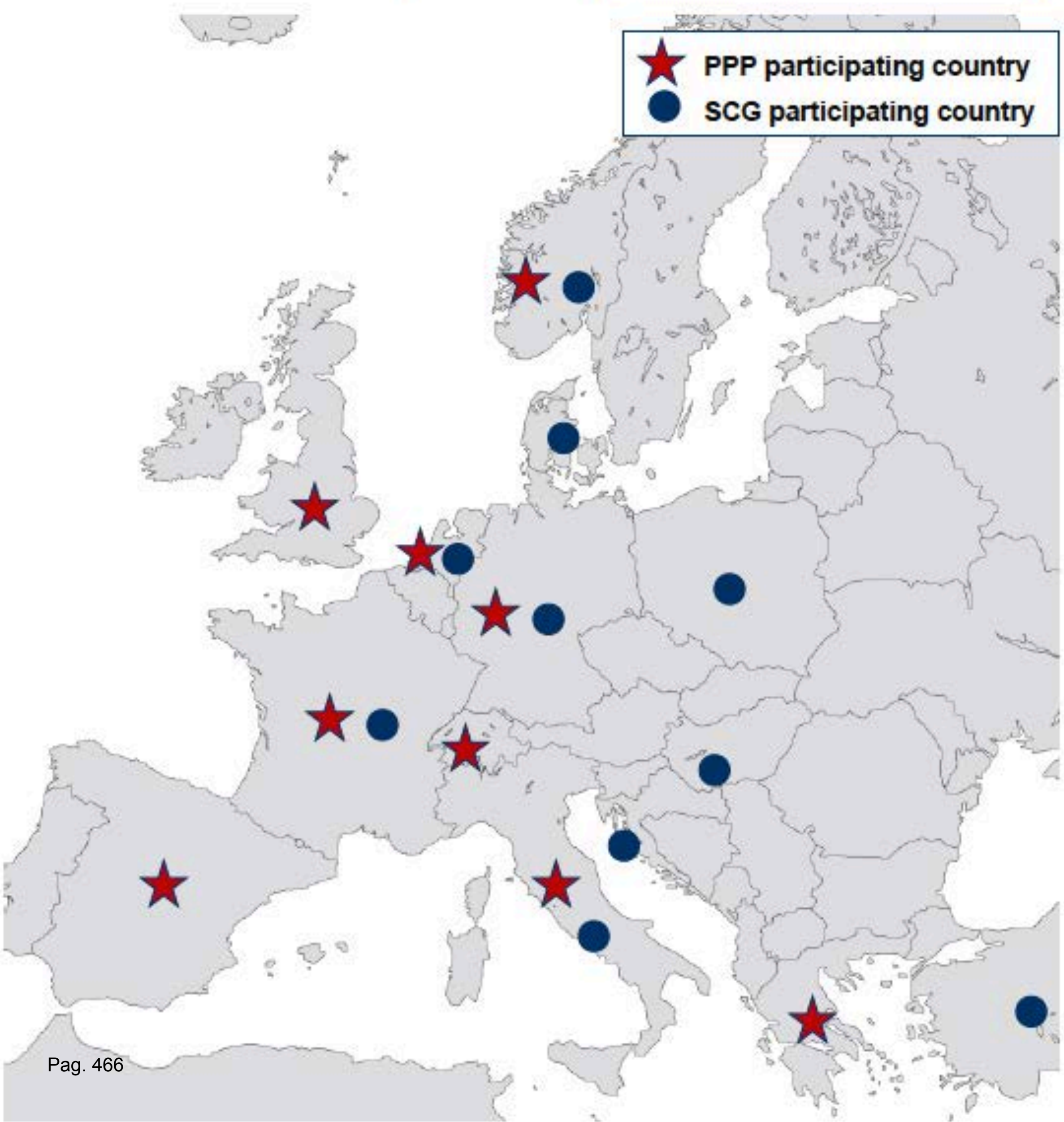
ECCSEL

European Carbon dioxide Capture and Storage Laboratory Infrastructure

Pag. 466

ENEA
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Countries participate in the Preparatory Phase Project



ECCSEL PPP Consortium

1. Norway (NTNU, SINTEF, RCN)
2. France (IFP & BRGM)
3. The Netherlands (TNO)
4. Germany (DLR)
5. United Kingdom (BGS)
6. Switzerland (ETHZ)
7. Spain (CIUDEN)
8. Italy (OGS, ENEA)
9. Greece (CERT/ISFTA)

2nd Sino Italian Scientific Meeting

Pag. 466

Main activities of national R/D Programme

Pag. 467

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

- "CERSE": technology innovation of the electricity system. Pre/post/oxy comb.
  - Combined production of hydrogen & power with CCS
  - Capture (pre and post combustion) technologies: sorbents/solvents/membranes
  - Coal to liquid / Plant integration
  - Feasibility analysis for a demonstrative power plant in Sardinia, with CCS
  - Oxy combustion: modelling and advanced tests
  - ECBM Site-Tests in Sardinia Sulcis Area)
  - Italian national road-map on CCS; public acceptance
- "Industry 2015" - Industry-oriented R/D program
  - advanced MILD combustion in coal oxyfired power plants.
- "Law 99/2009"
  - R&D programme for industrial innovation; support to demo projects
- PNR (to be launched)
  - Research projects
  - National research laboratories/infrastructures

2nd Sino Italian Scientific Meeting

Pag. 467

ZECOMIX test plant

Pag. 468

30 kg/h coal

2nd Sino Italian Scientific Meeting

Pag. 468

Pag. 469

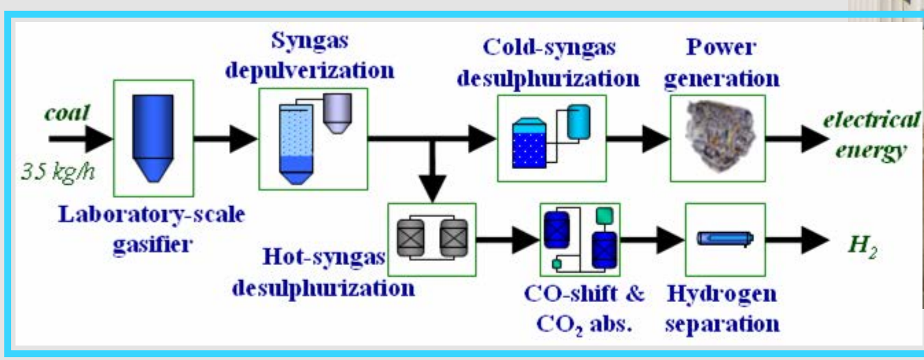
Sotacarbo pilot plant

700 kg/h coal

Pag. 469

Pag. 470

Sotacarbo bench scale plant

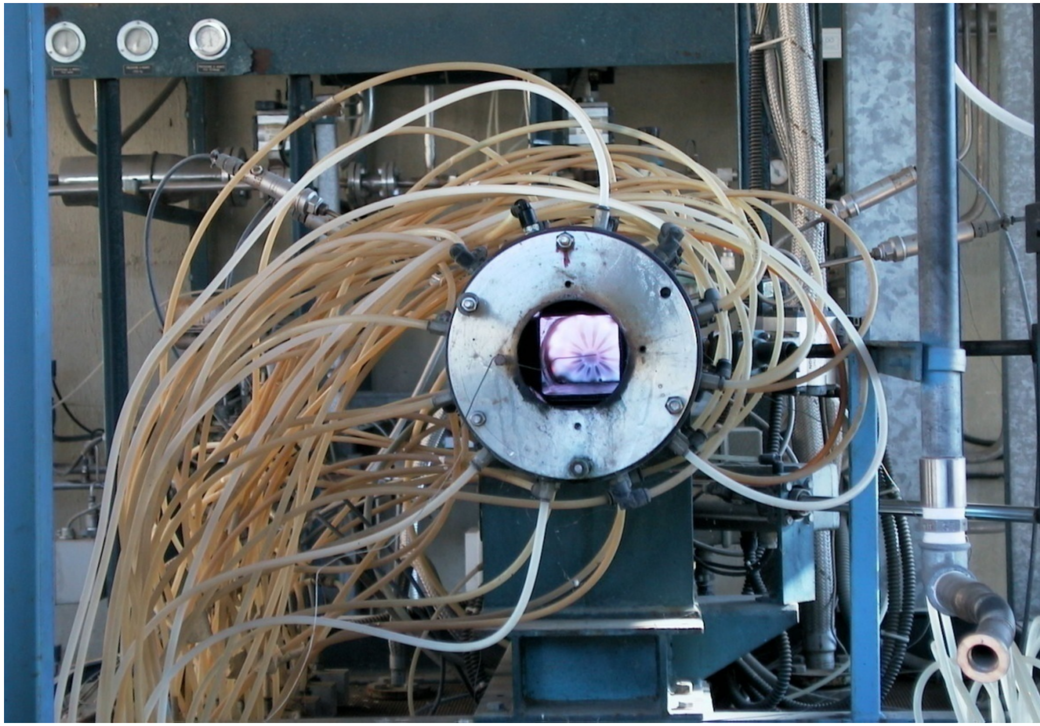


30 kg/h coal

2nd Sino Italian Scientific Meeting

Pag. 470

H2 combustion at ENEA



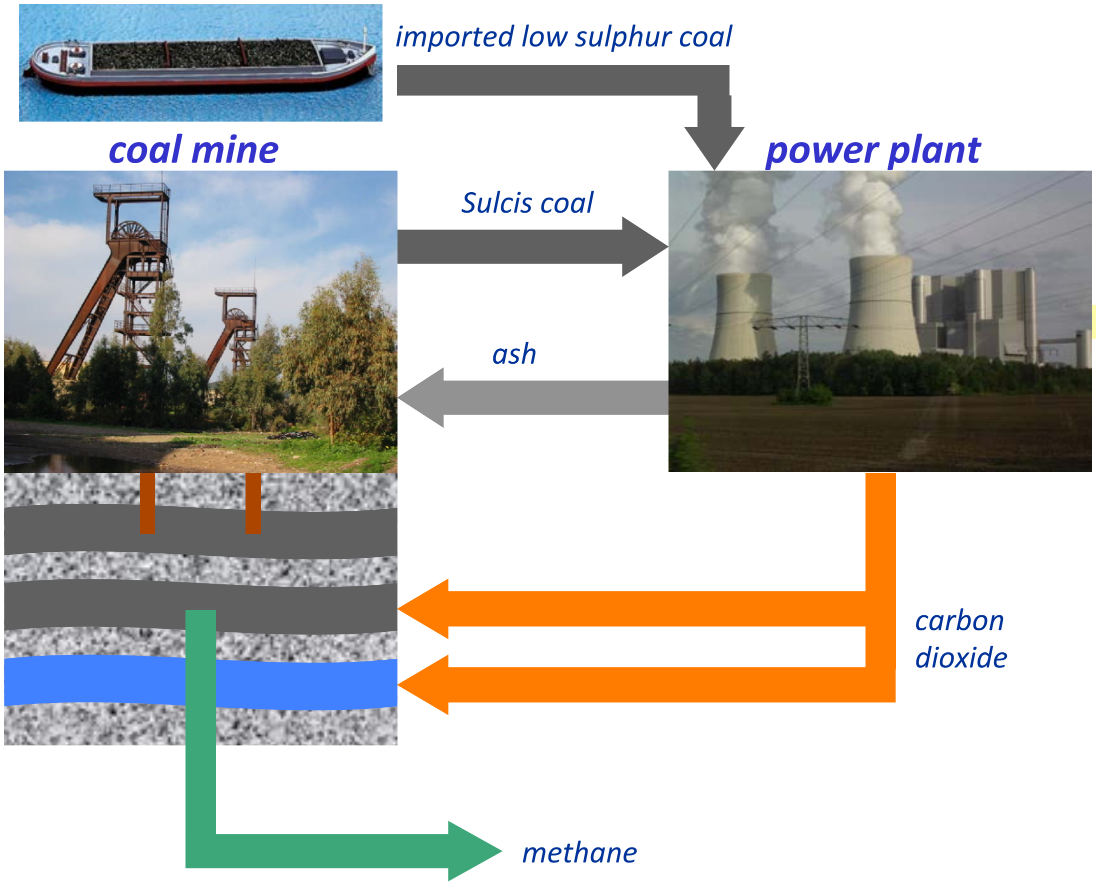
MICOS test plant

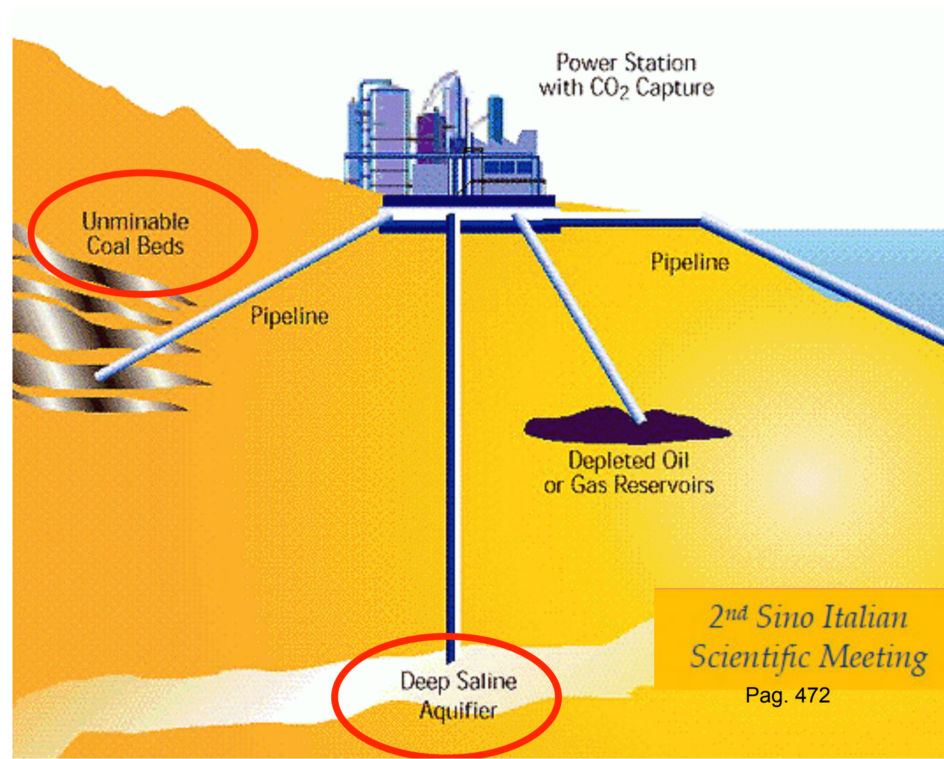
IDEA test plant

Pag. 471

400 MWe coal plant with CCS in Sardinia

Pag. 472





plant size: 350-450 MW_e

(italian law n°9 23/07/2009)

2nd Sino Italian Scientific Meeting
Pag. 472

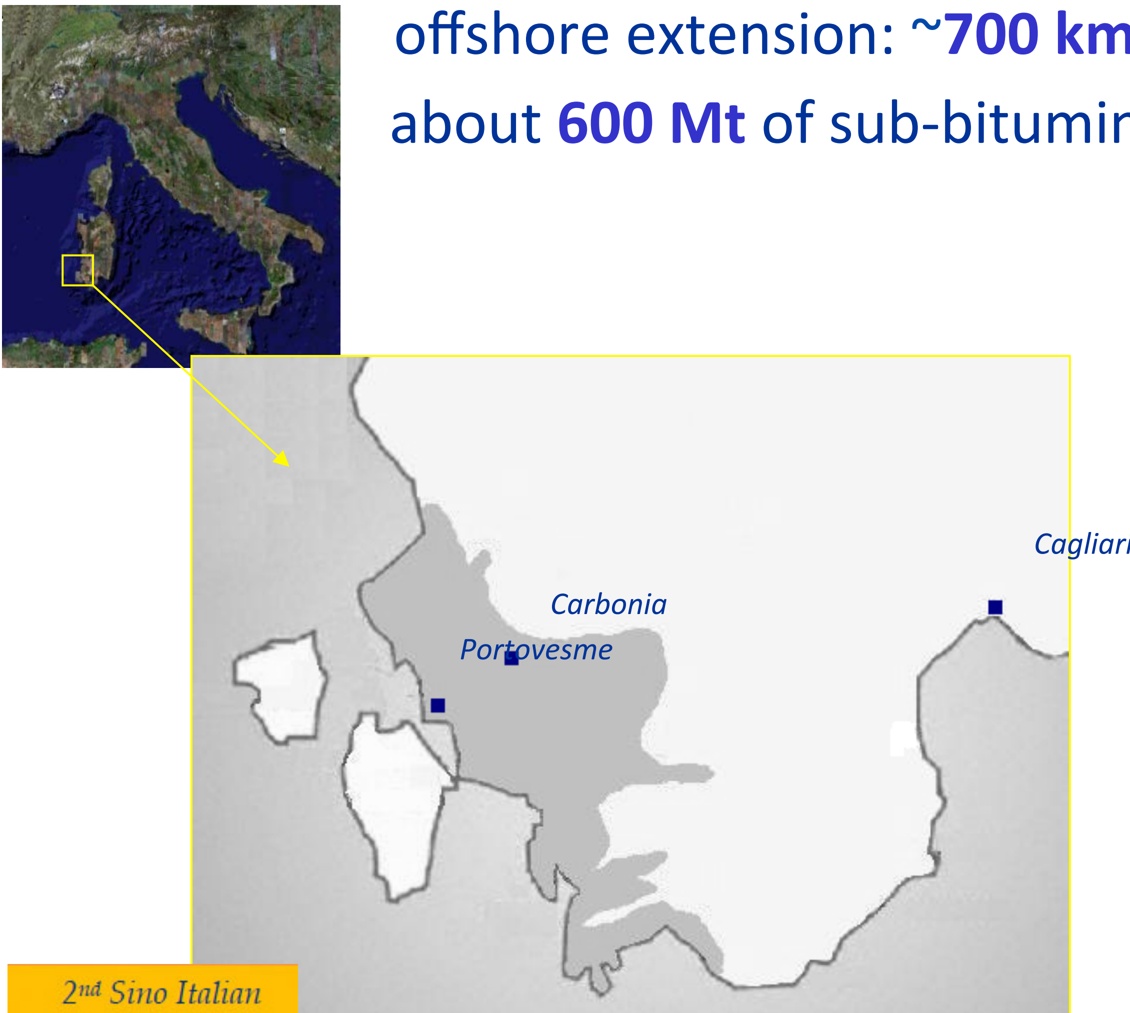
The Sulcis coal basin

Pag. 473

onshore extension: ~**700 km²**

offshore extension: ~**700 km²**

about **600 Mt** of sub-bituminous coal



Sulcis coal ultimate analysis	
Carbon	53.17
Hydrogen	3.89
Nitrogen	1.29
Sulphur	5.98
Oxygen	6.75
Chlorine	0.10
Moisture	11.51
Ash	17.31
LHV (MJ/kg)	20.83

Pag. 473

New CO2 storage project

Pag. 474

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

CO2 storage in Sulcis area ECBM/aquifers pilot tests

- The project is aimed at **testing, at pilot scale, CO2 storage in deep coal layers and in the underlying aquifers in the Sulcis coal area**, located in South-West of Sardinia Region-Italy, managed by Carbosulcis.

- The presence of two superimposed formations that are both appropriate for CO_2 storage (**ECBM and deep aquifers**) is unique in Italy, a situation which provides additional safety in the form of a secondary, higher-level barrier should storage be conducted in the lower unit

2nd Sino Italian Scientific Meeting

Pag. 474

Pag. 475

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

2nd Sino Italian Scientific Meeting

Thank you for your attention

Giuseppe Girardi
giuseppe.girardi@enea.it

Pag. 475

Pag. 476

COLLABORATION MEETING

ENEA - SINTEF

ENEA activities on CCS

Giuseppe Girardi

ENEA
Sustainable fossil fuels and CCS

SOTACARBO
vicePresident

giuseppe.girardi@enea.it

ENEA – Casaccia Research Centre
via Anguillarese, 301 - Roma
19 October 2011

Pag. 476

ENEA research centres and Sotacarbo

Pag. 477

Pag. 477

Electricity generation in Italy

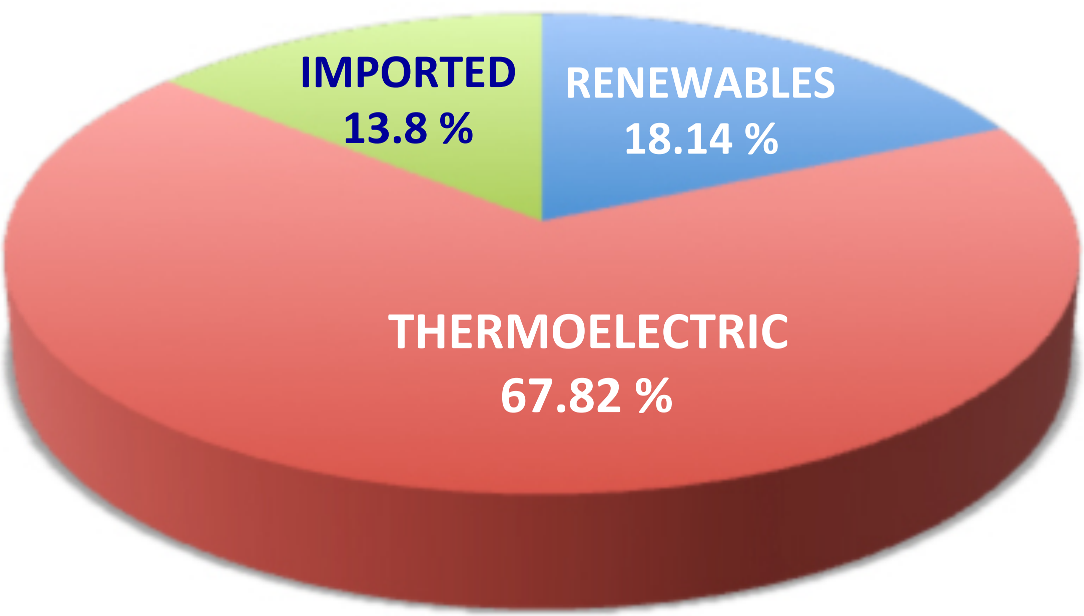
Pag. 478

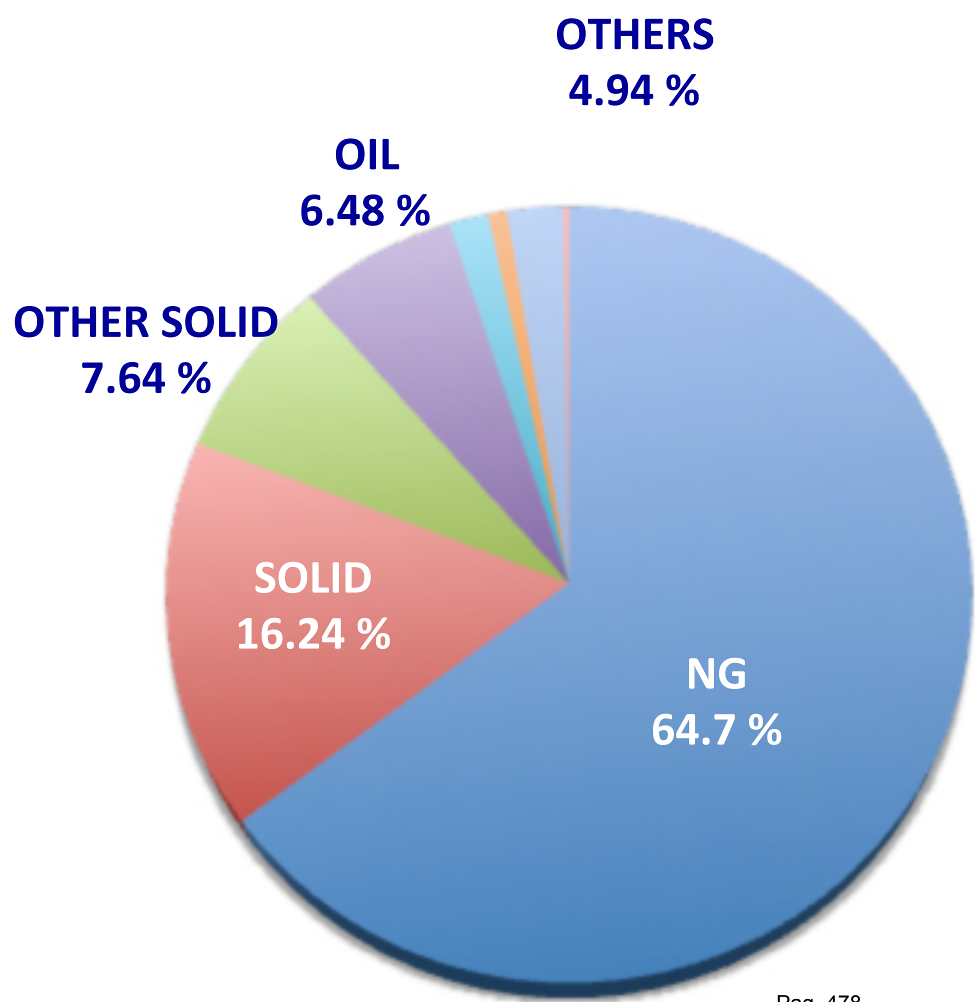
ENERGY REQUESTED:326,000 GWh

THERMOELECTRIC:	221,100 GWh
RENEWABLES:	59,150 GWh
IMPORTED:	45,000 GWh

THERMOELECTRIC ENERGY GENERATION: 221,100 GWh

HYDRO:	52,000 GWh (15.95 %)
WIND + PV:	7,150 GWh (2.19 %)





Pag. 478

Power Generation and CCS in Italy

Pag. 479

- We **had** a clear vision for power generation in the decade:
  - 25% nuclear CANCELLED
  - 25% coal
  - 25% renewables
  - other: fossil fuels

NEW COAL POWER PLANTS:

- Torre Valdaliga Nord (near Rome): started
- Porto Tolle: authorizations ongoing; post combustion DEMO
- Other coal power plants planned by ENEL and others
- 1 coal plant to be realized in Sardinia, with CCS

Pag. 479

CCS: the italian policy

Pag. 480

Law n.99 on "Regulations for the development and internationalization of enterprises and on the subject of energy:

- allowing the implementation of demonstrative projects on CO2 capture, and permanent storage of CO2 into suitable deep geological formations;
- realizing a coal fired with CCS demo plant in Sardinia region
- R/D Plan for industrial innovation

Other national initiatives

- Funds to Sotacarbo and Carbosulcis for common project with ENEA
- R&D national programs – on CCS - for the next four years
- Strong demonstration initiatives
  - ENEL/ENI
  - Sulcis integrated project - feasibility by ENEA/Sotacarbo
  - Sotacarbo/ENEA, firstly pilot

Pag. 480

Italian programme on CCS

Pag. 481

	project/ responsible	NATION. FUND			REGIONAL FUND (Sardinia)	EC FUND
		Electr. System	Energy Strategy	R&D Progr.		
DEMO	**Porto Tolle** ENEL-ENI					NER 300 other
	Sulcis 400 MWe Sotacarbo/ENEA				X	NER 300 other
PILOT	**Precomb (and coal-to-liquid)** Sotacarbo/ENEA	X			X	other
	CBM-ECBM in Sulcis basin Carbosulcis-Sotacarbo-ENEA	X			X	other
	Brindisi post comb ENEL					other
	Oxycomb ITEA - ENEA					other
R&D	**pre-comb** ENEA-Sotacarbo-ERSE	X			X	X
	post-comb ERSE-ENEA-ENEL	X			X	X
	oxy-comb ENEA-ITEA-Sotacarbo-CNR				X	X
	ECBM-wells-aquifers ENI-Carbosulcis-OGS-Univ., ENEA,..	X			X	X

Pag. 481

Transposition of Directive 2009/31

Pag. 482

- **Transposition has been done** (decree n. 162, Sptember 2011) after a wide consultation with stakeholders, mainly regional governments and local administrations: now Italy is one of the two members States in Europa that have approved a national transposition law.
- **A national committee** will manage CO_2 storage activities.
- Ministry of Economic Development will store and manage all the data concerning exploitation and storage activities of CO_2.

Pag. 482

ENEA programme in charge of Ministry of economic development

Pag. 483

- "CERSE": technology innovation of the electricity system
  - Efficiency improvement on SC and IGCC power plants,
  - Combined production of hydrogen & power with CCS,
  - Capture (pre and post combustion) technologies. Solid sorbents/solvents
  - Plant integration
  - Coal to liquid
  - ECBM Site-Tests in Sardinia (Sulcis Area)
  - Identification of national potential capacity to storage CO2

- "Industry 2015" - Industry-oriented R/D program
  - advanced MILD combustion in coal oxyfired power plants.

- "Law 99/2009"
  - R&D programme for industrial innovation,
  - Demonstration power plant, coal fired with CCS

Pag. 483

ENEA/Sotacarbo activities

Pag. 484

- Coal fired power plants with CCS
  - Italian national road-map on CCS; public acceptance
  - Testing on CO2 post combustion capture with solvents
  - Feasibility analysis for a SC coal demonstrative power plant in Sardinia, with CO2 storage in Sulcis coal area (ECBM, aquifers)
- Coal gasification with CO2 capture and storage
  - Experimental and modelling on pre combustion capture technologies and CO2 storage (with ECBM and saline aquifers
  - Feasibility analysis for a demonstrative power plant in Sardinia, with CCS
- Oxy combustion for coal fired power plants
  - Modeling, and "LES" simulation code (HeaRT) validation
  - testing with advanced diagnostics
  - feasibility analysis of a 48 MWt demonstrative plant (with ENEL).

Pag. 484

ENEA programme in charge of Ministry of Research

Pag. 485

- ZECOMIX Project - precombustion technology - ENEA

  coal gasification, syngas treatment and CO2 capture with solid sorbents, H2 production and burning for power generation

- COHYGEN Project - precombustion technology - SOTACARBO

  production of hydrogen and clean fuel gas (high temperature desulfurization) from coal and CO2 Capture from syngas using solvents

- CARBOMICROGEN Project – ENEA

  small power generation systems based on syngas and hydrogen generated by coal and/or biomass CCS systems

- PNR (to be launched)
  - Research projects
  - National research laboratories/infrastructures

Pag. 485

ZECOMIX test plant

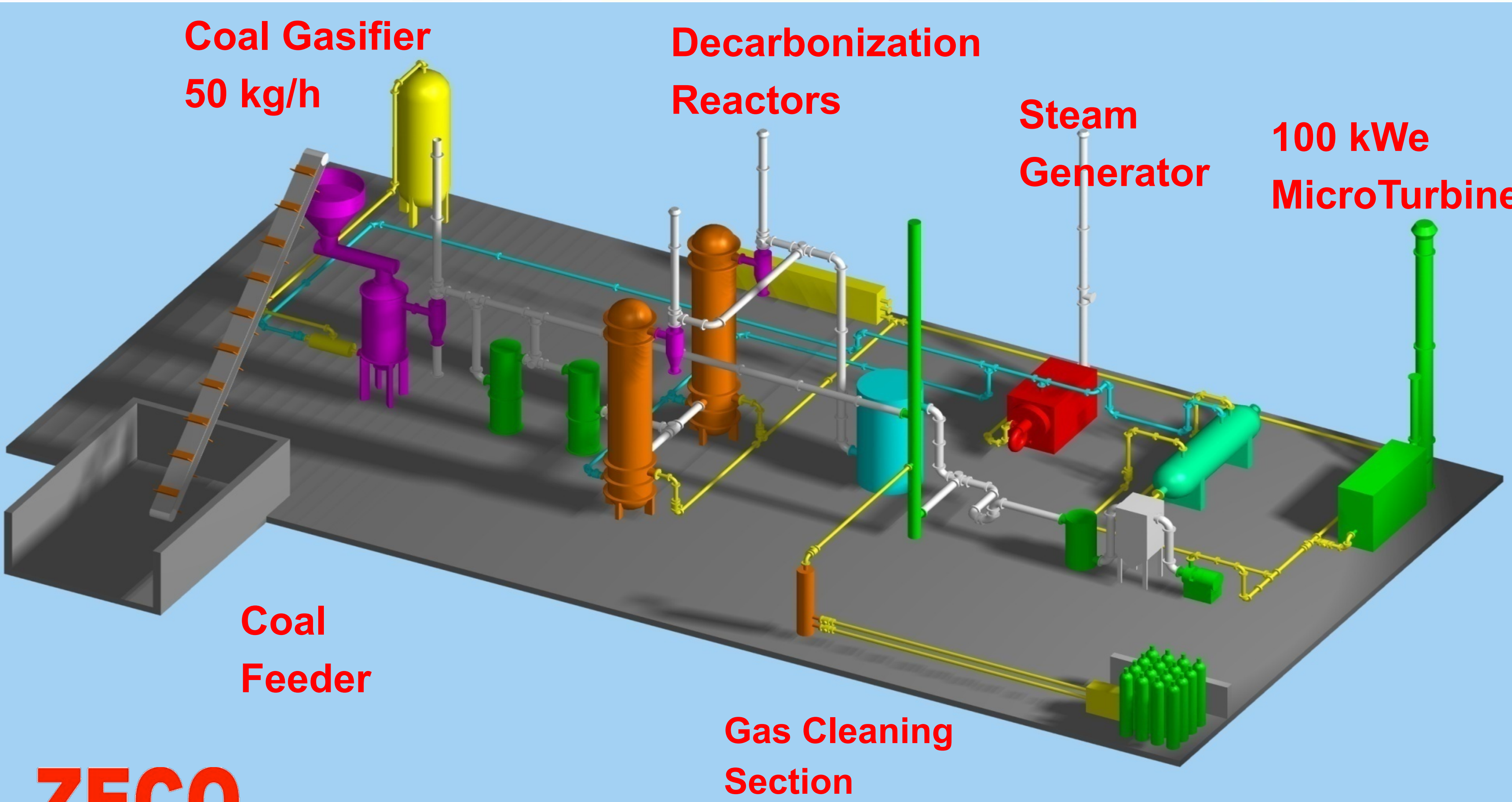
Pag. 486

30 kg/h coal

Pag. 486

ZECOMIX test plant

Pag. 487



ZECOmix

Pag. 487

Pag. 488

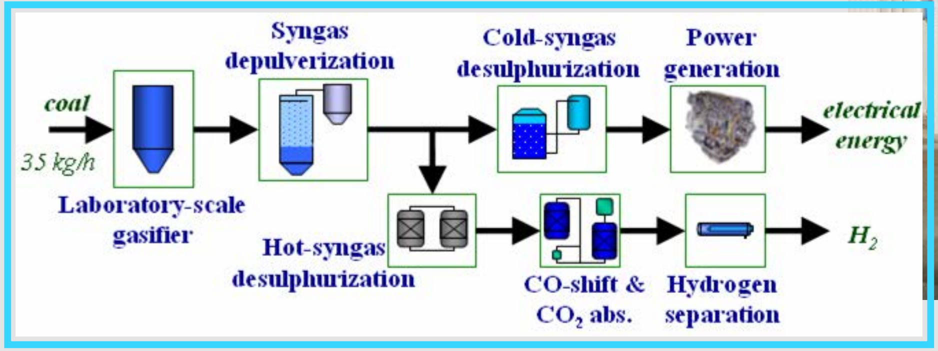
Sotacarbo pilot plant

700 kg/h coal

Pag. 488

Sotacarbo bench scale plant

Pag. 489



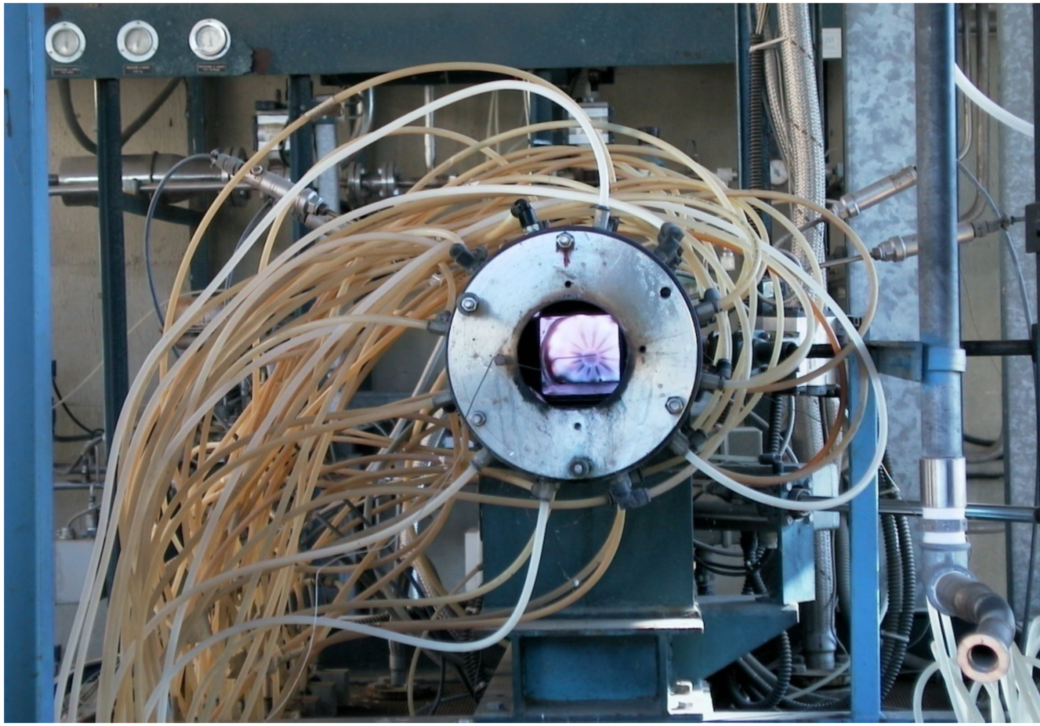
30 kg/h coal

Pag. 489

H2 combustion at ENEA

Pag. 490

ENEA
AGENZIA NAZIONALE
PER LE NUOVE TECNOLOGIE, L'ENERGIA
E LO SVILUPPO ECONOMICO SOSTENIBILE



MICOS test plant

IDEA test plant

Pag. 490

International cooperation: ENEA role

Pag. 491

- Carbon Sequestration leadership Forum (CSLF)
- Bilateral Agreement Italy-USA: CCT and CCS
- IEA Implementing Agreements
- Global Carbon Capture and Storage Institute (GCCSI)
- In the European context:
  - European technological Platform ZEP
  - SET Plan: European Energy Research Alliance EERA
  - SET Plan: European Industrial Initiatives
  - Coal&Steel Committee COSCO) – research fund for coal and steel
  - FP7: ECCSEL Project, for CCS european laboratory
- Support and advice for MSE and Government, at national and international level

Pag. 491

Pag. 492

Preparatory Phase Project

- main objective of the ECCSEL Preparatory Phase project (PP) is to address the primary tasks necessary to establish a new distributed, goal-oriented, integrated pan-European infrastructure for state-of-the-art research on technologies enabling CO_2 capture, transport and storage (CCS).
- The PP aims as bringing ECCSEL to the level of legal and financial maturity required for implementation.

- The ECCSEL PP is split into two phases, each phase approximately 2 years.
  - ✓ ECCSEL PP **phase I** started on 1 January 2011.
  - ✓ ECCSEL PP **phase II** has to be launched

Pag. 492

Pag. 493

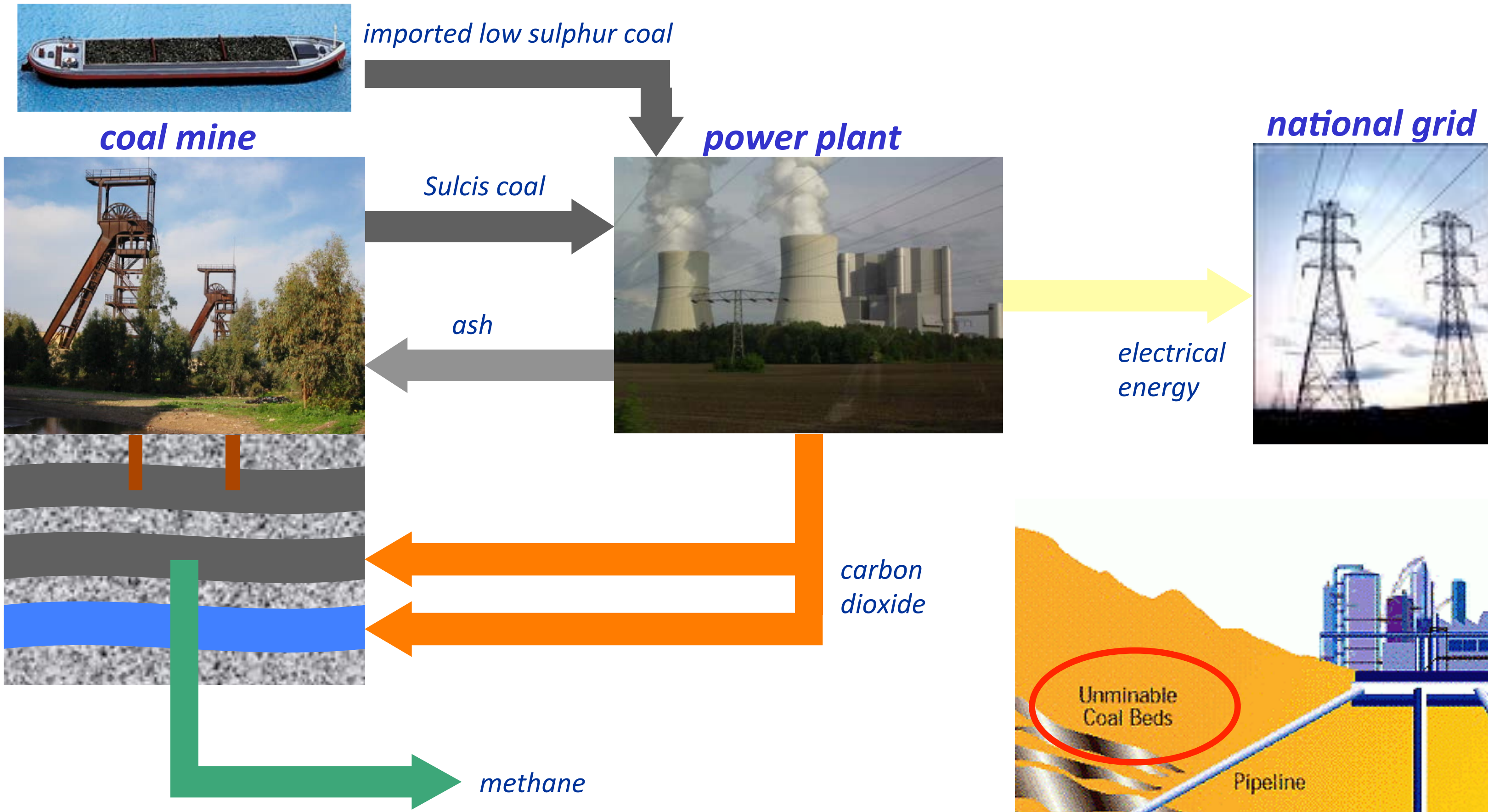
ENEA is partner of CCS JP of EERA

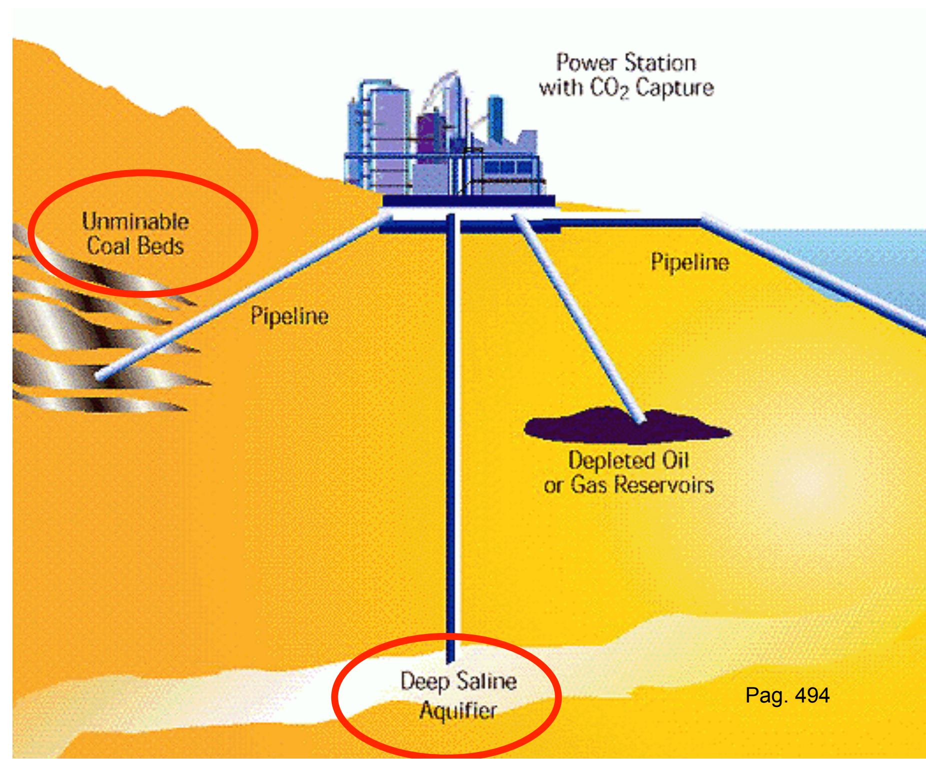
	POST - COMB			PRE - COMB			OXY FUEL				CROSS-CUTTING ISSUES			
		solv.	sorb.		sorb.	H2 turb.		oxy comb.	CLC	oxy turb.		proc. simul.	Bio CCS	
	total 1	1.1	1.2	**total 2**	2.2	2.3	**total 3**	3.1	3.3	3.4	**total 4**	4.1	4.2	**TOTAL**
ENEA	10		10	50	30	20	36	18		18	27	15	12	123
SOTACARBO	34	30	4								12	12		46
UNIVERSITIES														
Cagliari				4	4		3	3			6	6		13
Cagliari	4	4												4
Cagliari	3		3	2	2									5
Roma La Sapienza							8	8						8
Roma La Sapienza							6	6						6
Roma Tor Vergata				3	3									3
Roma Tor Vergata	5		5	5	5									10
Roma TRE				6		6								6
Pisa	5		5	5	5									10
Pisa							10	10						10
Politecnico Milano				5		5	8	4		4	3		3	16
L'Aquila				7	7						7	7		14
Napoli	18	8	10				18	6	12					36
CNR	30	10	20				30	18	12					60
TOTAL	109	52	57	87	56	31	119	73	24	22	55	40	15	370

Pag. 493

Pag. 494

400 MWe coal plant with CCS in Sardinia





plant size: 350-450 MW_e

(italian law n°9 23/07/2009)

Pag. 494

The Sulcis coal basin

Pag. 495

onshore extension: ~**700 km^2**

offshore extension: ~**700 km^2**

about **600 Mt** of sub-bituminous coal

Sulcis coal ultimate analysis	
Carbon	53.17
Hydrogen	3.89
Nitrogen	1.29
Sulphur	5.98
Oxygen	6.75
Chlorine	0.10
Moisture	11.51
Ash	17.31
LHV (MJ/kg)	20.83

Pag. 495

New CO2 storage project

Pag. 496

CO2 storage in Sulcis area ECBM/aquifers pilot tests

- The project is aimed at **testing, at pilot scale, CO2 storage in deep coal layers and in the underlying aquifers in the Sulcis coal area**, located in South-West of Sardinia Region-Italy, managed by Carbosulcis.

- The presence of two superimposed formations that are both appropriate for CO_2 storage (**ECBM and deep aquifers**) is unique in Italy, a situation which provides additional safety in the form of a secondary, higher-level barrier should storage be conducted in the lower unit

Pag. 496

Project activities

Pag. 497

- Study the **storage capacity** of the two stacked reservoirs, with the goal of better understanding the trapping mechanisms, migration processes, and potential leakage pathways.

- Develop **forecasting models** for both the physical evolution of the system (e.g. pressure migration, CO_2 migration, and CH_4 recovery optimisation) and chemical evolution (e.g. dissolution / precipitation reactions and modifications to groundwater chemistry).

- **Cap rock samples** can be collected to assess its integrity and containment capacity via numerical modelling of the system. Measurements would be conducted on oriented cores and will include fracture density and orientation, porosity, permeability and transmissivity.

- Measurements can be conducted **on the coal reservoir rock as wel**l, including CO_2 adsorption capacity and CH_4 desorption rate in the coal, and fracture density / orientation, porosity, permeability and rock chemistry in the carbonate unit.

Pag. 497

Project activities

Pag. 498

- **Sections of mine tunnels could be dedicated to experimentation and instrumentation** to study the processes of gas migration in the coal bed units and in the overlying caprock.

  This could include, for example, the drilling of several horizontal boreholes and the direct injection of CO_2 into the coal seams and/or the overlying cap rock, using some of the boreholes to monitor:
  - Absorbance rate of the CO_2 in the coal seams,
  - Migration rates of CO_2 in the cap rock

- **The use of the dedicated section of the mine may be extended to other partners or other organizations**, thus providing a facility to obtain *real data* on gas migration mechanisms and rates, gas adsorption processes, chemical reactions, etc.

- It may be possible to include this experimental Lab into **european RI network** – ECCSEL

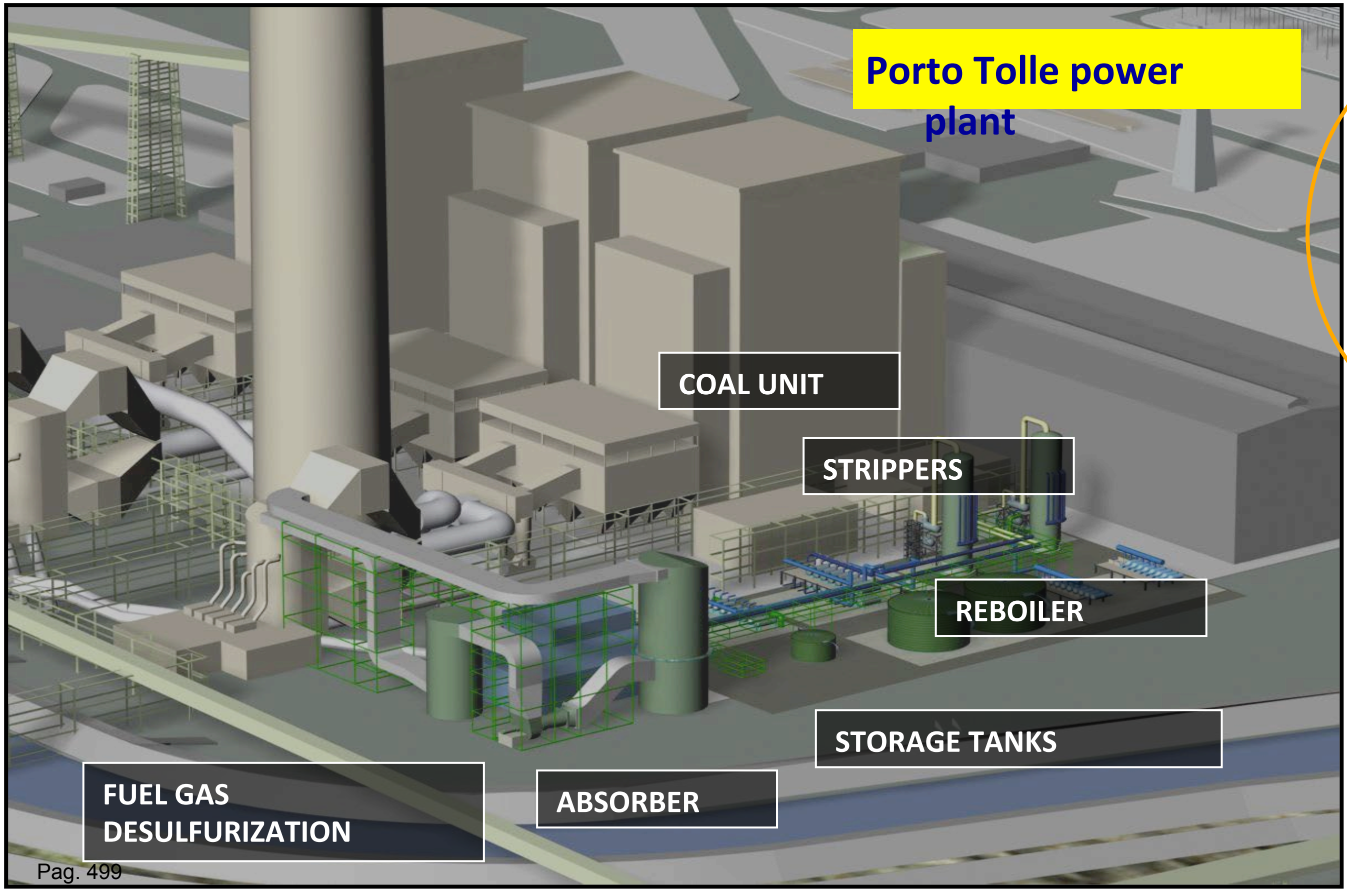
Pag. 498

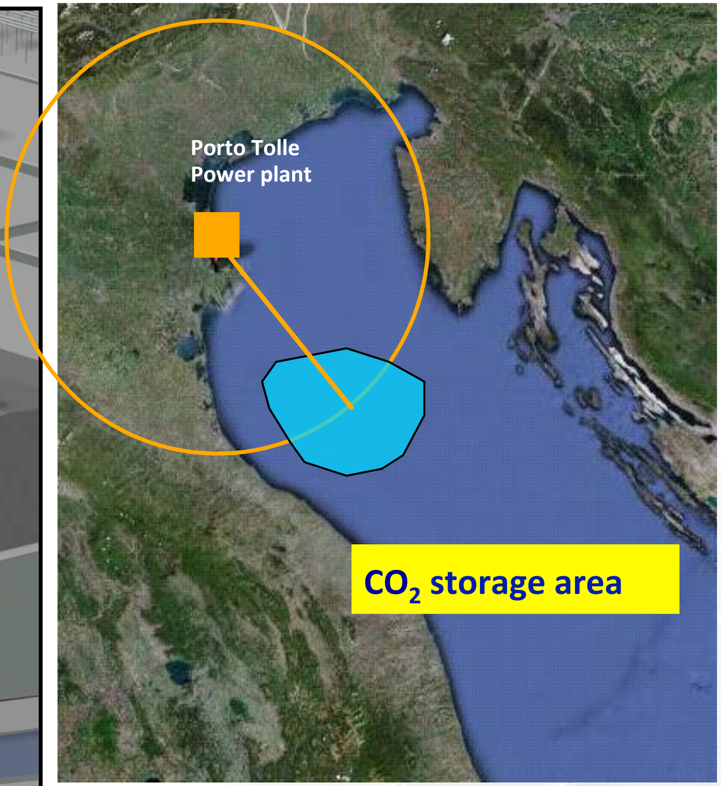
ZEPT: Zero Emission Porto Tolle (ENEL)

Pag. 499

Project goal

To retrofit one 660 MW_e coal fired unit of Porto Tolle power station with CO_2 post combustion capture equipment and start CO_2 underground storage in an off-shore saline aquifer by 2015





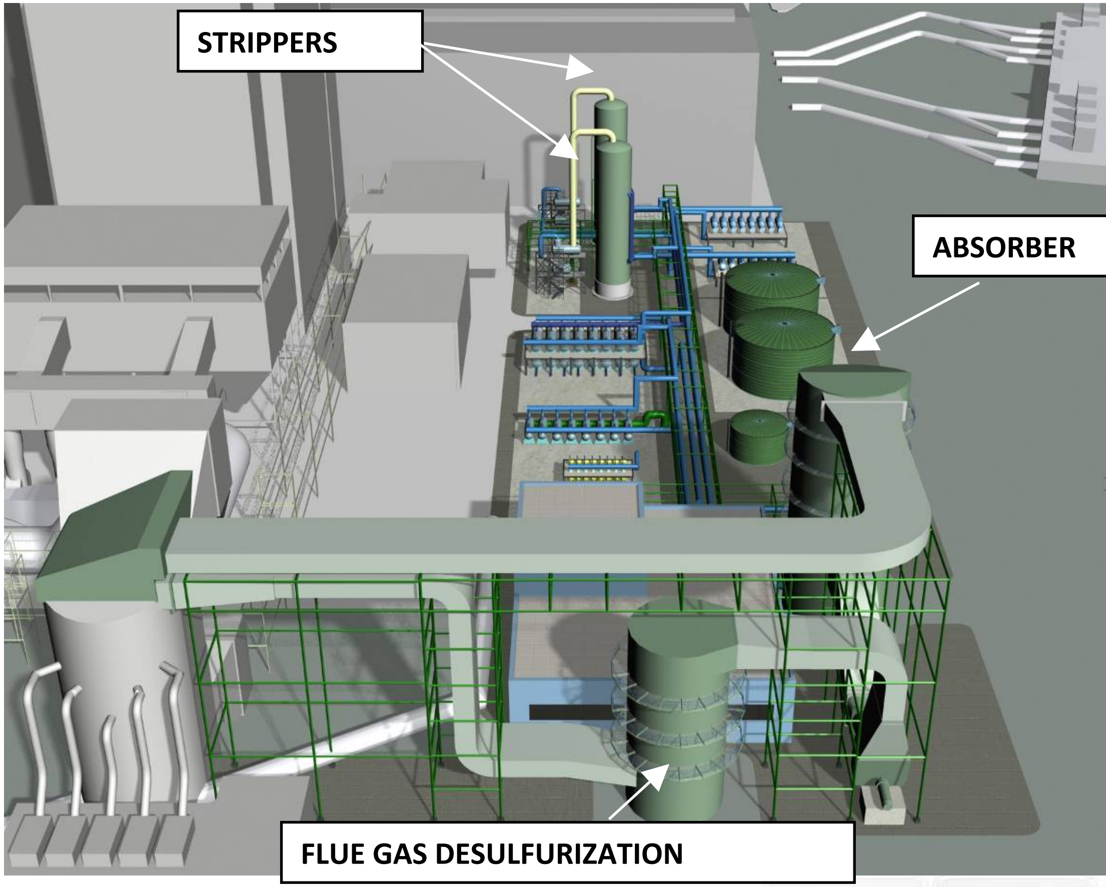
Pag. 499

ZEPT: Zero Emission Porto Tolle (ENEL)

Pag. 500

Demo main features

Type of Project	**Retrofit**
Power generation	**660 MWe**
Primary fuel	**Bituminous coal**
Secondary fuel	**Biomass**
Power Generation Tech	**USC-PC**
% of flue gas treated	**40%**
CO_2 Capture Tech	**Post Combustion Capture with Amine**
Stored CO_2	**Up to 1 Mt/y**
CO_2 Capture rate	**90%**
CO_2 Storage solution	**Deep saline aquifer**
Storage location	**North Adriatic Sea**
CO_2 value chain	**Pure storage**



Italian main industrial entities

Pag. 501

above all

- **ENEL** and
- **ENI**

which have started demonstrative projects of the greatest importance

and then

- **Sotacarbo**,
- **Carbosulcis**,
- **ITEA**,
- **Techint**,
- **Ansaldo**
- and others,

that has launched important demonstrative initiatives (both at pilot and industrial scale) and feasibility studies involving, even if with different stages of development, the three technologies for the capture and the main modalities for CO_2 storage

Pag. 501

FP7 INFRASTRUCTURES – 2012

Pag. 502

Funding scheme: Combination of “Collaborative project” and “Coordination and Support Actions

ECRI: European CCS research Infrastructure – Integrating Action

The RI include:

- Major scientific equipment or set of instruments
- Scientific collections, archives and structured information
- Enabling ICT-based “e-Infrastructures”
- Any other entity of a unique nature, used for research

The RI can be:

- “Single-sited” or “distributed”
- Activities:

(1) Transnational access and/or service activities and

(2) Networking activities,

(3) Joint research activities

Pag. 502

FP7: call FP-ENERGY-2012-1 (20 July '11)

Pag. 503

Deadline: For **CSA** topics (one stage submission): 25 October
For Collaborative Project (**CP**) topics (two stage submission):
First stage: 25 October 2011, Second Stage: 3 April 2012

ACTIVITY ENERGY.5: CO_2 CAPTURE AND STORAGE TECHNOLOGIES FOR ZERO EMISSION POWER GENERATION		
AREA ENERGY.5.2: CO_2 STORAGE	ENERGY.2012.5.2.1: Sizeable pilot tests for CO_2 geological storage *(Up to 2 projects may be funded)*	Collaborative Project *(Requested EU contribution per project shall not exceed EUR 9 Million)*
	ENERGY.2012.5.2.2: Impact of the quality of CO_2 on transport and storage behaviour	Collaborative Project
ACTIVITY ENERGY.5&6: CROSS-CUTTING ACTIONS BETWEEN ACTIVITIES ENERGY.5 AND ENERGY.6		
ENERGY.5&6.2: CROSS CUTTING AND REGULATORY ISSUES	ENERGY.2012.5&6.2.1: Support to the coordination of stakeholders' activities in the field of Zero Emission Energy Production *(Up to 1 project may be funded)*	Coordination and support action (supporting action)

Pag. 503

FP7: call FP-ENERGY-2012-2 (20 July ’11)

Pag. 504

Deadline: 8 March 2012

CROSS-CUTTING ACTIONS BETWEEN ACTIVITIES ENERGY.5 AND ENERGY.6 (ACTIVITY ENERGY.5&6)		
AREA ENERGY.5&6.1: POWER GENERATION TECHNOLOGIES FOR INTEGRATED ZERO EMISSION SOLUTIONS	Energy.2012.5&6.1-1 Pilot plant-scale demonstration of advanced post-combustion CO_2 capture processes with a view to integration in fossil fuel power plants	Collaborative Project with a predominant demonstration component
	Energy.2012.5&6.1-2: Pilot plant-scale demonstration and integration of emerging and new combustion technologies	Collaborative Project with a predominant demonstration component

Pag. 504

Conclusion

Pag. 505

Common project ongoing, already started or to be submitted

- ECCSEL, ECRI

Possible future common projects

STORAGE

- in Italy, in Sulcis basin

CAPTURE

- Pre and post combustion, solvents and sorbents
- Small (ENEA) and large (SOTACARBO) Pilot plants
    - DEMO PLANTS:
        - ✓ Sulcis 400 MWe power plant
        - ✓ Porto Tolle power plant
        - ✓ Other demo plants in Europe

Pag. 505

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Pag. 506

First KOREA-ITALY Symposium

GREEN TECHNOLOGY

Thank you for your attention

Giuseppe Girardi
giuseppe.girardi@enea.it

Pag. 506

Summary

Pag. 507

- Competence and market today, main strategy in the field
- Infrastructure, laboratories
- List of EUFP7 participations with / without the other party (ENEA / SINTEF)
- Perspectives on future industrial challenges in the field where we aim to make a difference
- Relevant calls in EUFP7 in the time to come

Pag. 507

Technological carbon management Options

Pag. 508

REDUCE CARBON INTENSITY

- Renewables
- Fuel switching

IMPROVE EFFICIENCY

- Demand side
- Supply side

SEQUESTER CARBON

- CCS or CCUS
- Natural sinks

All options need

- Satisfy ENERGY DEMAND
- Address ENVIRONMENTAL OBJECTIVES

Pag. 508

CCS Technology outlook: our vision in Italy

Pag. 509

- The **technologies** needed for CO2 capture, transport and storage are **mostly known** and some of that have been used for decades (as in EOR).
- On the other hand, a strong demonstration programme on a commercial scale is needed which verifies its effectiveness and safety, as well as medium-long term R&D for lowering the costs and increase efficiency.
- However, some questions have not been answered: **regulations** and **authorizations**, above all concerning CO2 transport and geological storage, and the problem of **social acceptability** of the entire CCS process

Pag. 509

Funds for CCS italian programme

Pag. 510

Fund for R&D on Electricity System	that collects the electricity bills (<0.03 c€/kWh) for co-funding technology innovation of the electricity system. More than 35 M€ have been already spent (mainly ERSE and ENEA) in the first 3-y programme.The new 3-y programme 2009-11 foresees 30 M€, and has already allocated, up to now, 19 M€.
Law n. 99/09: New Energy Strategy	for Promoting innovation in the energy sector; it introduces a project financing mechanism and a first hree-years RDD Plan: CCS is a priority in this plan.
Industria 2015	in the area of Areas Energy Efficiency a project on mild oxy-comb has been funded.
PNR: National Research Program	for financing medium-long term R&D programmes; the last 3-y programme funded more than 2.5 M€ to Zecomix project on advanced pre-combustion technologies; the next 3-y plan is going to be adopted.
EC public contribution	ENEL has already received 100 M€ contribution (EERP), but other contribution is expected (NER300, FP, etc..) in order to achieve a feasible national programme.

Pag. 510

Main objectives in the next few years

Pag. 511

- lowering the cost of the CO2 storage to values less than 40 €/t CO2;
- reducing the investment and operating costs of CCS installation;
- reducing the added energy required by CCS technologies;
- completing the mapping of geological sites suitable for CO2 storage in Italy;
- starting CCS demonstration projects on an industrial scale;
- Improving R/D programme

Background

Pag. 512

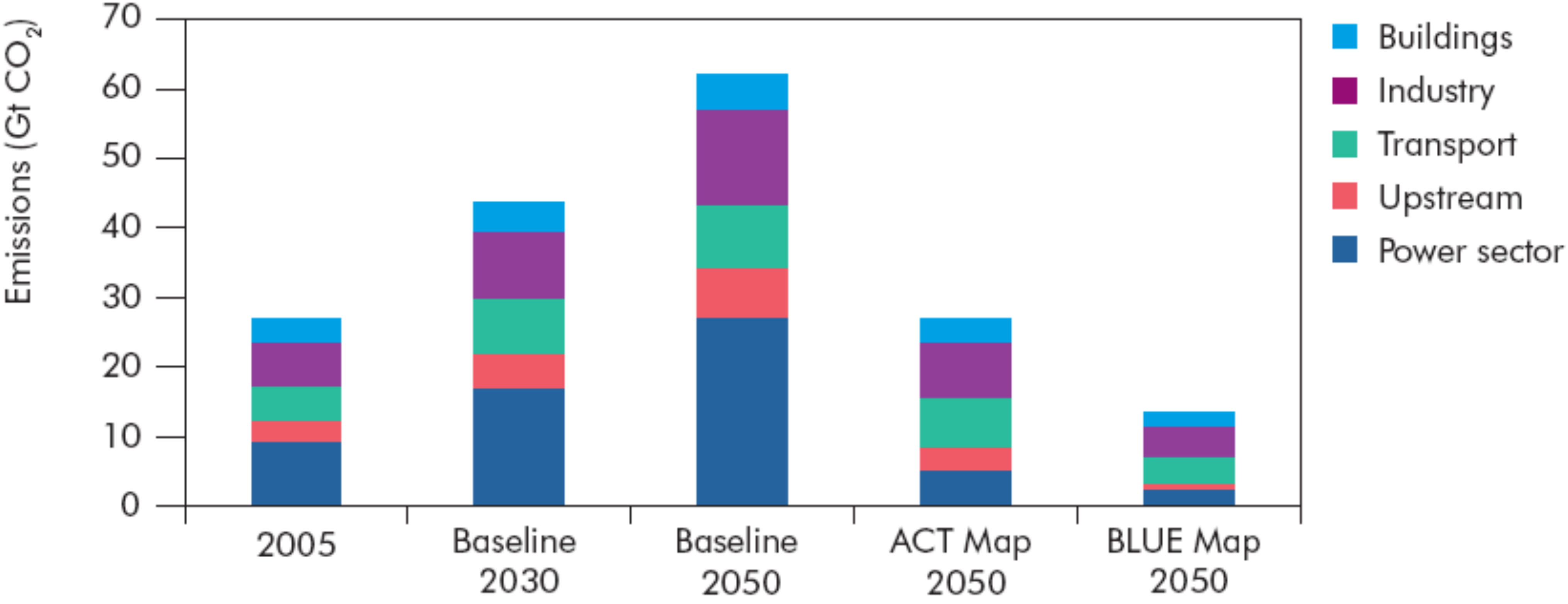
- fossil fuel demand will stay very high in the coming decades, above all in Emerging Economy Countries
- the development and commercial deployment of intrinsically zero emission technologies at a competitive cost will take longer
- it is necessary to act immediately to reduce CO2 emissions into the atmosphere generated by fossil fuel power plants

Pag. 512

IEA –Energy Technology Perspectives

Pag. 513

Figure 2.1 ▶ Global CO_2 emissions in the Baseline, ACT Map and BLUE Map scenarios



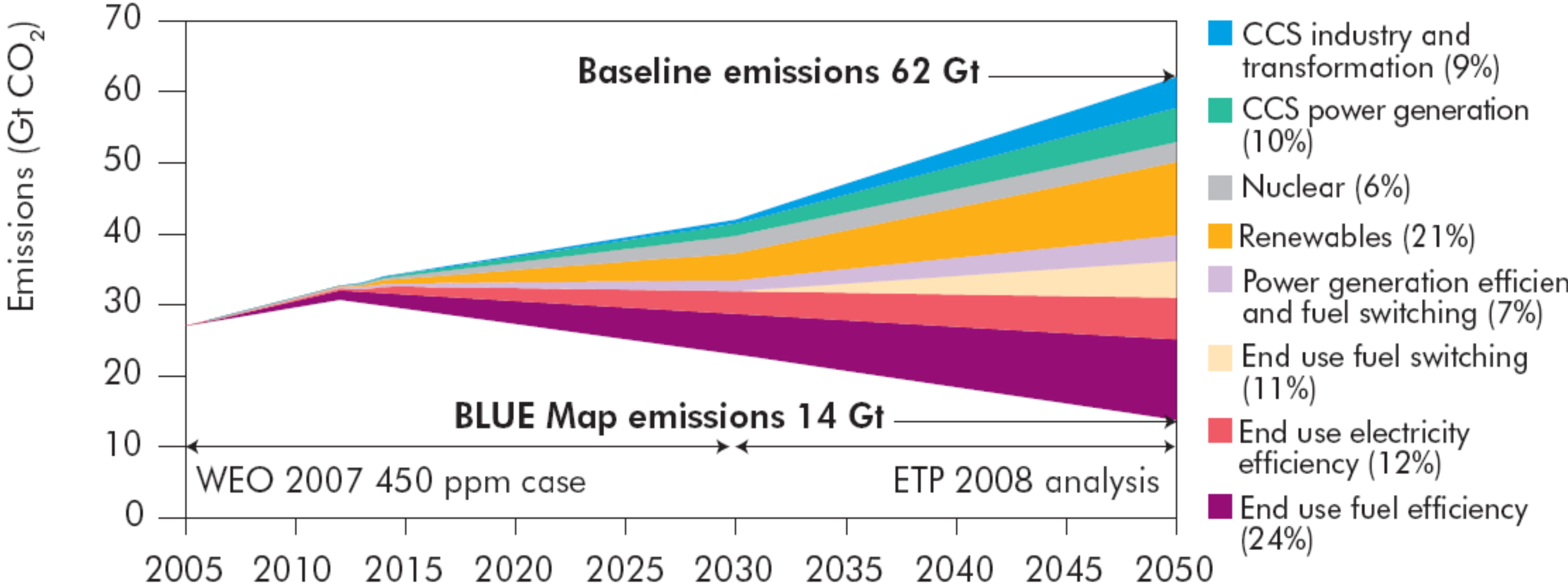
ACT scenario: techologies that already exist or are in advanced state of development
BLU scenario: reducing CO2 emissions by 50% (from current levels) by 2050

Pag. 513

IEA –Energy Technology Perspectives

Pag. 514

Figure 2.2 ▶ **Contribution of emission reduction options, 2005-2050**



Key point

The BLUE Map scenario is consistent with the World Energy Outlook 2007 450 ppm case.

Pag. 514

Pag. 515

gasification and decarbonization

CaO capture chemical looping

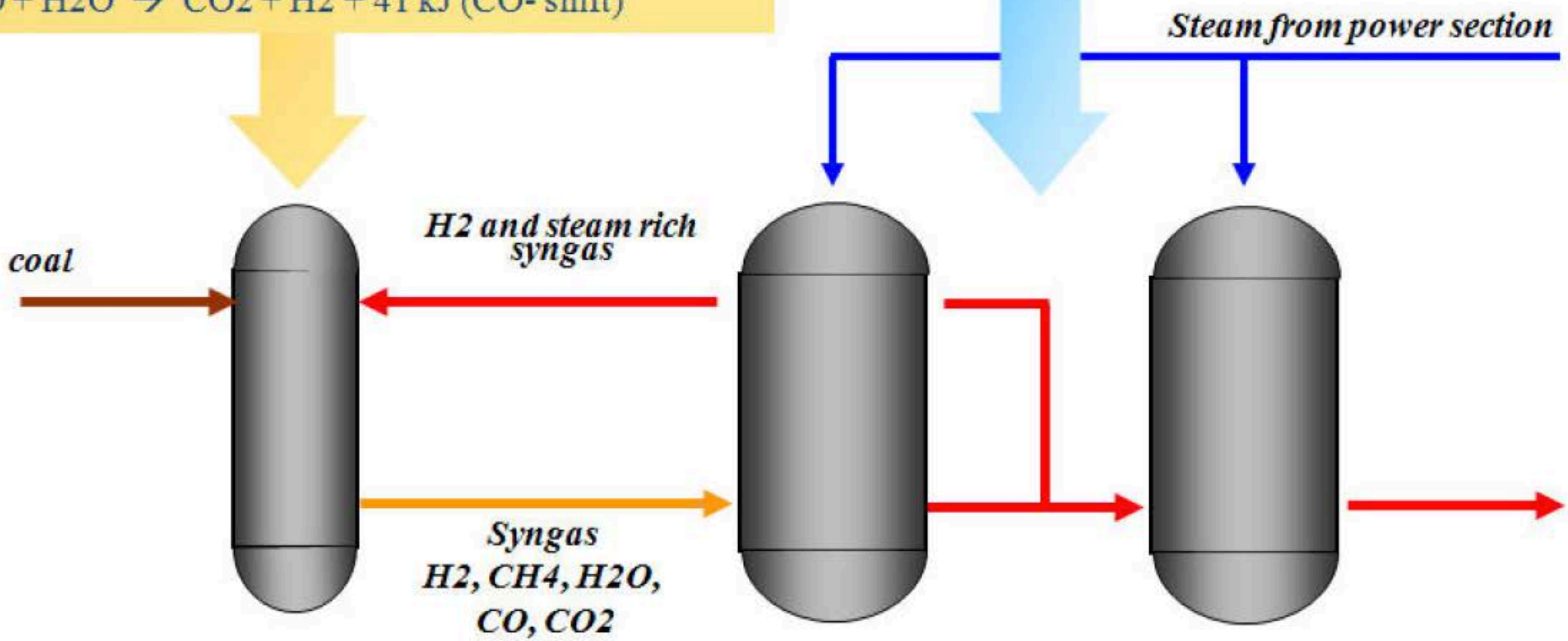
HYDROGASIFIER:

$C + 2H_2 \rightarrow CH_4 + 90$ kJ (hydrogasification)

$C + H_2O \rightarrow CO + H_2 - 131.6$ kJ (gassificazione)
$CO + H2O \rightarrow CO2 + H2 + 41$ kJ (CO- shift)

DECARBONATION REACTORS:

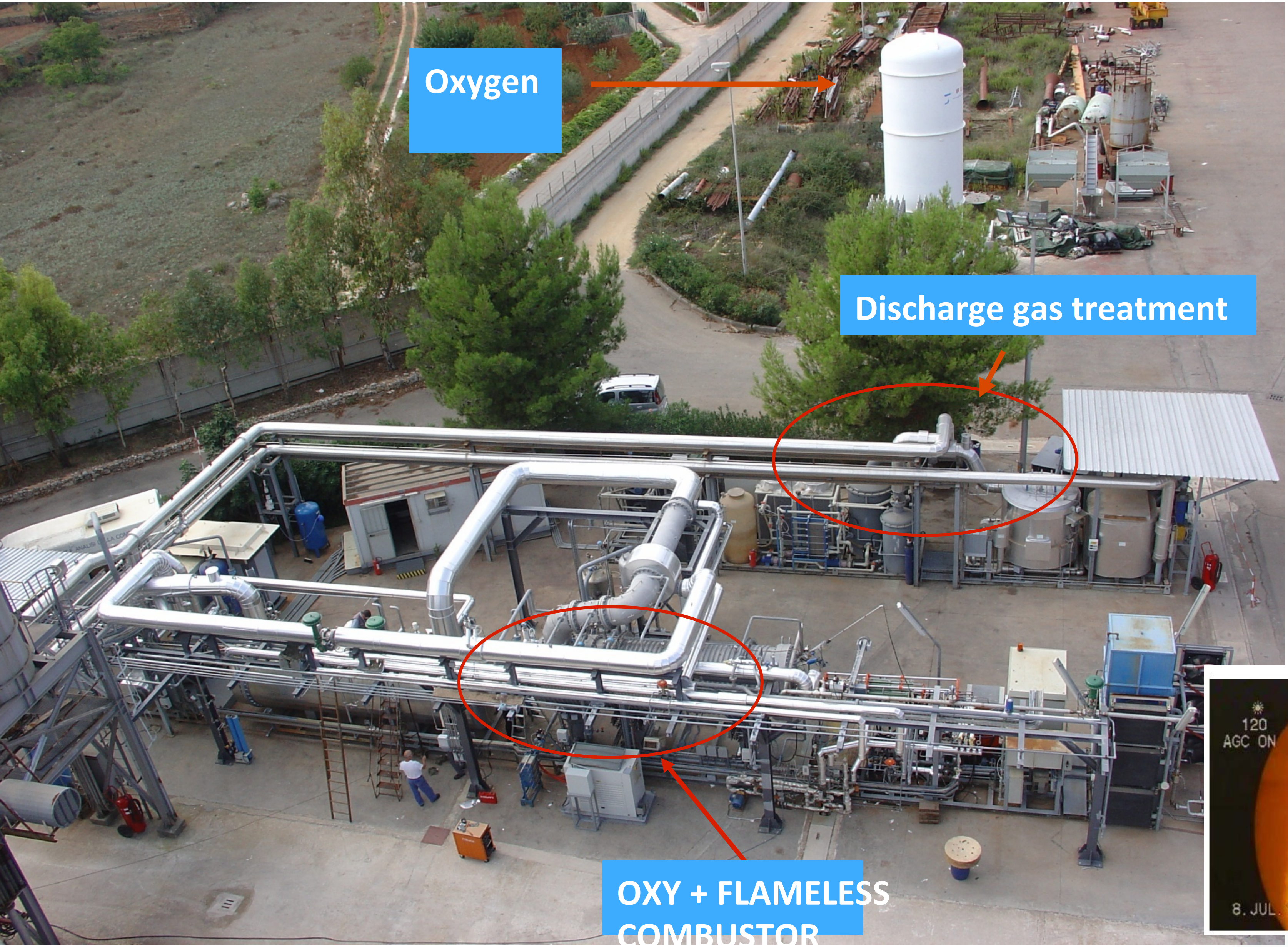
$CH4 + H2O + 206$ kJ $\rightarrow CO + 3H2$ (reforming)
$CO + H2O \rightarrow CO2 + H2 + 41$ kJ (CO-shift)
$CaO + CO2 \rightarrow CaCO3 + 178.8$ kJ (carbonation)



Pag. 515

Pag. 516

Oxy – Flameless combustion

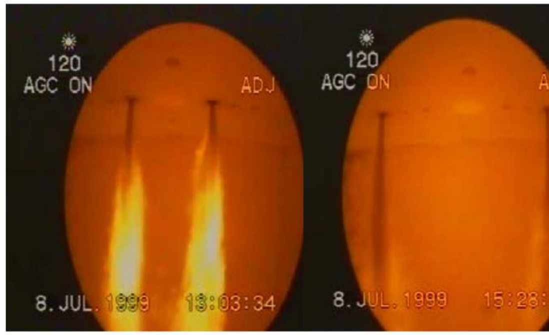


ENEL Project

- ENEA
- ENEL
- ITEA

MSE founded Project:

- ENEA
- ANSALDO E.
- ITEA
- SOTACARBO



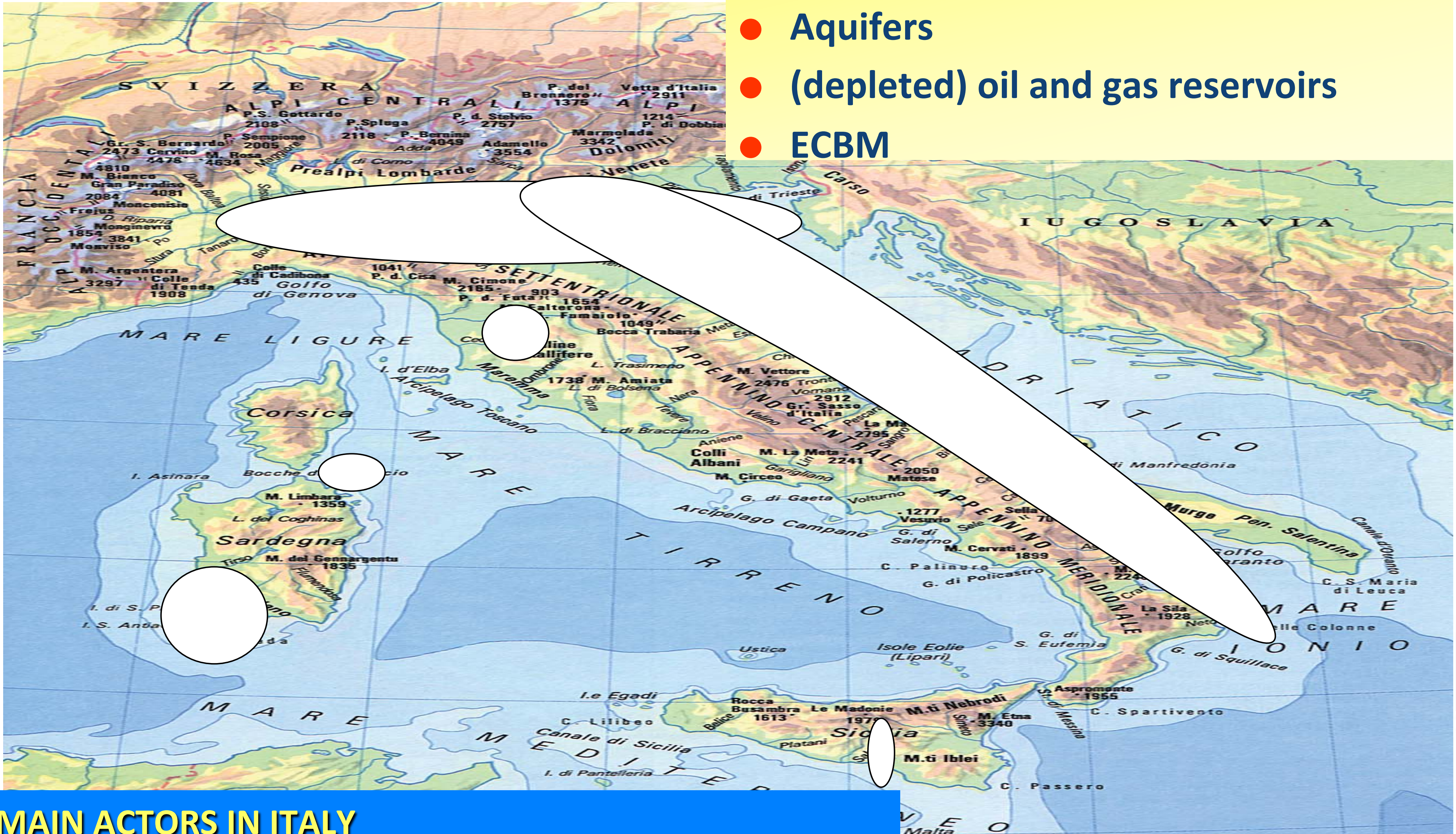
Pag. 516

Pag. 517

CCS Storage: where in Italy

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

- Aquifers
- (depleted) oil and gas reservoirs
- ECBM



MAIN ACTORS IN ITALY

<u>Research Inst:</u> RSE OGS INGV Universities CNR ENEA

<u>INDUSTRY:</u> ENI ENEL Carbosulcis

Pag. 517

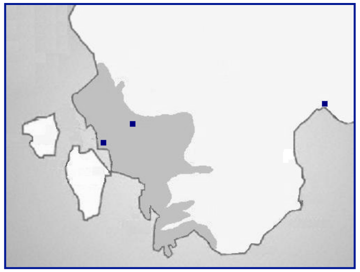
Pag. 517

Plant configuration

Pag. 518

assumption

location → very close to the coal mine



- low costs for transport of local coal
- low costs for ash storage in the exhausted seams of the coal mine

fuel mix → 50% of local coal

- high % of Sulcis coal → increase the coal mine production

  (important contribute for the occupation problems in the Sulcis area)
- high % of Sulcis coal → high costs for SOx emission reduction

plant size → 350-450 MW_e

- plant availability of 7600 hours/year
- respect of the emission limits

Pag. 518

Project activities

Pag. 519

- **The use of the dedicated section of the mine may be extended to other partners or other organizations**, thus providing a facility to obtain *real data* on gas migration mechanisms and rates, gas adsorption processes, chemical reactions, etc.
- It may be possible to include this experimental Lab into **european RI network** – ECCSEL
- It could be also interesting to use **this experimental lab as a teaching facility** for people involved in future CCS plans as well as a demonstration site for stakeholders at large.
- The results will be utilized immediately in the above mentioned Sulcis CCS demonstration plant

Pag. 519

Pag. 520

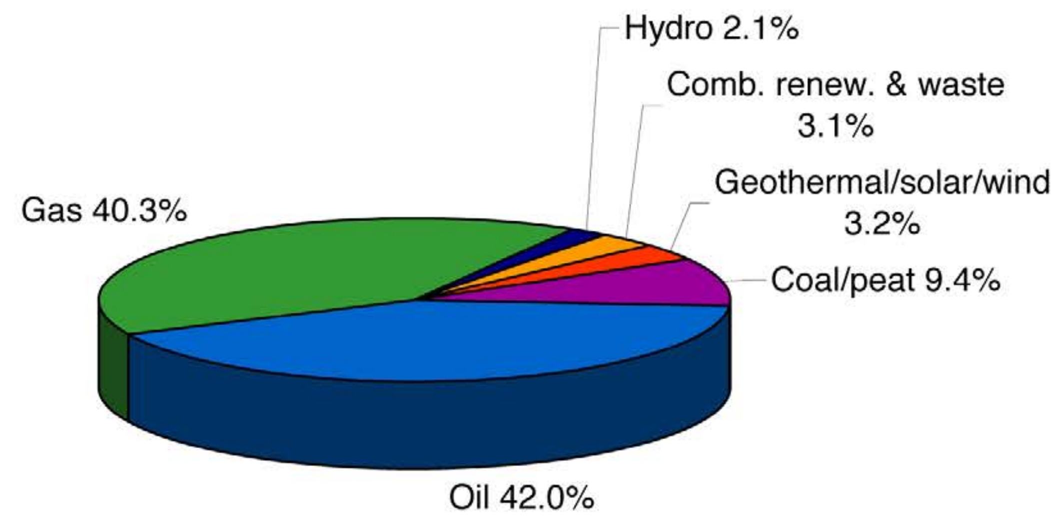
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

IEA Energy Statistics

Statistics on the Web: http://www.iea.org/statist/index.htm

Share of total primary energy supply* in 2008

Italy



176 Mtoe

* Share of TPES excludes electricity trade.

Note: For presentational purposes, shares of under 0.1% are not included and consequently the total may not add up to 100%.

Pag. 520

For more detailed data, please consult our on-line data service at http://data.iea.org.

Pag. 521

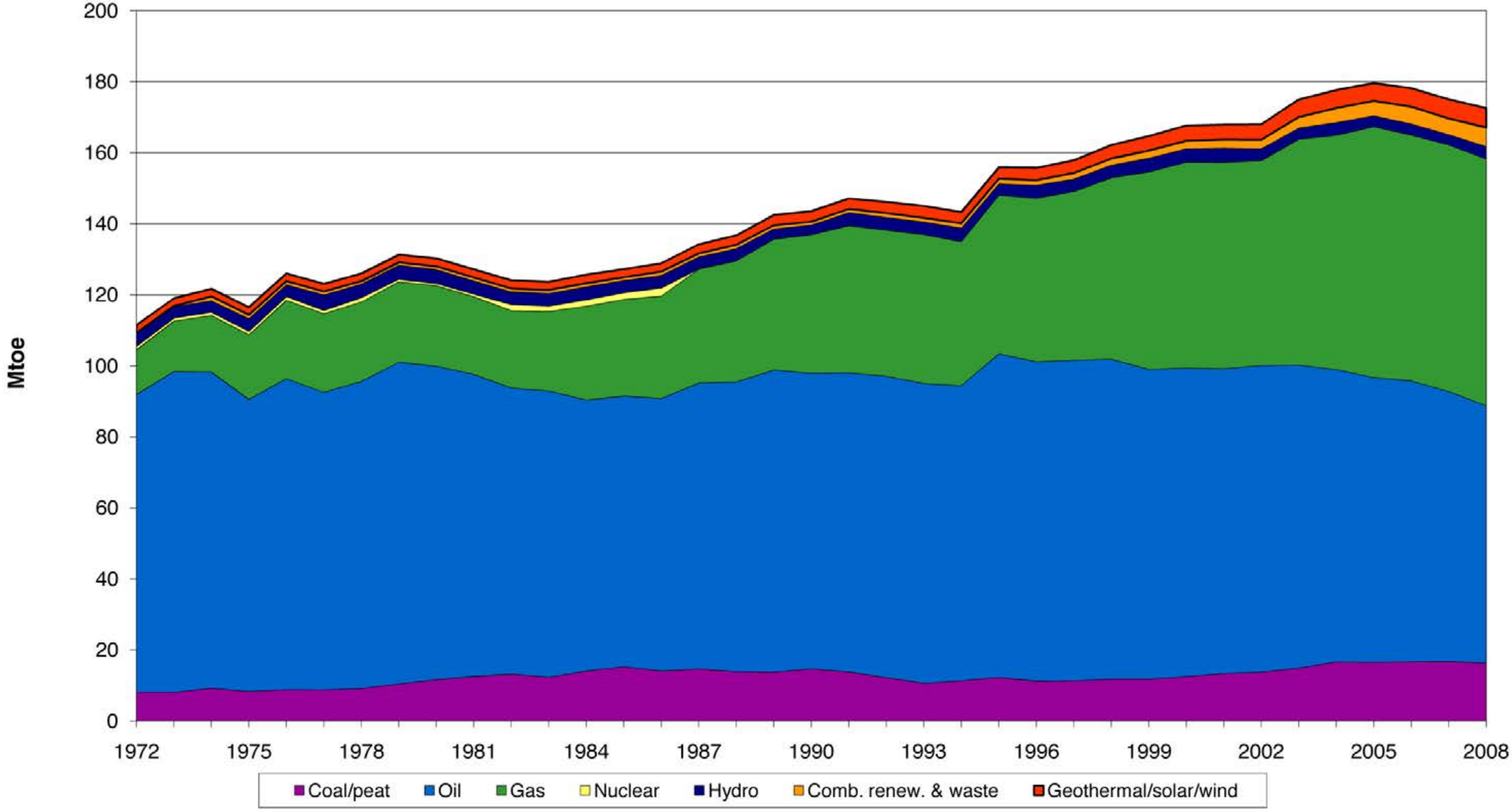
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

IEA Energy Statistics

Statistics on the Web: http://www.iea.org/statist/index.htm

Total primary energy supply*

Italy



* Excluding electricity trade.

Pag. 521

For more detailed data, please consult our on-line data service at http://data.iea.org.

Pag. 522

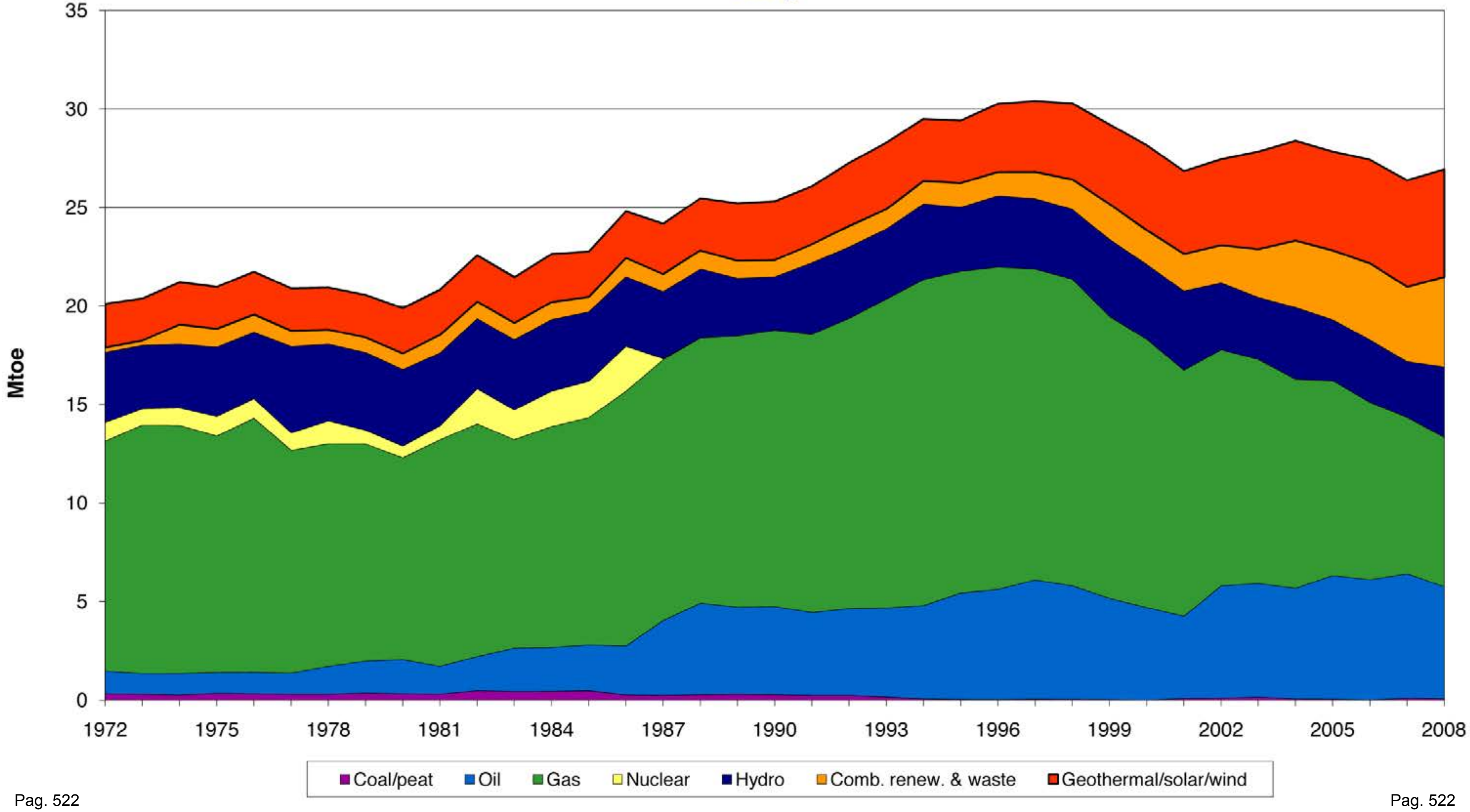
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

IEA Energy Statistics

Statistics on the Web: http://www.iea.org/statist/index.htm

Energy production

Italy



Pag. 522

For more detailed data, please consult our on-line data service at http://data.iea.org.

Electricity generation by fuel in Italy

Pag. 523

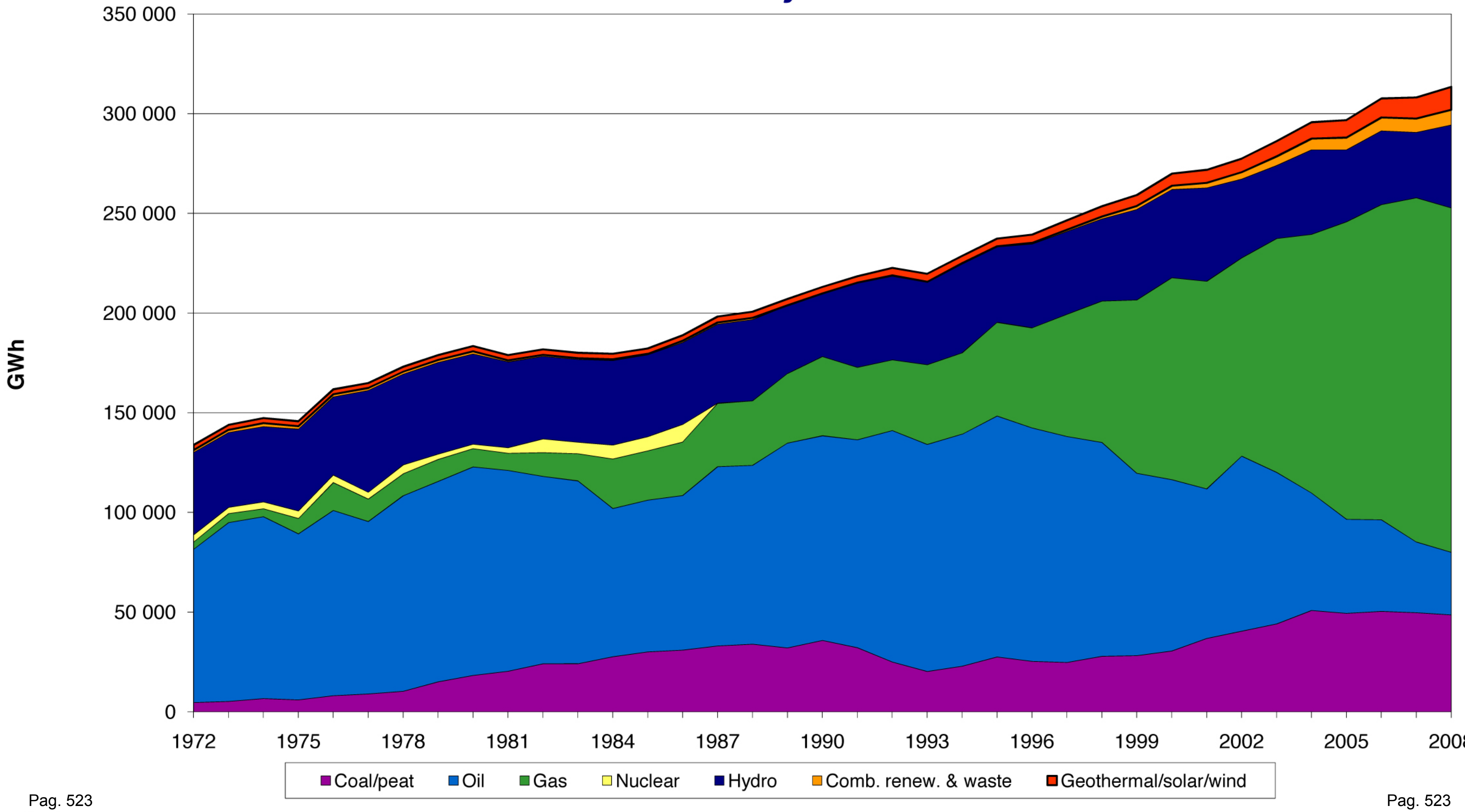
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

IEA Energy Statistics

Statistics on the Web: http://www.iea.org/statist/index.htm

Electricity generation by fuel

Italy



Pag. 523

For more detailed data, please consult our on-line data service at http://data.iea.org.

Pag. 524

European Carbon Dioxide Capture and StoragE Laboratory Infrastructure

www.eccsel.org

Morten Grønli (coordinator)
Astrid Lilliestråle (manager)
NTNU
Innovation and Creativity

Arne M. Bredesen
Olav Bolland
NTNU
Innovation and Creativity

Nils A. Røkke
Maria Barrio
SINTEF

European Strategy Forum on Research Infrastructures
ESFRI
Pag. 524

Pag. 525

European Strategy Forum
on Research Infrastructures

ESFRI

Common Strategy for Research Infrastructures in Europe

- Excellent European research needs a range of high quality research infrastructures
- European level RIs provide service to the whole European research community. Due to the high building and operation costs it makes sense to share much of these infrastructures
- ESFRI (**E**uropean **S**trategy **F**orum on **R**esearch **I**nfrastructures)
  - Forum of all EU member states and associated states + 1 representative of the EU (mandate from Council of Ministers 2004)
  - To foster an “open method of coordination” between different countries
  - To bring projects and initiatives to a point where decisions by ministers are possible
  - A stimulator and incubator role
  - To foster better coordination and to avoid duplication of efforts

Pag. 527

ESFRI published its first Roadmap with 35 RIs in 2006

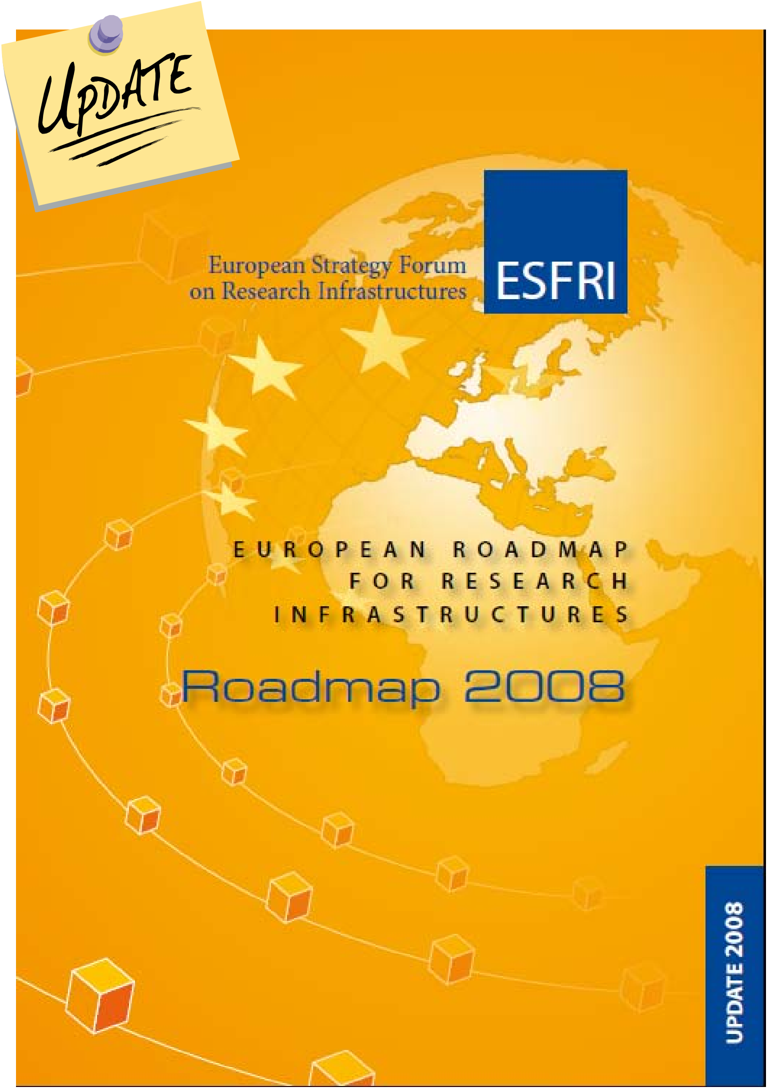
1. Social sciences and Humanities (6)
2. Environmental Sciences (7)
3. Energy (3) - all in the nuclear field
   - HIPER: High power long pulse for ignition fusion
   - IFMIF: International Fusion Materials Irradiation Facility
   - JHR: High Flux Reactor for Fission Materials Testing
4. Biological and Medical Sciences (6)
5. Materials and Analytical Facilities (5)
6. Physical Sciences and Engineering (7)
7. e-Infrastructures (1)

Some fields, in particular non-nuclear energy are not yet well represented on the ESFRI roadmap

Pag. 528

ESFRI published its updated Roadmap with 44 RIs in 2008

ECCSEL was the only new RI within the Energy field



>Energy

ECCSEL – European Carbon Dioxide Capture and Storage Laboratory Infrastructure

The facility:

The ECCSEL facility combines three approaches to capture (pre and post combustion and O_2/CO_2 -oxyfuel- recycle combustion capture) and three approaches to carbon storage (aquifers, depleted oil/gas fields, coal bed methane). The project includes the upgrading of existing national infrastructures to European level. The upgraded facility is composed of distributed parts in different countries and a coordination centre in Norway.

Background.

Carbon dioxide capture and storage (CCS) is identified as a key technology for reducing emissions from fossil energy use in the future. The demand for it is globally large, in particular in emerging economies. Europe lacks presently a large research infrastructure in this field. There is a very strong need for activities in this field and this topic is highly relevant for the EU Strategic Energy Technology (SET) plan. The core consortium of the upgraded facility consists of 10 European partners, but the network behind CCS is much broader.

What's new? Impact foreseen?

The ECCSEL infrastructure will be unique world-wide in its comprehensiveness for research in CCS and will be open to researchers through a joint management structure. It builds up on developments of the partners' specialised labs in course of national and EU programmes. The core hub of ECCSEL will be in Norway with partner institutions in Germany, the Netherlands, France, Denmark (including Greenland), Poland, Hungary, Switzerland and Croatia. The planned research infrastructure meets the different needs from basic research to experimental activities. In particular it will enable more advanced levels of research in post combustion absorption (needed to address the more near term options), new materials and processes (needed to reduce the cost and reliability of next generation CCS processes), combustion facilities (to enable oxy-fuel CCS processes and efficient hydrogen combustion) and storage facilities (needed for improving the knowledge of storage in aquifers and to develop qualification methods and mitigation strategies). These are all highly relevant to reduce the costs of CCS, improve the reliability of the various concepts and in particular to improve the knowledge of CO_2 storage and to develop qualification methods and mitigation strategies.

By facilitating international research and development ECCSEL will contribute substantially to the targets brought forward in the Road Map for EU Zero Emission Fossil Fuel Power Plants (ZEP) Technology Platform to achieve CO_2 reduction costs of less than 20€/ton, reduce efficiency loss to less than 6% and to help develop and implement competitive and sustainable CCS technologies.

| 41

>Timeline.

The facility will be in operation in 2017 and will meet the urgent needs in this field.

>Estimated costs.

Preparation costs:	3-4 M€.
Total construction costs:	81 M€.
Operation costs:	6 M€/year.
Decommissioning costs:	2 M€.

>Website: www.ntnu.no/eccsel

Pag. 528

European Strategy Forum
on Research Infrastructures
ESFRI

Pag. 529

European Carbon Dioxide Capture and StoragE Laboratory Infrastructure

- addresses the need for a powerful pan-European CCS Research Infrastructure

Pag. 529
European Strategy Forum on Research Infrastructures
ESFRI

Pag. 530

ECCSEL addresses the need for a powerful pan-European Research Infrastructure within CCS

ECCSEL mission

- To form a pan-European RI to build and operate new CCS laboratories, to:
  - Provide a scientific foundation to respond to the urgent CCS R&D needs
  - Maintain Europe at the CCS forefront
  - Increase the attractiveness of the European Research Area
  - Optimize the value of the Community financial support

ECCSEL will be

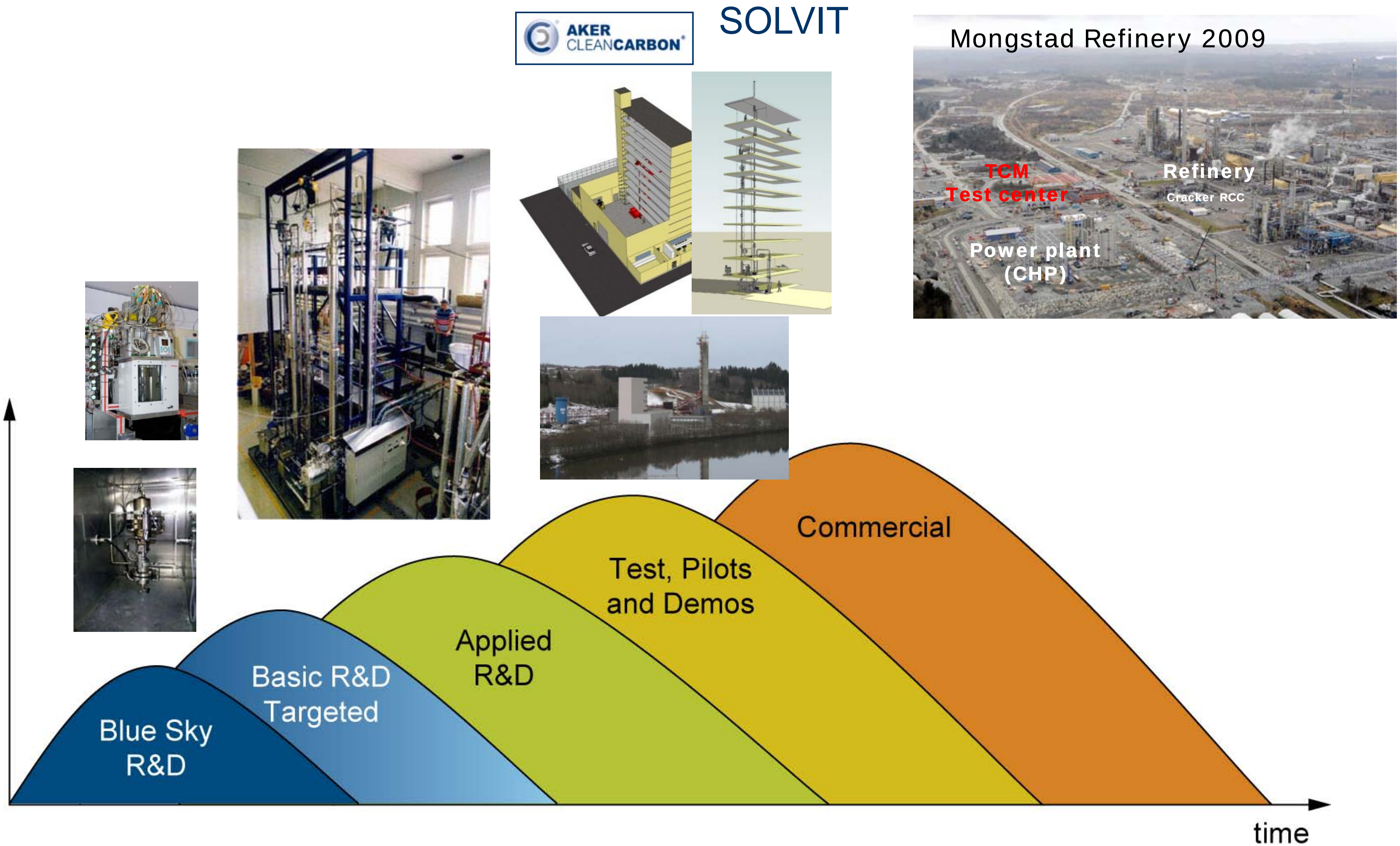
- A strong and coordinated pan-European ***distributed Research Infrastructure*** within CCS, meaning…
- An RI structured with **more than one site** and with **unique**
  - Legal status
  - Management structure
  - Strategy and development plan
  - Access point for users
  - Annual report and fiscal address
- An RI with pan-European interest, i.e. unique laboratories ensuring **open access** and creating a substantial added value

Pag. 530

Pag. 531

What kind of R&D do we need within CCS?

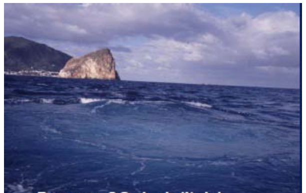
Post-Combustion as an example



Pag. 532

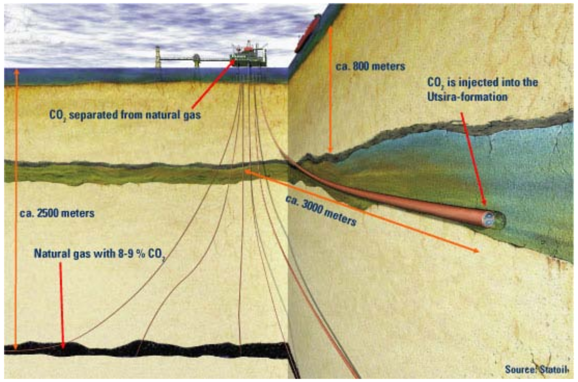
What kind of R&D do we need within CCS?

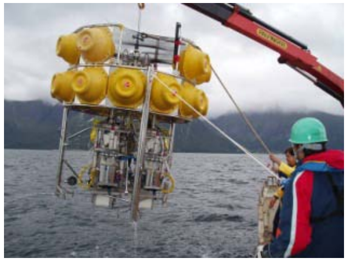
Storage as an other example

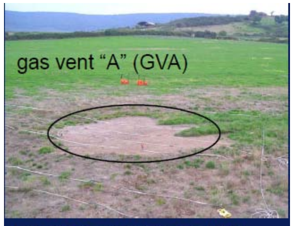


Panarea CO_2 leak (Italy)

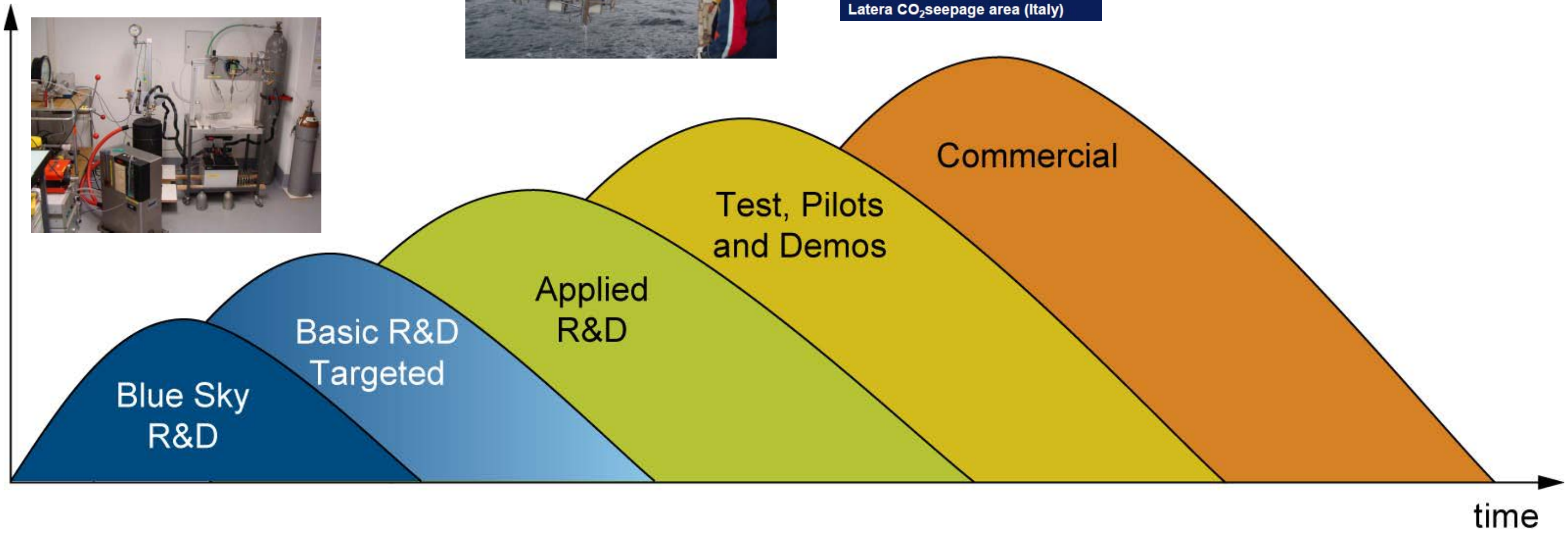
Sleipner







Latera CO_2seepage area (Italy)

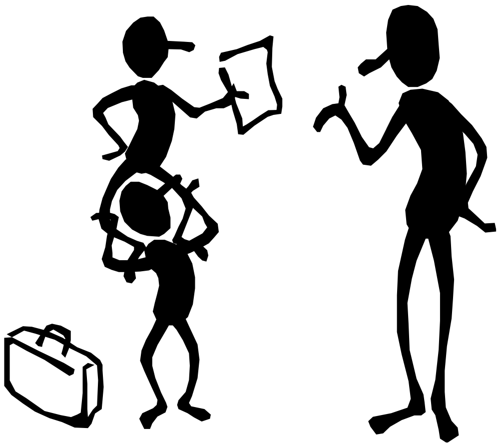


Pag. 532

Pag. 533

eccsel

Preparatory Phase Project



Pag. 534

The overall objective of the Preparatory Phase Project is to write the Business Plan for ECCSEL

Preparatory phase (2011-2013)

- **Governance and legal work**
  - Organization structure
  - IPR
  - RI access
- **Financial work**
  - Funding of new infrastructures
  - Funding of operational costs
- **Strategic work**
  - Gap analysis and plans for new investments
  - Third country collaboration
  - Socio-economic impact
- **Technical work**
  - Draft engineering plans

Business plan development

Implementation phase (~2014→)

- Establish ECCSEL partnership and legal basis, and an administrative office
- Early start with existing infrastructure
- Building of new infrastructure
- ECCSEL in full operation

Pag. 534
eccsel
European Strategy Forum on Research Infrastructures ESFRI

Pag. 535

ECCSEL Preparatory Phase Project

Strategic work
- Infrastructure needs and gap analysis
- Third country collaboration
- Socioeconomic impact

SP3

Financial work
- Funding mechanisms
- Financial commitments
- Access costs

SP2

Technical work
- Technology maturity studies
- Cost overview

SP4

Governance and legal work
- Organisation and decision making structure
- IPR
- Infrastructure access protocols
- Business plan development

SP1

Project managent and coordination
- Website and VRE development

SP0

ECCSEL PPP results
- ECCSEL business plan
- Coordinated infrastructure development plan
- Implementation scenarios
- Contract of Association for ECCSEL Consortium

Pag. 535

Countries participate in the Preparatory Phase Project

ECCSEL PPP Consortium

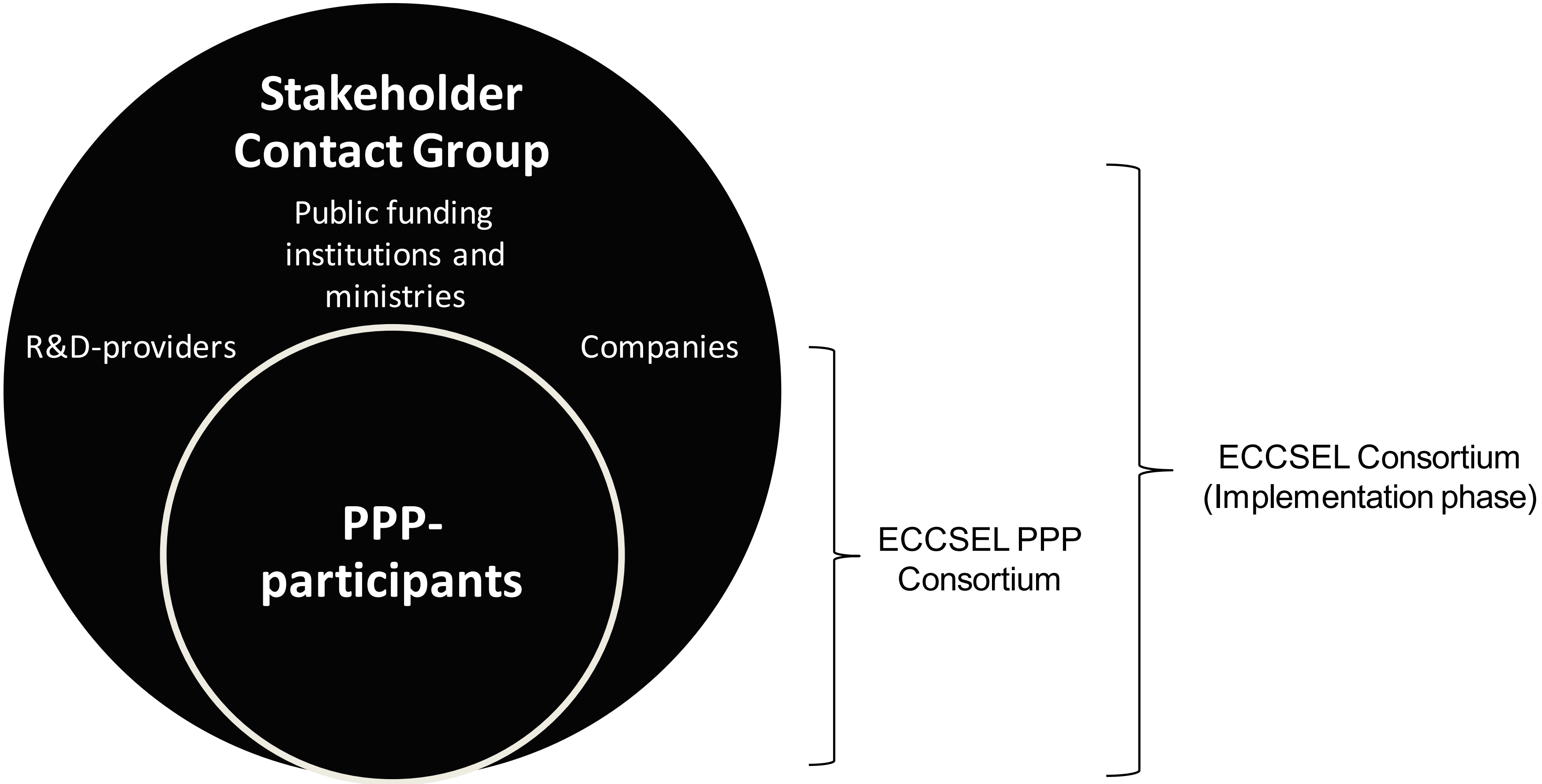
1. Norway (NTNU, SINTEF, RCN)
2. France (IFP & BRGM)
3. The Netherlands (TNO)
4. Germany (DLR)
5. United Kingdom (BGS)
6. Switzerland (ETHZ)
7. Spain (CIUDEN)
8. Italy (OGS, ENEA)
9. Greece (CERT/ISFTA)

eccsel

European Strategy Forum on Research Infrastructures ESFRI

Pag. 537

ECCSEL Stakeholders



Pag. 538

ECCSEL Stakeholder Contact Group (SCG)

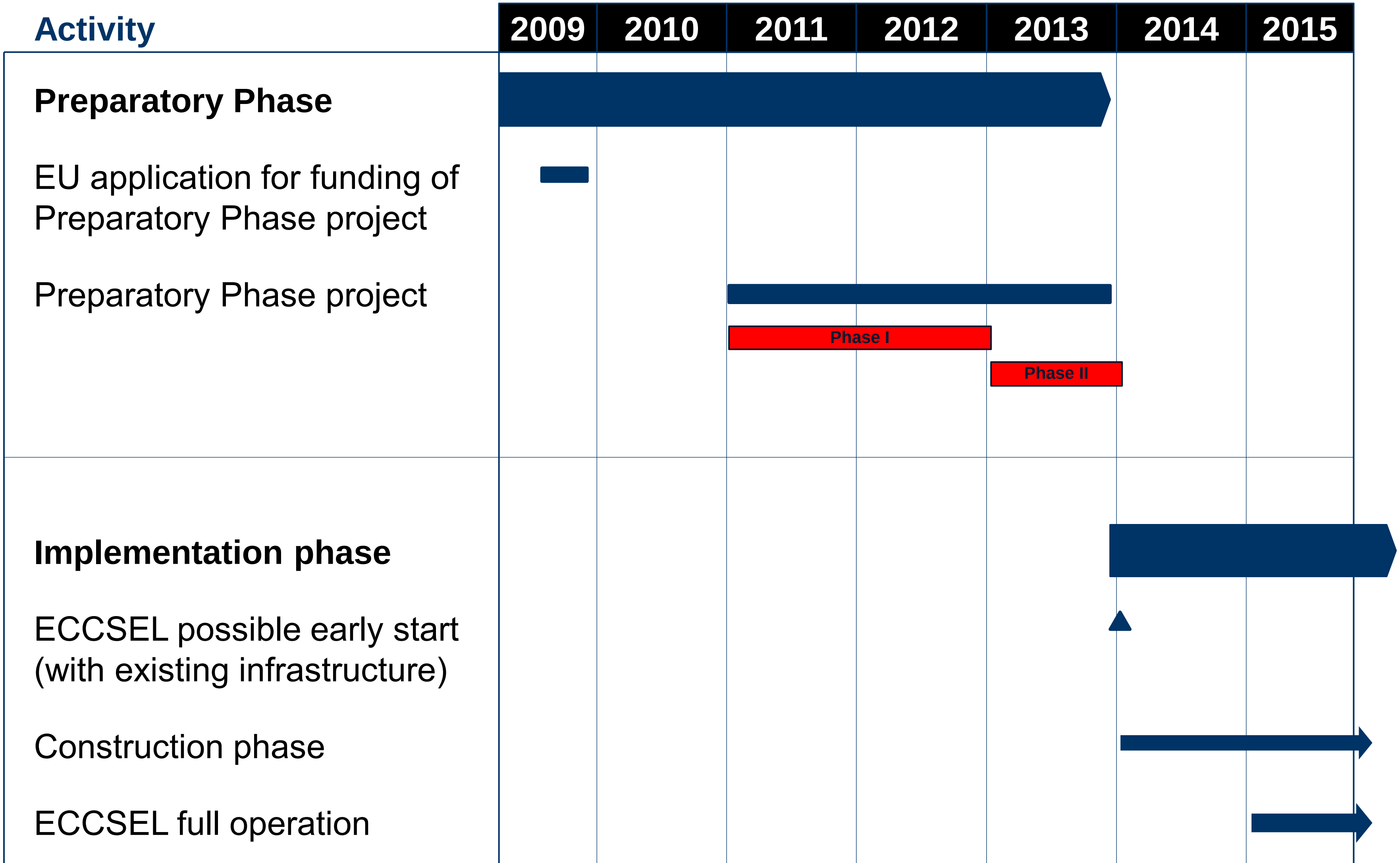
Name	Country
Technical University of Delft	The Netherlands
University of Stuttgart - Institute of Combustion and Power Plant Technology	Germany
Sapienza University of Rome - Fluid Geochemistry Group	Italy
Politecnico di Milano - Department of Energy Engineering	Italy
Geological Survey of Denmark and Greenland	Denmark
Eötvös Loránd Geophysical Institute of Hungary	Hungary
Polish Academy of Sciences	Poland
University of Zagreb – Faculty of Mining, Geology and Petroleum Engineering	Croatia
Middle East Technical University - Petroleum Research Center	Turkey
The University Centre in Svalbard	Norway
Risavika Gas Centre	Norway
Institute for Energy Technology	Norway
Enel	Italy
Air Liquide CRCD	France
Statoil	Norway

Pag. 538

European Strategy Forum on Research Infrastructures ESFRI

Pag. 539

ECCSEL Revised time line



Pag. 539

Pag. 540

Funding of ECCSEL

- **Funding of Preparatory Phase Project**
  - FP7-Capacity + some national co-funding
- **Funding of upgrading and new RI**
  - National funding
  - European Investment Bank
  - European Structural funds

- **Funding of operation and access cost**
  - FP7 Cooperation - R&D projects
  - FP7 People - Marie Curie actions
  - FP7 Capacity – Integrating Activities (I3)
  - Industry sponsors

ECCSEL aims to be the Research Infrastructure for ongoing and future CCS R&D projects in Europe

eccsel

Pag. 540
Pag. 540

European Strategy Forum on Research Infrastructures ESFRI

Funding of new infrastructure is applied for on a national level and distributed within the ECCSEL RI

Pag. 541

Traditional ESFRI investment

- **Single location investment:** Partners contribute to funding of single-site laboratory

ECCSEL investment

- **Multiple locations investment:** Partners contribute to funding of multiple-site RI
  - Partners apply for national funding
  - Funding is split based on decision made within the ECCSEL RI

 Pag. 542

Thank you for your attention!

 Pag. 542

European Strategy Forum on Research Infrastructures

 Pag. 543

SEVENTH FRAMEWORK PROGRAMME
FP7–INFRASTRUCTURES–2012-1
Preparatory Phases

Proposal Part B

Proposal full title:	**European Carbon Dioxide Capture and Storage Laboratory Infrastructure - Preparatory Phase 2**
Proposal acronym:	PP2
Type of funding scheme:	Combination of Collaborative Projects and Coordination and Support Actions for Preparatory Phases
Work programme topics addressed:	**INFRA-2012-2.2.3:** ECCSEL (European Carbon Dioxide and Storage Laboratory)

Coordinator name	Prof. Dr Olav Bolland
Coordinator organisation name	Norwegian University of Science and Technology
Coordinator email	olav.bolland@ntnu.no
Coordinator phone	+47 73 59 16 04
Coordinator mobile	+47 918 97 209

 Pag. 543

List of participants

No.	Participant organisation name	Short Name	Country	Date enter project	Date exit project
1 (Coord)	Norges teknisk-naturvitenskaplige universitet	NTNU	Norway	1	24
2	SINTEF Energi AS	SINTEF ER	Norway	1	24
3	Stiftelsen SINTEF	SINTEF	Norway	1	24
4	Panstwowy Instytut Geologiczny – Panstwowy Instytut Badawczy	PGI-NRI	Poland	1	24
5	IFP Energies nouvelles	IFPEN	France	1	24
6	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek – TNO	TNO	Netherlands	1	24
7	Deutsches Zentrum fuer Luft - und Raumfaht e.V.	DLR	Germany	1	24
8	Fundación Ciudad de la Energía	CIUDEN	Spain	1	24
9	Natural Environment Research Council	BGS	UK	1	24
10	Bureau de Recherches Geologiques et Minieres	BRGM	France	1	24
11	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale OGS	OGS	Italy	1	24
12	Centre for Research and Technology Hellas	CERTH/ISFTA	Greece	1	24
13	Eidgenössische Technische Hochschule Zürich	ETH Zurich	Switzerland	1	24
14	Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile	ENEA	Italy	1	24
15	Norges Forskningsråd	RCN	Norway	1	24

Abstract

This proposal constitutes the **second part** of the preparatory project ECCSEL, designated Preparatory Phase 2 (ECCSEL PP2, 2013-2014). It aims at forming a **new distributed research infrastructure** devoted to world-class experimental research pertaining to CCS. The project responds directly to the open call under **Work Programme 2012, CAPACITIES (Part I), FP7-INFRASTRUCTURES-2012-1, INFRA-2012-2.2.3: ECCSEL** (European Carbon Dioxide and Storage Laboratory), **Call N^{o} 10, Construction of new infrastructures (or major upgrades) – preparatory phase**.

The project will **bring the new research infrastructure up to the level of legal and financial maturity required for its implementation**.

Pursuant to this endeavour, a **consortium** has been established to provide the techno-economic, legal and commercial framework required to shift from planning to operation of the pan-European Carbon Dioxide Capture and Storage Laboratory, ECCSEL.

Based on the outcome of a preceding preparatory project (ECCSEL PP, 2011-2012), the consortium will address and settle remaining prerequisites associated with the organising and structuring of the new research infrastructure operating under a joint hallmark, ECCSEL.

The consortium will essentially divert efforts towards **management planning, governance, financing, legal issues, strategy and technical work** to **complete the preparatory phase**. This will be made in due accordance with the **project idea** and the **vision of ECCSEL**, as outlined in Sections 1.1 and 1.1.2, **pursuant to the objectives and targets** of this proposal, stated in Section 1.1.3.

Emphasis will be placed on

- outlining and **preparing the commercial setting of ECCSEL** (to be established in 2015) – resulting in the format of a **prospectus** (the ECCSEL Business Plan)
- **implementation planning** of the research infrastructure – as required to form ECCSEL
- **knowledge and innovation management** in science and technology pertaining to
    - the **systemic handling** of distributed research laboratory facilities
    - **improvement** of the research infrastructure and its related services
    - **second (and third) generation technologies** – aiming especially to reduce the energy penalty, lowering the cost of electricity (or yields) and cutting the lead time for CCS.

The consortium, made up by world-leading research and demonstration providers within the field of carbon dioxide capture and storage (CCS), offers an extensive collection of **profound knowledge and experience within CCS**-related research. This implies that the project – and its succeeding operational phase – will be supported by solid institutions that jointly possess (and offer) a **unique expertise along the entire CCS chain** with regard to science and technology.

Some partners have extensive **experience in running large European projects** relating to research and demonstration.

On the notion 'infrastructure'

The term *infrastructure* is generally defined as **the set of interconnected structural elements that provide the framework supporting an entire structure** of development.

Hence, for the interpretation of this proposal the word *infrastructure* applies to the level of ECCSEL – forming the entire structure, under which numerous substructures exist and interact.

In accordance with the Work Programme, these substructures are generally made up by – and referred to as – ***facilities, resources, systems and related services that are used by research communities to conduct top-level research*** *in their respective fields.*

These substructures cover: ***major scientific equipment or set of instruments; knowledge-based resources*** *such as collections, archives or structured scientific information; ICT-based e-Infrastructures (networks, computing resources, software and data repositories) for research and education; any other entity of a unique nature essential to achieve or enable excellence in research.* In the case of ECCSEL the research infrastructure will be 'distributed' (a network of resources).

How evaluation criteria are addressed

In order to fully understand the call and its underlying priorities, the evaluation criteria for *Construction – preparatory and implementation phases*, as stated in the Work Programme, have been used for guidance.

Hence, emphasis is placed on i) the **scientific and technological excellence** of the project, ii) the **quality and efficiency of implementation and management**, and iii) **expected impacts** of the project.

This has, firstly, had an **impact on the selection of the consortium members**, secondly, on **the structuring of the project** with regard to responsibility, governance and management, thirdly, on the **consented vision** of ECCSEL **along with stated objective and targets**, the **formation of ECCSEL**, and last, but not least, on the **content and deliverables of the work packages**.

More specifically, the proposal responds to the **evaluation criteria** in various sections as indicated in the following table:

Criterion (as in Work Programme)	Addressed in section	Commentary
1. Scientific and/or technological excellence (relevant to the topic addressed by the call		
Clarity and appropriateness to reach the fundamental objective of offering a world-level service in response to needs of users from the research community	1.1.2, 1.1.3, 1.1.5, 1.1.6, 1.1.7 Figure 7	The objective responds to the Work Programme, the call, and a consented vision of ECCSEL. Stated targets are linked with the objective and the work plan. Targets are clear-cut in terms of specificity, relevance, measurability, achievability – and they all relate to the project period and the planned funding resources. A timeline suggests the development of ECCSEL over two operational phases (initial and advanced). Budget and responsibility of work packages and tasks are allocated to partner institutions.
Contribution to scientific European excellence and to the coordination of high quality research in Europe	Abstract, Rationale, 1.1, 3.1, 3.2, 3.3	The project aims at scientific European excellence. In this pursuit proper coordination is essential in order to obtain high quality research. ECCSEL shall set up and offer transnational access to its research infrastructure to partners and third parties, and help researchers access the best facilities. The same applies to related services. Emphasis is placed on 2nd and 3rd generation CCS technologies, including environmental issues, derisking, consideration of socioeconomic aspects and acceptance. The consortium reflects the European dimension reasonably well with regard to European CCS research laboratory infrastructure and networking capacity. ECCSEL will further engage with institutions outside Europe (i.e. Australia, China, USA) as appropriate – mainly for synergistic reasons.
Quality and effectiveness of the coordination mechanisms, and associated work plan, for the construction of the proposed infrastructure	1.2.1, 1.1.1, 1.1.5	Quality and effective coordination is ensured via the overall strategy of the associated work plan, and by the proficiency of the consortium. These elements – combined with the stated objective and a clear-cut subset of targets and selection criteria – provide the critical components to ensure quality and effectiveness of the execution and coordination of the project to achieve its targets. Prior work in ECCSEL PP1 (2011-2012) on the legal and governance structure, and on current and future needs for experimental research facilities relating to CCS, will – along with a finance strategy – clarify and strengthen the work plan. This will ensure proper coordination of PP2 (2013-2014) and the later construction, implementation and operation of the proposed infrastructure, ECCSEL.
2. Quality and efficiency of the implementation and the management		
Appropriateness of the proposed management structure, procedures and implementation plan to achieve the objectives of the project.	2.1 Cf. also 1.1.1 1.1.2 1.1.3 1.1.4 1.1.5 1.1.7	The proposed management structure with the required support functions complies with the way that several large CCS-based IPs under EC-FP6 and FP7 have been organised successfully. The structure and operating procedures leave no doubt about responsibility, decision rules and sanctions within the consortium (project). The progress plan is based on the work package structure and

		set out along the timeline of the project that is subordinated to the objective and targets proposed. In this way the management structure is deemed appropriate to achieve the objectives of the project.
Quality of partnership: the extent to which the proposal demonstrates the relevant commitment and experience of participants, and brings together all relevant parties that need to work together in order to realise the proposed infrastructure, as specified by the topic	Abstract, 2.3, 2.2	The quality of partnership is envisaged by the fact that the consortium is made up by partners in the forefront of CCS research. They operate (or plan to operate) world-class experimental facilities within the field of CCS. The operators of the research facilities possess profound knowledge and expertise which will be offered to users of ECCSEL as part of the services to be extended.
Appropriate allocation and justification of the resources to be committed (staff, equipment…), by task and participant, having due regard to the whole project life-cycle	1.3, 2.1, 2.1.1	The planned, committed resources are allocated and justified by the extensive work to be conducted by the project. Partners are committed to provide the resources and capabilities required to fulfil the duties and obligations. The overall management will be provided by the Project Coordinator with the required (lean) staff. One responsible partner will be allocated to each work package and likewise for underlying task leadership. The leaders will be selected on the basis of their merits. The work packages and tasks will be carried out according to the WP descriptions and rules set out in the Consortium Agreement.
3. Impact		
Contribution to the expected impacts listed in the Work Programme under the relevant topic.	3 In particular 3.1 Also on innovation in 1.1.8 and WP4	The project contributes significantly to the expected impact. As required by the Work Programme, ECCSEL PP2 responds to the periodic updates of the ESFRI roadmap to reach the level of technical, legal and financial maturity required to enable the construction work to start. Thereby ECCSEL will contribute to the technological development capacity and to the scientific performance and attractiveness of the European research area. ECCSEL also contributes to the *Innovation Union* commitment to complete or launch by 2015 the construction of 60% of the priority European research infrastructures currently identified by ESFRI, and to increase the potential for innovation to be carried out in research infrastructures. Furthermore, the project will have impacts on education, stakeholders, socio-economy, EU policy, and on the prevalent issues of *climate change* and *security of energy supply* etc.
Contribution to the realisation of the infrastructure (for example, the proposal directly addresses those critical questions that urgently need to be resolved in order to reach a European / international agreement on the joint implementation of the infrastructure).	1.1.2, 1.1.3, 1.1.6, 1.1.7, 1.2.1	The project contributes to the realisation of the infrastructure in various ways: ECCSEL PP2 (along with ECCSEL PP) aims at clarifying and completing all critical issues – especially the legal and governance framework – necessary to implement the operational phase of ECCSEL. ECCSEL PP2 will further aggregate strategies into a business plan, and establish the ECCSEL Operations Centre to initiate operations under the hallmark of ECCSEL in 2015. The project will also solicit initiatives under Integrating Activities, and engage – as appropriate – with industries and candidate collaboration schemes in third countries (i.e. Australia, China and USA).
Contribution of the proposed infrastructure to technological development capacity, the attractiveness of the ERA and the Community objective of balanced territorial development, taking into account the potential of the convergence regions as well as the outermost regions; contribution to the reinforcement of research-based clusters of excellence around such new infrastructure(s) and contribution to socio-economic impacts.	Rationale, 1.1.5, 3.2	The project will contribute significantly to technological development capacity, and to the attractiveness of the ERA: According to the stated targets, planning of the operational phase will be made in due consideration of a subset of priorities that apply directly to the demand for improving the efficacy of the CCS chain, lowering its levelised cost, and cutting the lead time for CCS (as required by 2nd and 3rd generation CCS technology). These priorities are relevant not only to Europe, but to the whole world. As stated in the Rationale, the relevance and importance have been further emphasised to indicate the urgency for technological development capacity. The contribution of

		ECCSEL to technological development will have a significant impact in the future. This also underpins the attractiveness of the ERA and the Community objective of balanced development – especially with regard to the harmonising of CCS regulation with the industrialised world and developing countries (esp. China).
Added Value of the Community financial support: the extent to which the proposal demonstrates a catalytic and leveraging effect of the EC involvement and the inability of existing mechanisms at national level to achieve the objective.	1.1.2, 1.1.7, 3.3	The project will pave the ground for creating values and repay the Community for its financial support (most probably at a high gearing). Moving the frontier in technology from the state-of-the-art is far beyond the capacity of a single nation. Therefore, the project suggests the construction of a new CCS research infrastructure – with substantial multi-national funding – to make advanced research facilities accessible to researchers across nations. In this way the project will demonstrate a catalytic and leveraging effect of the EC involvement and the inability of existing mechanisms at national level (per se) to achieve the objective. ECCSEL aims at offering open access to its research facilities and their related services to institutions (scientists, researchers and industries) in need of such access and services. It seems obvious that the pooling of experimental facilities and knowledge via improved usage will add value to the Community by cost improvements and enhanced usage. Combined with the vast experience of the consortium, this may also be used to create additional value to the stakeholders in various ways – via industrial projects and new jobs. It is also regarded an important issue to provide cost-efficient CCS techniques with lower energy penalty, which will help accelerating CCS towards a transition to large-scale deployment in Europe and other significant nations.

Reading the proposal

The proposal is structured according to the guidelines. **Bold letters** are used to highlight essential parts of the text. By reading the words in bold **a fairly high understanding** may be reached.

Table of Contents

Pag. 550

Pag. 550

Rationale

The partners are of the opinion that the **demand for CCS research in Europe will increase to the extent that it cannot be met by today's research laboratories and organisations** alone. This demand stems from the urgent and growing need for clean energy and the crucial role for CCS in meeting this need in due time and at a reasonable cost for society.

As CCS remains in the **pre-commercial phase** (point A in Figure 1)**,** time is a limiting factor. History suggests that at least three decades are needed from the time when a successful energy technology becomes available (when delivering 1000 TJpa) until it is material (when reaching 1% of the global energy mix) [1].

In contrast, to meet the 450 ppm scenario of the IEA[2], **CCS must be developed and deployed within just one decade** (cf. CCS trajectory in Figure 2). This represents an unprecedented challenge that calls for the highest political leverage to **mobilise the required capacities and financial resources**[3].

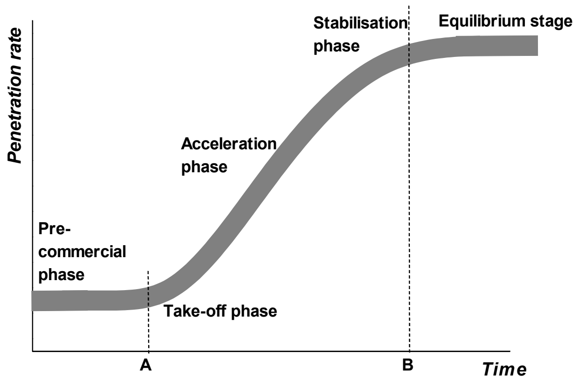


Figure 1: Phases of technology adoption from idea to commercial operation

Figure 2: Timeline for broaching new energy technology into society

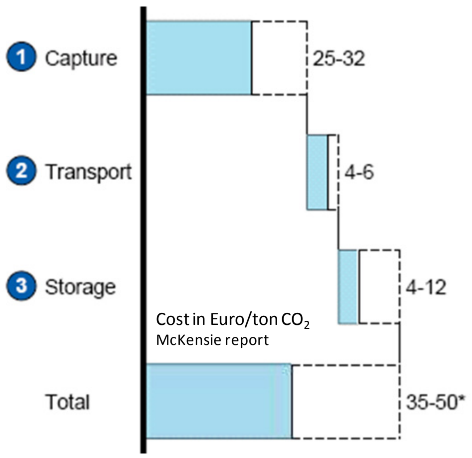


Figure 3: Cost structure of CCS chain. McKenzie report

One immediate **drawback of CCS is the high penalty on energy and cost**. Another issue is **liability**, as **CO_2 must be kept trapped for several thousand years** to obviate the climate change issue[4]. Whereas **CO_2 capture is by far the most costly and energy-intensive node** of the CCS chain (item 1, Figure 3), qualification of **storage sites appears to constitute the critical path** in terms of deployment of CCS on a large scale. This is a plight that calls for extended **coordinated research** across nations.

In this setting and beyond this preparatory phase project, the establishment of a future research infrastructure (designated **ECCSEL) represents a robust strategy** to build upon current research and the experience that will be gained through, for example, large scale CCS demonstration projects. These projects represent first generation CCS technology, and further **research is needed to**

- reduce the cost and energy penalty of CO_2 capture

[1] Kramer, G.J.; Haigh, M.: "No quick switch to low-carbon energy". Nature, Vol 462, 3 December 2009

[2] Blue Map, consistent with the 2°C target by 2050

[3] Hetland, J.: *Broaching CCS into Society. Timeline Considerations for Capture Technologies and the Challenge of Capacity Building*. TCCS-6, Trondheim, 15-16 June 2011. (Cf. proceedings http://www.sintef.no/tccs-6)

[4] Lindeberg, E.: *The quality of a CO_2 repository: What is the sufficient retention time of CO_2 stored underground*, Proceedings of the 6th International Conference on Greenhouse Gas Control Technologies, Edited by J. Gale and Y. Kaya, Vol I, pp 255–266, 2003

Pag. 552

- ensure the safety of the CCS chain as projects grow in scale
- develop new second generation (and third generation) CCS technology.

The **scale of further research** will also have to increase if these benefits shall be realised in the required timeframe and at an industrial scale, as illustrated by the following statements:

- *expanded global collaboration on CCS research and development and technology transfer will be critical to achieve the BLUE Map emissions target*[5].
- *Global public energy R&D funding should double, to around $20 billion, for the development of a diverse portfolio of technologies*[6].

The **ECCSEL initiative has been in preparation since 2006** and was **posted on the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI) in 2008**. The goal is to have ECCSEL fully operational, as a distributed European research infrastructure, by **2015**.

[5] IEA CCS Roadmap, 2009

[6] Stern Report, 2006

Pag. 552

1 Scientific and/or technical quality, relevant to the topics addressed by the call

The scope of this project is limited to accomplishing the preparatory phase. Hence, the **scientific and technical quality of the project relates to the outlining, planning and stated objectives and targets leading up to ECCSEL** – to be formed as a joint European commercial undertaking devoted to CCS research (intentionally by 2015). This undertaking builds on a **vision of ECCSEL** as a distributed research infrastructure made up by a **distributed world-class European CCS research laboratory** under the joint **hallmark ECCSEL**.

Main elements of this vision are **based on the state-of-the-art in science and technology** combined with **future needs and opportunities** in a pan-European context.

ECCSEL will establish an appropriate **balance between commercial exploitation, societal needs, and urgency**. It will also create an **environment for researchers by offering access to the most advanced CCS research infrastructure** (anywhere in the world). In this context, swift and expedient validation of conceptual techniques is key in any action.

The **main challenge in developing second (and third) generation CCS technology** is to **cut lead time, cost and techno-economic risk**. Success requires that **all steps and actions are properly addressed, understood and made operational.**

1.1 Concept and objectives

1.1.1 Project idea – ECCSEL PP2

ECCSEL PP2 is a planned EU action **aimed at constructing a new CCS research infrastructure** having a **clear European dimension and added value** in terms of **performance and access**. New advanced CCS laboratories (pilots or test sites) shall be planned for later inclusion in ECCSEL – tentatively in 2015, or later.

This infrastructure is foreseen **to contribute significantly to the development of European research and innovation capacities**. Emphasis will be placed on **preparing the construction of critical new facilities** building upon work conducted by the European Strategy Forum on Research Infrastructures (**ESFRI**), and it will **help researchers to access the best facilities**. No distinction will be made between **power generation** and **industrial processes** in terms of the CCS techniques addressed.

A new approach to funding and operating CCS research laboratories is required to achieve future goals in a cost-effective manner. Three immediate challenges that need to be addressed in order to scale up CCS research in Europe are **cost**, **coordination** and **cross-fertilisation** of ideas.

Being the successor of the initial preparatory phase (ECCSEL PP, 2011-2012), this project (ECCSEL PP2, 2013-2014) will **divert efforts to assess the formal inputs as provided by ECCSEL PP**. It will **conduct work** as required **to conclude the preparatory phase**, consistent with the overall development plan of the ECCSEL initiative, as indicated in the timeline depicted in Figure 4.

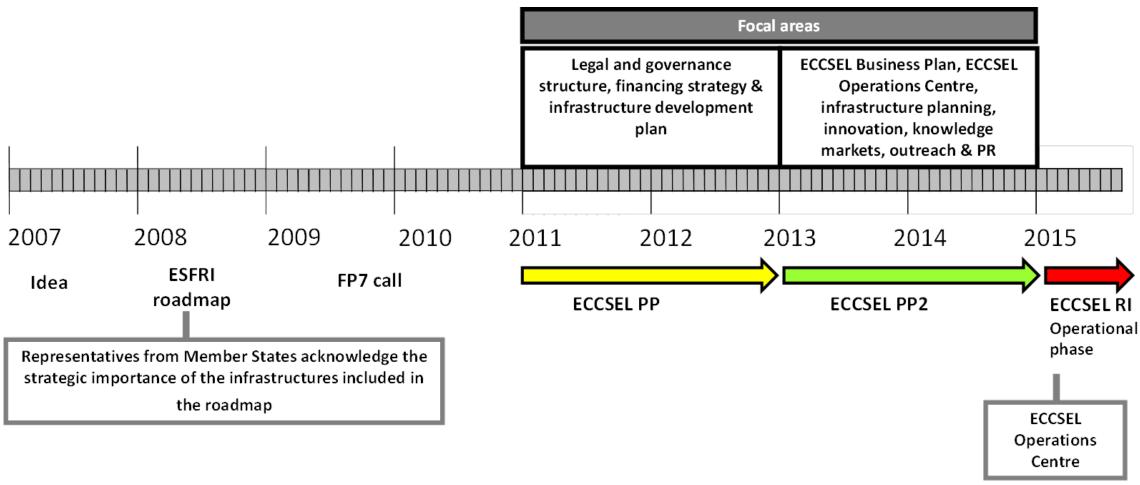


Figure 4: The overall time line of the ECCSEL initiative.

 Pag. 554

The **transition from ECCSEL PP to ECCSEL PP2** is further indicated in Figure 5 by relating work packages between the two projects. The connectors imply specific information and findings – such as recommendations, strategies and relevant input.

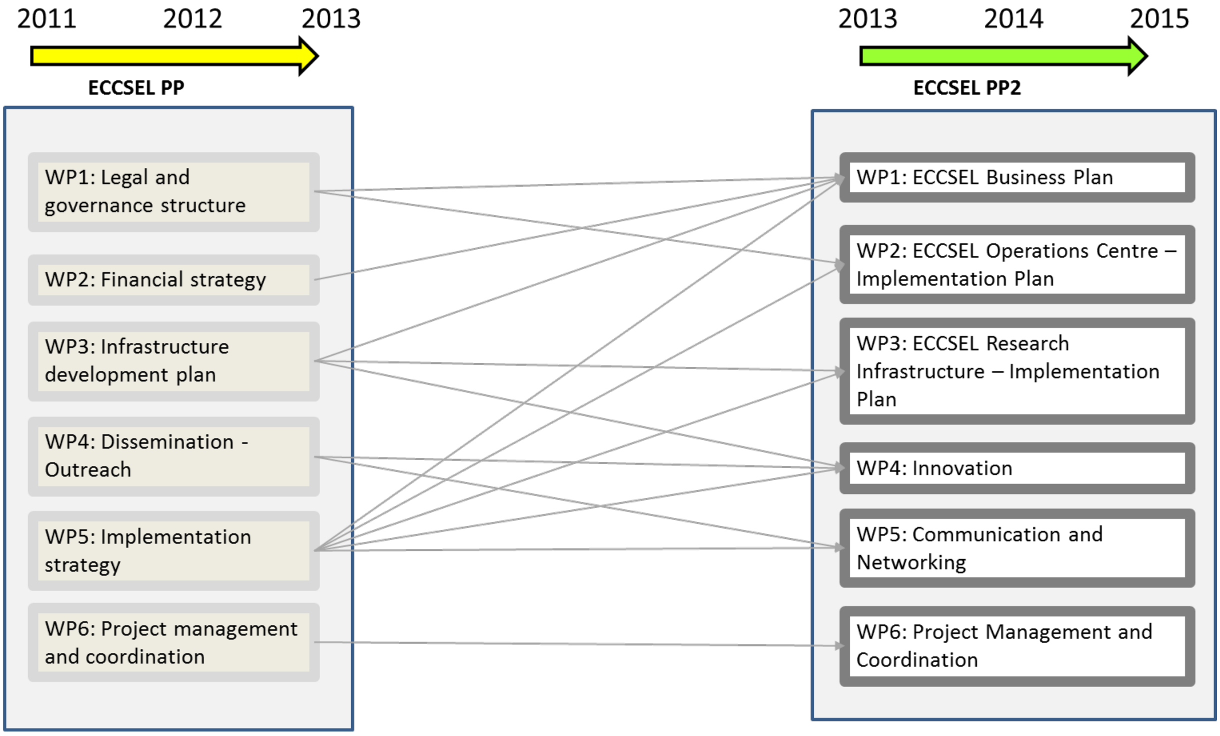


Figure 5: Work package content of ECCSEL PP and ECCSEL PP2 and the transfer of findings and recommendations from the former project to this project.

In this project (ECCSEL PP2), the **prerequisites for forming the ECCSEL research infrastructure and the ECCSEL Operations Centre will be defined.** Optional recommendations will be considered in terms of impact and viability. Alternatives will be reduced in a strategic converging process. The outcome is used to form a consented **ECCSEL Business Plan** and **an overarching governance structure.**

Whereas a significant component of the project is technical, efforts will be made to carry out **conceptual studies of the infrastructure aimed at meeting the growing needs,** and for the purpose of budgeting the required research facilities and installations.

As this step includes **geographic issues** to maintain **the pan-European dimension,** the consortium as a whole must be widely involved in this endeavour.

A relevant aspect is **shared ownership** across institutional, national and cultural borders, which is prone to give rise to **innovative thinking and contribution** via cultural disparities and experiences from multiple disciplines.

Furthermore, **innovative thinking shall apply** to the intrinsic functioning of the research infrastructure to ensure a highest practical **quality-over-cost ratio** for the experimental work.

Specific actions will be extended towards

- **political and institutional support** deemed necessary to make available the most relevant – and advanced – research facilities for extended use on a time-sharing basis.
- **financial and legal issues:** if/when brought up, such issues must be **settled prior to implementation** of ECCSEL (or parts thereof).
- **involvement by stakeholders:** considered mandatory in order to ensure the required progress. This also includes the **firm decision** and **financial commitment** prior to **construction of any new facility** (e.g. via national/regional ministries/governments, research councils, funding agencies).
- **involvement of operators** of research facilities, research centres, universities, and industries.

Intentionally, **the ECCSEL initiative** will be funded according to the following plan:

 Pag. 554

 Pag. 555

- Preparatory Phase (ECCSEL PP&PP2):
  - EC-FP7-Capacity
  - national co-funding
- Funding sources for upgrading and new laboratory facilities under ECCSEL (cf. Section 1.1.6):
  - national and multi-national funding
  - European structural funds
  - European Investment Bank
- Funding of operations of ECCSEL and access projects:
  - EC funding (new funding instruments) equivalent to the current EC-FP7 (Cooperation R&D projects),
  - EU funding sources (if available) like the current EC-FP7 People (Marie Curie), FP7 Capacity (Integrating Activities, I3).
  - Additional sources: industrial players and other public funding instruments.

Furthermore, the ambition is that **national infrastructural investments and the demand for research** will be **coordinated via ECCSEL**. In this way **ECCSEL will contribute to complementarity and efficacy** in European **research and innovation** devoted to CCS.

1.1.2 Vision of ECCSEL

Responding to the severe global issues of *climate change* and *security of energy supply*, ECCSEL shall build a **top-notch research infrastructure** devoted to **second generation** (and third generation) **CCS technology** in a swift and structured way. ECCSEL shall become the **hallmark of world-class experimental research pertaining to CO_2 capture and storage techniques** (CCS).

In recognition of the pronounced urgency of CCS and the growing demand for improvements along the **CCS chain,** ECCSEL will **release huge national and international investments to set u**p a new CCS research infrastructure offering access to **highly-advanced European research facilities** dedicated to the CCS chain. This will enable ECCSEL to operate a **pool of distributed European key laboratories** – structured as indicated in Figure 6.

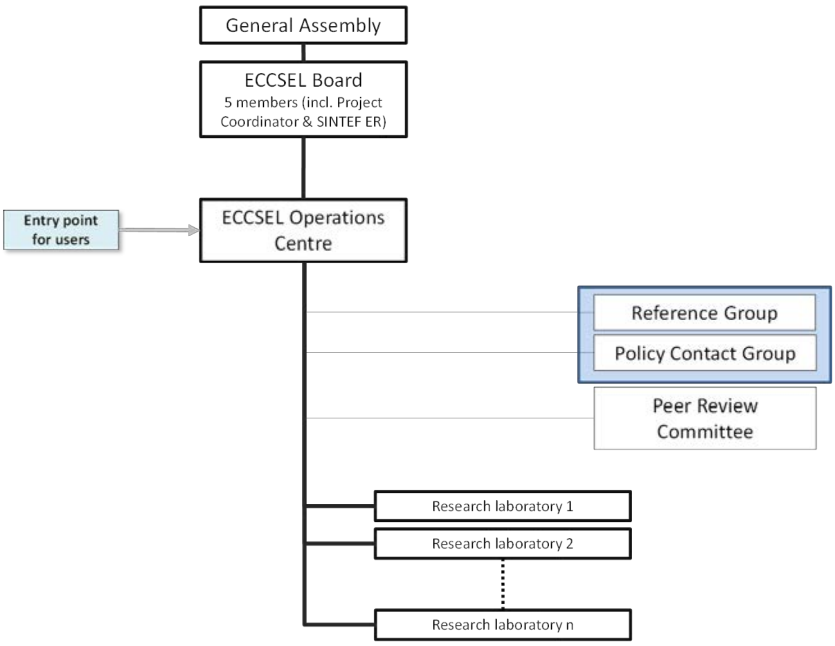


Figure 6: The structuring of ECCSEL

The **idea** is to

- establish a **world class CCS research infrastructure** in Europe
- integrate and **upgrade existing laboratory facilities and supplement with new advanced ones**
- **enhance European science**, technology development, innovation and education in the field of CCS.

In particular, ECCSEL intends to

 Pag. 555

- **build a most advanced CCS research infrastructure** comprising – from the outset – existing and upgraded research facilities. Later **new laboratories (pilots and test sites) shall be constructed to set new standards in science and technology** beyond the state-of-the-art.
- help researchers to **access** the best research facilities and draw upon the related services **on competitive terms and conditions**.
    - Priority shall be given to projects according to scientific **quality, relevance and topical approach**. This requires selection criteria and targets to be updated on a regular basis.
    - Emphasis will be placed on **experimental verification, validation and calibration** of emerging CCS techniques, concepts, theories, physiochemical phenomena, methods and specific computer codes. In this undertaking, **innovative schemes** will be applied to the CCS chain, including the valorisation from CO_2 at the tail-end (i.e. CCS and CCU). Important issues to address are how CCS relates to **environmental and socioeconomic aspects, and public acceptance**.
- carry out **joint research activities** subject to consolidated planning and coordination, to improve the services provided by ECCSEL in quality and/or quantity.
    - This will include **technological and experimental support** to institutes, industries and academics involved in specific emerging CCS techniques, concepts and related needs, with relevance mainly to the capture, transport and storage of CO_2.
- establish its CCS research infrastructure on the basis of dedicated **institutional and national laboratories** within the member states and associated countries.
    - In the **initial phase**, **ownership** of existing facilities and other tangible/intangible assets **will (in principle) remain with the host institutions**. In the **advanced phase**, shared **ownership will be gradually taken by ECCSEL**, especially for the new advanced laboratories to be constructed (cf. Figure 7).
    - Whereas the **operation of facilities** will be **decentralised**, a joint superstructure ismandated to coordinate the overall actions within ECCSEL. The authority of this superstructure will be vested in the **ECCSEL Operations Centre**, which will duly report to - and take directions from - the executive board.
- seek direct **involvement** by existing reference laboratories – possibly with major upgrades.
    - **New sophisticated laboratory facilities** will be planned, designed, built and operated, subject to **specific scientific needs and priorities**. In this pursuit, ECCSEL will form a venue for appropriate assessment of needs, specification and validation. As appropriate, events will be arranged using structured forecasting techniques (**collective intelligence**).
    - New schemes for the preparation, funding and shared ownership of such facilities will be applied, aiming (mainly) at **cutting lead time** and improving the **pace and quality of the scientific and technological results** of experimental research.
- extend actions towards **national key research laboratories** and **institutions outside of Europe** in order to create **synergy** by combining efforts on a) networking, b) access, and c) joint research on CCS-related topics.

This vision makes the basis for ECCSEL – in particular for the planning of the required research infrastructure and the implementation of the commercial operations (cf. WP3).

1.1.3 Objective

Subordinate to the vision (above) and consistent with the call, this project – ECCSEL PP2 – shall be structured and provided with the capacity and skills required to accomplish the primary objective stated below.

> ECCSEL PP2 shall complete the preparatory steps and define the prerequisites needed to **form ECCSEL as a new distributed pan-European research infrastructure devoted to scientific and technological aspects of the CCS chain in accordance with the vision of ECCSEL** (Section 1.1.2).
>
> Within two calendar years (2013 and 2014), **the new CCS research infrastructure shall be outlined and brought up to the level of legal and financial maturity required for its implementation**. Hence, the formal, legal, financial, functioning, and structural framework of ECCSEL shall be established, including the principles for management, logistics, planning,

> governance, financial and legal work (with the rules for IPR) required to **shift from the preparatory phase to operations** (in 2015).
>
> In this endeavour, emphasis shall be placed on **how to provide the necessary quality, capability and capacity** of research facilities and related services to give rise to breaking ideas via joint research actions and open access across nations. On this basis, **ECCSEL** aims at gaining **recognition** as a **world-class research infrastructure, made up by leading CCS research facilities**.
>
> The operational framework shall take into account the following items:
> - The research infrastructure shall **appear as one unity** under the **hallmark of ECCSEL.**
> - **Access** to the research infrastructure shall be offered to scientists, research teams and student to conduct **research** on pressing CCS topics **pursuant to a subset of criteria and peer review.**

The objective will be met **via proper planning, prioritising, good governance and networking**.

For the planning, **a subset of specific, achievable and measurable targets have been stated** in paragraph 1.1.5, to provide guidance for criteria for the selection and prioritisation of research topics to be pursued.

1.1.4 Secondary objectives (stated on work package level)

ECCSEL PP2 shall carry out duties, as set out in specific work packages outlined in paragraph 1.2.1, and as defined in the individual work package descriptions. The objectives of these work packages are listed in Table 1.

Table 1: Secondary objectives, as stated in the work package descriptions

WP#	*Work package name*	*Stated subordinated objectives*
1	ECCSEL Business Plan	• provide the prerequisites for establishing ECCSEL by 2015 • prepare a consented ECCSEL business plan for sustainable operations of the infrastructure • ensure that infrastructure needs of ECCSEL (provided by WP3) are harmonised with the committed funding resources and consented strategy • have the statutes of the legal entity for ECCSEL signed by the consortium members of ECCSEL (end of 2014) • provide a communication plan aimed at convincing funding agencies in member states and associated countries, regional funds as well as industries to invest in ECCSEL operations
2	ECCSEL Operations Centre – Implementation Plan	• finalise the prerequisites for establishing the ECCSEL Operations Centre and its underlying services by 2015 • accomplish specific parts of the ECCSEL Business Plan to accommodate the Operations Centre • ensure proper operations and services of ECCSEL by direct partner involvement
3	ECCSEL Research Infrastructure – Implementation Plan	• enable ECCSEL to form a world-class CCS research infrastructure • establish the inventory of ECCSEL – locate and describe existing infrastructure, determine and quantify the needs for upgrades and new laboratories • carry out conceptual studies for technical planning, structuring, and budgeting • accomplish the initial logistical planning of ECCSEL
4	Innovation	• increase the potential for innovation with regard to • increase the innovation impact of ECCSEL with regard to ○ research push ○ market pull • enable ECCSEL RI to deliver knowledge and innovation to market players (industry, NGOs, planning authorities)
5	Communication and Networking – seeking stakeholder engagement	• make efforts to engage in relevant knowledge markets • attract the interest from relevant institutions and industrial players seeking involvement in ECCSEL in actions devoted to integrating activities and joint research • provide appropriate communication strategies and communication planning • ensure science outreach and public awareness/understanding of the societal potential of CCS
6	Project Management and Coordination	• ensure effective performance and coordination of ECCSEL PP2

Pag. 558

1.1.5 Specific targets

A viable development plan for the **implementation of the CCS laboratories into one research infrastructure** shall be established with due regard to the tangible contribution and involvement by stakeholders and the outcome of the preceding work resulting from ECCSEL PP (2011-2012).

The planning will comprise a subset of **operational and managerial principles** - including decision making and rules for giving access to third parties to the research infrastructure (e.g. independent scientists, research groups and industrial players). The project will make necessary steps for **closing the financial gaps** and for concluding the necessary commitments and funding agreements.

Based on this work, ECCSEL PP2 will conduct strategic and technical work directed towards the most significant needs for advanced research laboratory facilities and their prioritisation.

The following targets shall apply:

- The **ECCSEL Business Plan** shall be accomplished and the statutes and specific agreements within ECCSEL shall be developed for partner commitment pertaining to laboratory facilities, as well as human and financial resources. Work also includes solicitation and negotiation of funding of ECCSEL operations and investments.
- **The ECCSEL Operations Centre** shall be planned to operate after the project period (i.e. 2015) – and be organised with an underlying structure of selected research facilities.
- the **ECCSEL research infrastructure** shall be planned for implementation of the most advanced CCS research laboratories. These laboratories shall be made up by existing facilities (CAT-1), major upgrades of existing facilities (CAT-2) and new unique laboratories, pilots and test sites (CAT-3).
  - o At the outset, the research infrastructure shall assemble - as a minimum – facilities covering the **three main capture routes** [7] intended for power generation – or equivalent for industrial processes – selected according to **appropriateness, quality and uniqueness**. Major upgrades and new laboratories shall be constructed, as required to **develop second and third generation CCS technology** and **emerging concepts** (including monitoring and storage).
- **Innovation** shall apply to the planning, structuring and systemic handling of ECCSEL as a research infrastructure characterised by widespread internal/external interactions.
  - o Emphasis shall be placed on improvements of the research infrastructure and the related services in order to **provide innovative advantage**.
  - o Innovation shall be planned in consideration of **CCS research challenges** such as **techniques** and their integration, and in **combining technologies** into systems likely to become **more efficient** and **less costly** than hitherto.
- **Three critical dimensions shall prevail** that are all deemed essential for CCS to reach the stage of large-scale transition, notably **lead time, energy penalty and cost**:
  - o in the planning phase, emphasis will be placed on **emerging concepts** (rather than conventional techniques) - especially those representing a reasonably high **potential for improvement** (i.e. efficiency/energy penalty, cost, and expected technological break-through – including HSE issues, and options for tail-end usage of the CO_2).
  - o preference will be given to processes relevant to the **European power sector** using **coal and natural gas**, and alternative CCS concepts related to **large point-sources in industry**.
- Selection of projects to enter the research infrastructure of ECCSEL shall be made according to either **scientific criteria and/or techno-economic potentiality including derisking of CCS technologies.** This mainly refers to the capability of justifying techniques or concepts that significantly
  - o contribute to **lowering the efficiency penalty to below 8%-points** including compression (in power generation, or equivalent level in industrial processing)
  - o limit the **cost of CO_2 avoided** to well below the current level of **50-60 €/ton CO_2** (or

[7] i.e. pre-combustion, oxy-combustion and post-combustion CO_2 capture, or equivalent for industrial processes.

Pag. 558

 Pag. 559

equivalent numbers when targeting industrial processes).
    - As the frontiers of CCS technologies are moved, the **targets will be sharpened** accordingly (cf. Figure 13 concerning 2nd generation and 3rd generation CCS technologies)
- Qualification of **storage sites**, pertaining mainly to pre-normative research and testing
    - This includes test facilities for monitoring, modelling and validation, verification and calibration of models, and field testing (seismic shooting, core drilling, well testing)
    - Derisking of geological storage addressing possible CO_2 leakage, risk management and remediation techniques (including HSE issues).

Priority shall be given in two main directions, notably i) the **academic dimension** (generic/fundamental research and education) and ii) **innovation** (applied research, operational issues, guidance to regulators) (cf. the knowledge triangle, Figure 12). Projects belonging to the latter direction shall be ranked according to their potentiality and capability for **reducing the overall energy penalty** and **lowering the levelised cost** of the CCS chain, and also for **ramping up the speed and capacity** needed for **CCS to become material** (Figure 2).

1.1.6 Forming the ECCSEL Research Infrastructure

As depicted in Figure 7, the ECCSEL research infrastructure will be developed in two phases: i) the initial phase, and ii) the advanced phase.

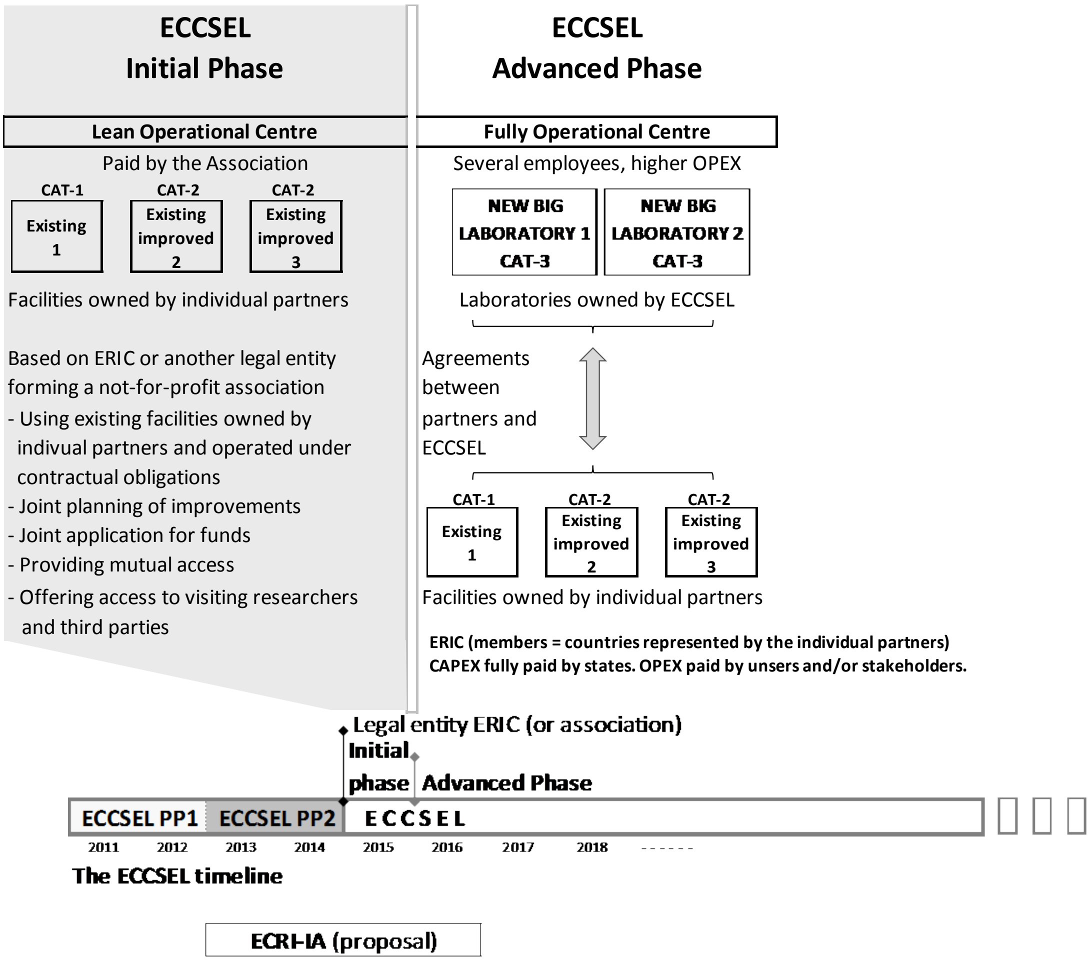


Figure 7: Two stages (i.e. initial phase and advanced phase) of development of ECCSEL to a fully integrated infrastructure using the European Research Infrastructure Consortium model (ERIC – or similar). A proposal under call identifier INFRA-02012-1.1.18 designated ECRI-IA will (if granted) overlap with ECCSEL PP2 and the operational phase of ECCSEL by two years. This will enable ECCSEL to draw upon experience – and vice versa – and it may lead to a swift and quick start of ECCSEL in 2015.

 Pag. 559

1.1.6.1 Initial phase

The ***initial phase*** will have a lean operational management structure, as required to operate the ECCSEL partnership during this rather critical starting phase. Although about one year is indicated on the timeline, efforts will be made to compress this phase to a practical minimum –to less than a year. Activities will mainly be based on **existing research facilities within partners' organisations**. Access will be offered to visiting researchers and third parties. The **legal basis will preferably be a European Research Infrastructure Consortium (ERIC)**. Alternatively, an extended consortium agreement may be used initially, in which access rights to dedicated facilities and the use of services are enacted, should the ERIC not be agreed on in due time.

It is foreseen that early **operations can be merged with a new project proposal designated ECRI-IA** (planned operational for the years 2013-2016 pursuant to call identifier *INFRA-02012-1.1.18 Carbon Capture and Storage (CCS) facilities for energy research*, in which the majority of ECCSEL partners take part). By joining efforts in this manner, the after-use of ECRI-IA will be ensured, whilst (if granted) ECCSEL will gain experience from the integrating activities of ECRI-IA. In this way **ECRI-IA can have an important role in quick-starting ECCSEL** (2015) by combining efforts throughout the initial phase and the early advanced phase (as indicated by the timeline in the lower part of Figure 7).

The initial phase will also be used to gradually develop the advanced phase. Partners will undertake i.a. a) **joint planning for improvements**, b) submit **joint applications for funding**, and c) **provide open access to visiting researchers**.

It is assumed that some existing research facilities will be in **need of major upgrading** to serve the growing **demands for advanced research**. But still the **operational centre will be kept lean**, and its operations will be funded mainly by the **revenues generated** by the activities of the legal entity.

1.1.6.2 Advanced phase

In the ***advanced phase***, the operations centre will grow in terms of staff and operational expenses. Main efforts will be vested in the planning, designing and building of **new big research laboratories and test sites** devoted – essentially – to capture techniques and storage-related issues (i.e. complex and advanced facilities). These operations will form the **core of ECCSEL**. Nevertheless, as indicated in Figure 7 a part of the initial portfolio of existing and upgraded facilities will be kept within the research infrastructure of ECCSEL, provided, however, that these facilities are required to **ensure the appropriate quality, relevance and complementarity of ECCSEL**.

1.1.6.3 The European Research Infrastructure Consortium model (ERIC)

In the event that the **ERIC model** is retained (based on the outcome of the preparatory phase, PP and PP2), the impact is that **members are countries** (represented by partners), whereby commitments will be anchored at state level. Hence, as agreed, **capital expenses** required for constructing and upgrading the ECCSEL research infrastructure **must be provided by the states** committed via the ERIC treaty, whereas the **operational expenses must be covered by users** and stakeholders.

1.1.7 ECCSEL Business Plan

According to the Work Programme,

> *project consortia should involve all the stakeholders necessary to make the project move forward, to take decision and to make financial commitments before construction can start (e.g. national/regional ministries/governments, research councils, funding agencies). Appropriate contacts with Ministries and decision makers should be continuously reinforced allowing further strengthening of the consortia. Operators of research facilities, research centres, universities, and industry may also be involved whenever appropriate.*

Hence, a **prospectus** designated to the ECCSEL Business Plan will be provided to **summarise the commercial, statutory, financial and operational basis for establishing ECCSEL in 2015**. The business plan shall state the scientific, technological and commercial **ambitions of ECCSEL**, and give reasons for why these ambitions are **believed attainable**, and it shall provide a **viable plan for how the ambitions will be reached**. The ECCSEL Business Plan shall include the relevant background information and describe the organisation behind ECCSEL and the team.

In principle, the ECCSEL Business Plan will be set up to **serve two distinct purposes,** one of these being **internal**; the other **external**. Whereas the former will address targets that are important to the partners (i.e. visionary, scientific and technological targets, investments, operational aspects pertaining to excellence and critical success factors), the latter will emphasise aspects that are important to external stakeholders, particularly authorities, funding agencies, financial stakeholders, industrial players, clients and users.

The **ECCSEL Business Plan** will be based on the following structure:

1. Preamble
2. Executive summary
3. List of content
4. Introduction/Vision and relevant background information
5. Commercial concept, objectives and targets
6. Changes in perception and branding the ECCSEL hallmark
7. Market and business environment analysis
8. Legal framework of ECCSEL
    a. Legal and governance structure
    b. Disclosure and IPR requirements
    c. Access rules
9. ECCSEL Operations Centre
    a. Formal structure
    b. Mandate, responsibilities, duties and sanctions
10. ECCSEL Research Infrastructure
    a. Inclusion of existing research facilities (2015)
    b. Major upgrades of existing research facilities (2015-2017)
    c. Planning and construction of new research facilities (2015-2025)
11. Financial plan
    a. Operating costs of ECCSEL Operations Centre
    b. Funding of upgraded and new research facilities (investments and CAPEX)
    c. Funding of operational costs of research facilities
    d. Funding of transnational access and joint research
12. Operational plan
    a. Research, education and innovation
    b. Project selection criteria
    c. Prioritising research projects and topics
    d. Future market needs
    e. Networking and communication
    f. International cooperation and integration by third parties
    g. Access, transnational access and joint research actions
    h. Quality assurance
    i. Health, safety and environment issues

1.1.8 Innovation

It is widely accepted in commercial circles that **competitive advantage is required** for any specialised enterprise **to succeed**. This requires continual innovation, meaning the creation of better and/or more efficient ideas, processes, technologies and products.

Innovation is seen as a substantial positive change rather than a modest incremental modification. Innovation targets may vary between **improvements of products, processes and services**, which challenges the myth that innovation deals mainly with new product development.

Usually, three factors are required to trigger innovation:

1) a (recognised) **specific need**
2) **competent people** with relevant technology

3) financial support

Specific needs are such as:

- improved quality
- reduced energy penalty (or reduced energy demand)
- reduced cost
- reduced lead time (e.g. to bring a new technology from laboratory to market)
- reduced environmental impact (e.g. lower greenhouse gas emission)
- improved production processes (cf. reduced energy penalty, and reduced cost, or HSE)
- less materials
- replacement of products/services
- extension of product and/or range
- creation of new markets
- conformance to regulations

Innovation may be initiated either by 1) **technology push**, or 2) **market pull**. Whereas the former is traditionally recognised as manufacturer innovation, the latter is often innovated by end-users in order to meet specific new needs. **End-user innovations are considered the most important** and critical. Hence, in order to drive innovation, systemic approaches are needed to assess the potential of these two directions aimed at identifying new, viable solutions.

Innovation can be achieved in several ways. Much attention is now given to formal research and development for "**breakthrough innovations**". Whereas the more **radical and revolutionary innovations tend to emerge from research and development**, the more incremental innovations are prone to emerge from practice.

Moreover, in order to run successful innovation processes, emphasis should be placed on five components:

1) **definition of targets**
2) **alignment of actions to targets**
3) **participation** in teams
4) **monitoring** of results
5) communication and access to **information**

1.2 S/T methodology and associated work plan

1.2.1 Overall strategy for the work plan

The overall strategy is to provide **the prerequisites for two operational outlets** of ECCSEL PP2: i) the **Research Infrastructure** comprising European laboratory facilities, and ii) the **Operations Centre**, whereof the latter will form the overarching superstructure and the coordinating body of ECCSEL. Hence, the work will be summarised in a working document, taking into consideration the structure, mandate and commercial aspects of these outlets, to be presented as a prospectus (ECCSEL Business Plan, cf. Section 1.1.7).

The consortium believes that there are **five complementary areas to emphasise and complete** – in addition to management and coordination (WP6). These areas are addressed in specific work packages (WP1-5), which require different approaches – as indicated in more detail in Figure 8.

WP1 ECCSEL Business Plan: The prerequisites of ECCSEL will be accomplished and summarised in the ECCSEL Business Plan. The business plan will constitute a prospectus having two distinct purposes: One internal, addressing issues of importance to the partners, the other purpose is external, addressing topics of relevance to stakeholders, particularly funding agencies, investors, industrial players, clients and users. As this work package covers – in a conclusive manner – all aspects of legal, financial, strategic, commercial and techno-economic relevance, it is considered the main deliverable of the project.

WP2 ECCSEL Operations Centre – Implementation Plan: The ECCSEL Operations Centre with its underlying services shall be duly planned for swift start-up forming the core hub of ECCSEL in 2015. The geographical location of the ECCSEL Operations Centre is yet to be decided.

Pag. 563

WP3 ECCSEL Research Infrastructure – Implementation Plan: Proper planning will be made to meet the timeline for establishing the research infrastructure under the hallmark of ECCSEL in 2015. This will be based on the vision articulated in paragraph 1.1.2 *Vision of ECCSEL*.

WP4 Innovation: The purpose is to increase the potential for innovation mainly in three directions, notably to improve: 1) laboratory functions, 2) communication, 3) technology issues.

WP5 Communication and Networking – seeking Stakeholder Engagement: This work package shall provide appropriate communication strategies and communication plans for networking, solicitation and negotiations, and for branding the ECCSEL hallmark.

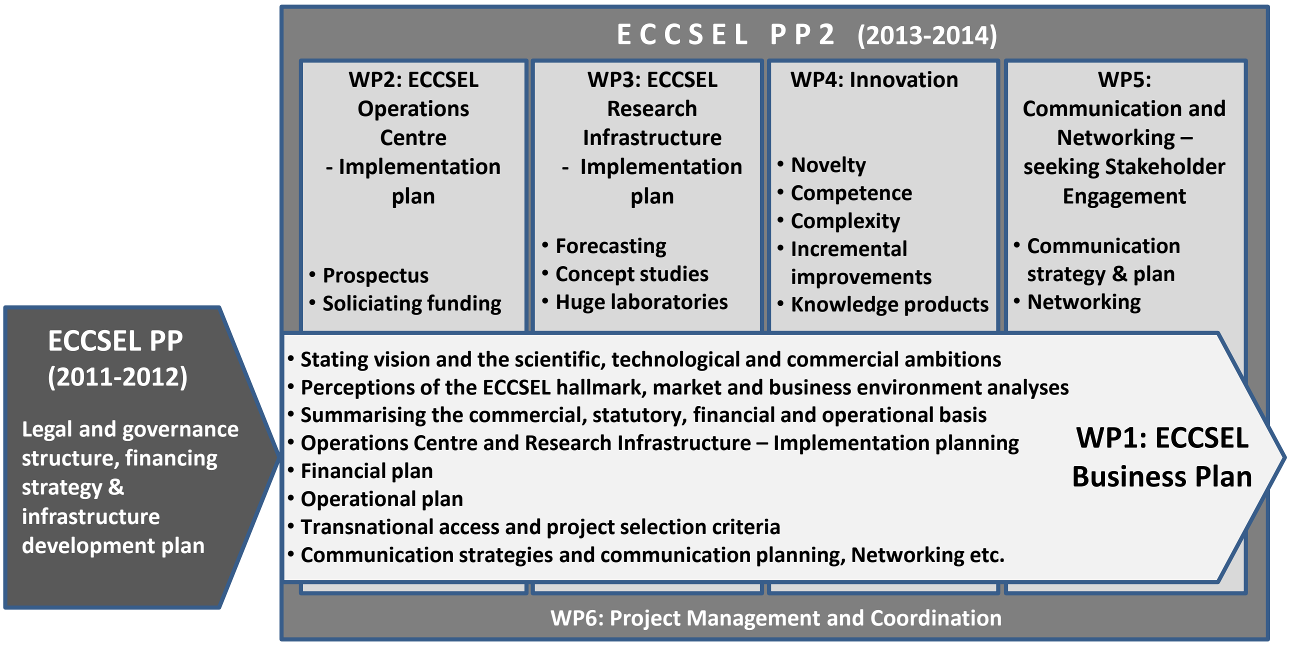
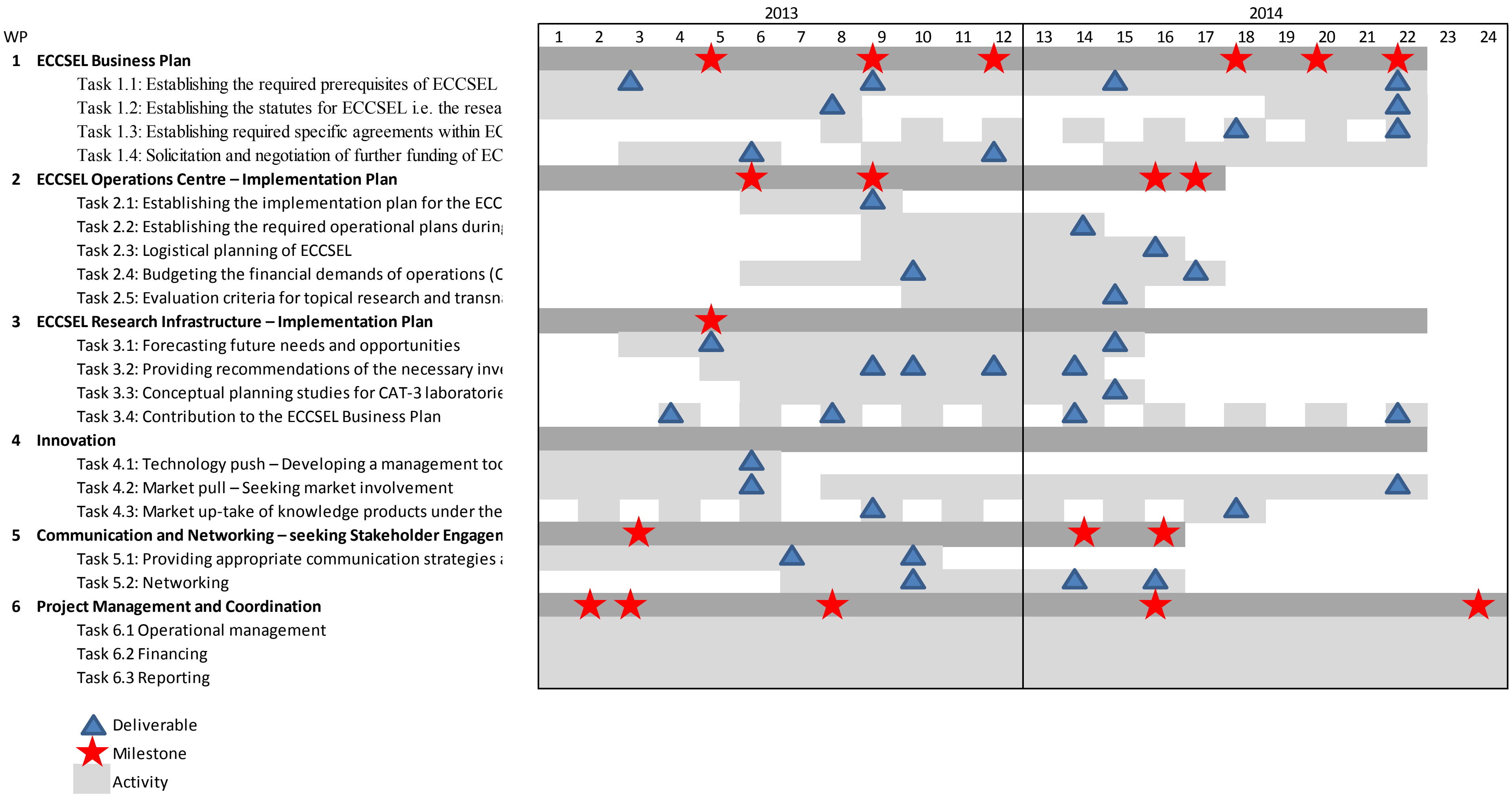


Figure 8: Work breakdown structure of ECCSEL PP2. The strategy of the work plan is envisaged: to provide the prerequisites for forming ECCSEL by 2015, building on results and recommendations from ECCSEL PP (2011-2012). The project will have two main outlets: the ECCSEL Operations Centre and the ECCSEL research infrastructure (implemented by 2015).

Pag. 563

Pag. 564

1.2.2 Timing of work packages and their components (Gantt chart)



Pag. 564

Pag. 565

1.3 Table 1.3 a: Work package list

Work package No	Work package title	Type of activity	Lead participant No	Lead participant short name	Person-months	Start month	End month	Indicative Total costs	Indicative requested EC contribution
1	ECCSEL Business Plan	SUPP	3	SINTEF	42	M1	M24	837 973	554 678
2	ECCSEL Operations Centre – Implementation Plan	SUPP	11	OGS	33	M1	M24	464 467	300 723
3	ECCSEL Research Infrastructure – Implementation Plan	SUPP	5	IFPEN	85	M1	M24	1 248 768	949 233
4	Innovation	SUPP	6	TNO	24	M1	M24	462 282	293 236
5	Communication and Networking – seeking Stakeholder Engagement	SUPP	8	CIUDEN	23	M1	M24	350 634	232 135
6	Project Management and Coordination	MGT	1	NTNU	10	M1	M24	166 400	166 400
				TOTAL	217			3 530 524	2 496 404

Pag. 565

 Pag. 566

1.3.1 Table 1.3 b1: Deliverables List

Del. no.	Deliverable name	WP no.	Nature	Dissemination level	Delivery date (month)
D1.1.1	Outline description of ECCSEL Business Plan	1	R	PU	3
D1.1.2	ECCSEL Business Plan – Draft version 00	1	R	RE	9
D1.1.3	ECCSEL Business Plan – Version 1	1	R	RE	15
D1.1.4	ECCSEL Business Plan – Final	1	R	PU	22
D1.2.1	Draft statutes of the legal entity for ECCSEL	1	R	PU	8
D1.2.2	Final statutes signed	1	R	PU	20
D1.3.1	Binding access rules delivered	1	R	PU	18
D1.3.2	Binding agreements partner commitments	1	R	PU	20
D1.4.1	Solicitation plan – Draft	1	R	RE	6
D1.4.2	Negotiation schemes with required analyses	1	R	RE	12
D1.4.3	Summary of negotiations with funding bodies	1	R	PU	22
D2.1.1	Implementation plan for ECCSEL OC	2	R	PU	6
D2.2.1	Operational plans during implementation and the first five years of operation	2	R	PU	9
D2.3.1	Logistical plans for ECCSEL OC, with dry-runs	2	R	PU	14
D2.4.1	Financial plan, for OPEX costs, and funding schemes	2	R	RE	16
D2.4.2	Contribution to Business Plan (Chapter 9)	2	R	PU	10
D2.4.3	Contribution to Business Plan (Chapter 10)	2	R	PU	17
D2.5.1	Evaluation criteria for topical research and transnational access projects	2	R	PU	20
D3.1.1	Forecast – future needs	3	R	RE	5
D3.1.2	ECCSEL Research Infrastructure - Implementation Plan	3	R	RE	15
D3.2.1	Inventory of ECCSEL (CAT-1, CAT-2 and CAT-3)	3	R	PU	9
D3.2.2	Template(s) of Fact sheet(s) for CAT-1 description	3	R	PU	14

 Pag. 566

Pag. 567

D3.2.3	Fact sheets for CAT-1 facilities	3	R	PU	10
D3.2.4	Upgrading plans for CAT-2 facilities	3	R	PU	12
D3.3.1	Conceptual studies for CAT-3 facilities	3	R	PU	15
D3.4.1	Contribution to Business Plan (Draft/Version 1/Final)	3	R	PU	8/14/20
D4.1.1	ECCSEL knowledge management tool	4	R	PU	6
D4.2.1	Innovation score card	4	R	PU	6
D4.2.2	Market pull inventory	4	R	PU	8/ 22
D4.3.1	Report on knowledge products under the hallmark of ECCSEL (Draft/Final)	4	R	PU	9/18
D5.1.1	ECCSEL Communication Strategy for Fund-raising (Draft/Version 1)	5	R	PU	7/10
D5.1.2	ECCSEL Communication Plans for Soliciting and Negotiating Commitments – and branding the hallmark of ECCSEL (Draft/Version 1)	5	R	PU	10/16
D5.2.1	Pan-European Outreach plan	5	R	PU	14
D5.2.2	Communication targeting Synergy in collaboration with China, USA and Australia	5	R	PU	16
D6.1.1	Project master plan including full transparency of resources, schedule and cost/performance	6	R	PU	3
D6.2.1	Mid-term report to the European Commission (Month 12)	6	R	PU	12+60 days
D6.3.1	Final report to the European Commission	6	R	PU	24+60 days
D6.4.1	Public executive summary	6	R	PU	24+60 days

Pag. 567

1.3.2 Table 1.3 c: List of milestones

Milestone number	Milestone name	WP(s) involved	Exp. date (month)	Means of verification
M1.1	Input for ECCSEL Business Plan – Draft version 00	1	5	
M1.2	Input for ECCSEL Business Plan – Version 1	1	12	
M1.3	Input for ECCSEL Business Plan – Final	1	20	
M1.4	All required documents ready for incorporation/registration of the legal entity for ECCSEL	1	18	
M1.5	Draft agreements partner commitments presented	1	18	
M1.6	Solicitations initiated	1	9	
M1.7	Fund-rising accomplished	1	22	
M2.1	Implementation plan passed by the project members	2	6	Plan accepted by project General Assembly
M2.2	Determination of geographical localisation of ECCSEL OC	2	9	Geographical localisation accepted by project General Assembly
M2.3	Financial plan passed by the project members	2	16	Financial plan accepted by project General Assembly
M2.4	Recommendation for the first call for open access research with guidance and topical descriptions	2	17	Recommandations accepted by project Steering Board
M3.1	Forecast study report	3	5	
M5.1	Outline communication strategy and plan	5	3	
M5.2	Communication strategy document – selected target groups	5	14	
M5.3	Communication plan document – approaching selected target groups	5	16	
M6.1	First GA meeting/consortium workshop (kick-off meeting)	6	2	
M6.2	Project planning and reporting tools ready	6	3	
M6.3	Second GA meeting/consortium workshop	6	8	
M6.4	Third GA meeting/consortium workshop	6	16	
M6.5	Final GA meeting/consortium workshop (final meeting)	6	24	

1.3.3 Table 1.3 d: Work package descriptions

Work package number:	WP1	start date of event:	M1	end date of event:	M24
Work package title	ECCSEL Business Plan				
Activity Type	SUPP				

Participant number	1	2	**3**	4	5	6	7	8	9	10	11	12	13	14	15	
Participant short name	NTNU	SINTEF ER	**SINTEF**	PGI-NRI	IFPEN	TNO	DLR	Ciuden	BGS	BRGM	OGS	CERTH/ISFTA	ETH Z	ENEA	RCN	SUM
Person month per participant:	7	7	**7**	1	5	2	1	2	2	1	1	1	1	1	3	42

Objective

- To provide the prerequisites for establishing ECCSEL by 2015
- To prepare a consented ECCSEL business plan
- To ensure that infrastructure needs of ECCSEL (provided by WP3) are harmonised with the committed funding resources and consented strategy
- To have the statutes of the legal entity for ECCSEL signed by the consortium members of ECCSEL (end of 2014)
- To provide a communication plan aimed at convincing Funding Agencies in Member States and Associated Countries, Regional Funds as well as industries to invest in ECCSEL operations

Description of work

The conditions of forming ECCSEL will be met and summarised in the ECCSEL Business Plan according to the structure as outlined in Section 1.1.7. These include legal, economic, HSE (health, safety and environment), and ethical issues required for starting operations from day one. The ECCSEL Business Plan shall state the vision along with the scientific, technological and commercial ambitions of ECCSEL, and give the rationale and reasons for why these ambitions are sustainable and believed attainable. It shall also provide a viable plan for how the ambitions will be reached. The ECCSEL Business Plan shall include the relevant background information and argue its ambitions and priorities along the structuring of the European Research Area (ERA), supporting innovation, improving efficiency, and providing the best possible research facilities. It shall describe the organisation(s) behind ECCSEL and the team attempting to reach the ambitions.

Previous work carried out in ECCSEL PP1 shall be amalgamated with the further work of this project, ECCSEL PP2.

Furthermore, notice of ideas and recommendations will be taken from other work packages – particularly with regard to substantial investments that require significant financial arrangements, in close collaboration with the Policy Contact Group and the Reference Group. It is required that specific input prepared by other work packages for inclusion in the ECCSEL Business Plan is converged into firm, consented recommendations.

As ECCSEL shall be settled as a non-profit entity by 2015, its commercial operations are expected to undergo a major development owing to the anticipated growing needs for knowledge and innovation with the development of new, second and third generation CCS technologies. Hence, the ECCSEL Business Plan will cover in detail the first 5 years and in some less detail the continuous development to take place throughout the following 5-10 years.

Over this period of time the ECCSEL Business Plan shall target changes in perception and branding of the ECCSEL hallmark by its stakeholders (i.e. the EC, regional and national authorities, the European Research Area, and last by not least the global CCS research community).

Emphasis shall be placed on the following tasks:

- Task 1.1: Establishing the required prerequisites of ECCSEL in the format of a business plan
- Task 1.2: Establishing the statutes for ECCSEL i.e. the research infrastructure (IR) and the operations centre (OC) as a legal entity
- Task 1.3: Establishing required specific agreements within ECCSEL for operations from day one
- Task 1.4: Solicitation and negotiation of further funding of ECCSEL operations and investments

Specific work:

Task 1.1: Summarising the prerequisites of ECCSEL in the format of a business plan
The ECCSEL Business Plan will provide the roadmap for sustainable operations and further development of ECCSEL. Justification and description will be built on the (tentative) headlines as presented under section 1.1.7 *ECCSEL Business Plan*. To be covered directly under this task are items 1-8, 11 b and c, item 12 a-c and e-h, pursuant to the (above) work description of this work package. The remaining items will be developed in collaboration with WP2 (items 9 and 11 a) and WP3 (items 10 and 12 d).

Task 1.2: Establishing the statutes for ECCSEL i.e. the research infrastructure (IR) and the operations centre (OC) as a legal entity
This will include i.a.

- the legal framework and an overarching governance structure (based on Task 1.1 in PP1)
- consented rules for partnership acceptance

Task 1.3: Establishing required specific agreements within ECCSEL for operations from day one
The work will include

- binding agreements for partner commitments pertaining to laboratory facilities, human and financial resources (WP2 and WP3)
- consented rules for access (based on Task 1.3 in PP1)

Task 1.4: Solicitation and negotiation of further funding of ECCSEL operations and investments
Emphasis will be placed on

- bilateral agreements with the national funding agencies of partner countries
- regional funding bodies and structural funds
- private investments (industries)

In the execution of this task, appropriate advice and assistance will be sought from the Policy Contact Group. The intention is to make use of the Policy Contact Group to provide relevant information on national policies, funding programme and procedures. Ideas regarding road mapping activities and assessment of critical timelines will also be discussed with the Policy Contact Group for the purpose of finding ways to realise a sustainable financing of ECCSEL, in terms of its implementation, operation and investments in new and upgraded facilities. An important milestone is the signing of a Memorandum of Understanding (MoU) signed by the participating countries. This MoU will define the basis for future collaboration, and it will clearly show that ECCSEL has the support it needs to move towards a pan-European research infrastructure on CCS.

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D1.1.1	Outline description of ECCSEL Business Plan	3
D1.1.2	ECCSEL Business Plan – Draft version 00	9

Pag. 571

D1.1.3	ECCSEL Business Plan – Version 1	15
D1.1.4	ECCSEL Business Plan – Final	22
D1.2.1	Draft statutes of the legal entity for ECCSEL	8
D1.2.2	Final statutes signed	24
D1.3.1	Binding access rules delivered	18
D1.3.2	Binding agreements partner commitments	24
D1.4.1	Solicitation plan – Draft	6
D1.4.2	Negotiation schemes with required analyses	12
D1.4.3	Summary of negotiations with funding bodies	22
Milestones		
Mile. no	**Milestone name**	**Exp. date (month)**
M1.1	Input for ECCSEL Business Plan – Draft version 00	5
M1.2	Input for ECCSEL Business Plan – Version 1	12
M1.3	Input for ECCSEL Business Plan – Final	20
M1.4	All required documents ready for incorporation/registration of the legal entity for ECCSEL	18
M1.5	Draft agreements partner commitments presented	18
M1.6	Solicitations initiated	9
M1.7	Fund-rising accomplished	22

Pag. 571

Pag. 572

Work package number:	WP2				start date of event:		M1			end date of event:					M24
Work package title	ECCSEL Operations Centre – Implementation Plan														
Activity Type	SUPP														
Participant number	1	2	3	4	5	6	7	8	9	10	**11**	12	13	14	15	
Participant short name	NTNU	SINTEF ER	SINTEF	PGI-NRI	IFPEN	TNO	DLR	Ciuden	BGS	BRGM	**OGS**	CERTH/ISFTA	ETH Z	ENEA	RCN	SUM
Person month per participant:	3	2	1	1	2	2	1	1	1	1	**10**	4	1	2	1	33

Objective

- To finalise the prerequisites for establishing the ECCSEL Operations Centre and its underlying services by 2015
- To accomplish specific parts of the ECCSEL Business Plan to accommodate the Operations Centre
- To ensure proper operations and services of ECCSEL by direct partner involvement

Description of work

Whereas the operation of each laboratory will be decentralised, a joint overarching superstructure will be mandated to coordinate the overall actions within ECCSEL. The ECCSEL Operations Centre shall be defined by the required operational functions, structure, provided services, localisation, bylaws and the required financing needed for its operations.

Under this work package, emphasis is placed on the following tasks:

- Task 2.1: Establishing the implementation plan for the ECCSEL OC as the core hub of ECCSEL
- Task 2.2: Establishing the required operational plans during implementation and the first five years of operation
- Task 2.3: Logistical planning of ECCSEL
- Task 2.4: Budgeting the financial demands of operations (OPEX) with agreed funding schemes
- Task 2.5: Evaluation criteria for topical research and transnational access projects

Specific work:

Task 2.1: Establishing the implementation plan for the ECCSEL OC as the core hub of ECCSEL

- Defining the required mandate, responsibilities and duties ensuring the internal integration and collaboration of ECCSEL
- Defining the relationship with the ECCSEL Board (see Figure 6), the Reference Group, the Policy Contact Group, the Peer Review Committee and the owners of the research laboratories
- Establishing the organisational structure and managerial principles required to handle ECCSEL under a common hallmark
- Providing input for inclusion in the ECCSEL Business Plan (WP1)

Task 2.2: Establishing the required operational plans during implementation and the first five years of operation

This task shall be conducted in accordance with the planned duties and responsibilities of the operations centre.

- Defining the services to be provided to fulfil the mandate of the ECCSEL OC
- Establishing the procedures to guarantee the services and the required staff, during the initial phase and the advanced phase

Pag. 572

- Defining the structure and the functionalities of the informatics system needed to handle the operations of the OC
- Consenting on geographical localization
- Providing input for inclusion in the ECCSEL Business Plan (WP1)

Task 2.3: Carrying out the logistical planning of ECCSEL

- Planning the organisation of the logistic support for researchers, including informatics
- Testing the logistic support service with dry-runs for at least three specific research laboratories
- Providing input for inclusion in the ECCSEL Business Plan (WP1)

Task 2.4: Budgeting the financial demands of operations (OPEX) with agreed funding schemes

- Defining the operative costs of the OC during the initial phase and the advanced phase
- Defining various scenarios of funding schemes
- Providing input for inclusion in the ECCSEL Business Plan (WP1)

Task 2.5: Establishing the evaluation criteria for topical research and transnational access projects

- Establishing consented selection criteria for topical research – particularly with regard to transnational research and joint research actions
- Providing recommendation for the first call for open access research (e.g. transnational research actions) to visiting researchers with guidance and topical descriptions, to be announced before the end of the project towards the turn of 2014.

Important aspects to incorporate in the criteria to be established under this task are quality, uniqueness, and relevance vis-à-vis the state-of-the-art in reasonable time spells, and the ability to attract (genuine) interest from the CCS community. Due regard shall be given to the vision of ECCSEL (Section 1.1.2), the stated objective and targets (Section 1.1.3 and Section 1.1.5) and also the forming of the ECCSEL Research Infrastructure (Section 1.1.6).

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D2.1.1	Implementation plan for ECCSEL OC	6
D2.2.1	Operational plans during implementation and the first five years of operation	9
D2.3.1	Logistical plans for ECCSEL OC, with dry-runs	14
D2.4.1	Financial plan, for OPEX costs, and funding schemes	16
D2.4.2	Contribution to Business Plan (Chapter 9)	10
D2.4.3	Contribution to Business Plan (Chapter 10)	17
D2.5.1	Evaluation criteria for topical research and transnational access projects	20

Milestones

Mile. no	**Milestone name**	**Exp. date (month)**
M2.1	Implementation plan passed by the project members	6
M2.2	Determination of geographical localisation of ECCSEL OC	9
M2.3	Financial plan passed by the project members	16
M2.4	Recommendation for the first call for open access research with guidance and topical descriptions	17

Work package number:	WP3		start date of event:	M1			end date of event:							M24	
Work package title	ECCSEL Research Infrastructure - Implementation Plan														
Activity Type	SUPP														
Participant number	1	2	3	4	**5**	6	7	8	9	10	11	12	13	14	15	
Participant short name	NTNU	SINTEF ER	SINTEF	PGI-NRI	**IFPEN**	TNO	DLR	Ciuden	BGS	BRGM	OGS	CERTH/ISFTA	ETH Z	ENEA	RCN	SUM
Person month per participant:	4 + 35*	3	4	3	**7**	3	3	4	4	3	3	2	4	3		85

*A monetary allocation corresponding to approximately 35 person months is temporarily set aside in the Coordinator's budget for later allocation among the beneficiaries in WP3. This implies that 35 person months remain to be assigned to the beneficiaries in WP3. The reason is that the need for specific capabilities to carry out specific conceptual planning studies in WP3, Task 3.3, cannot be decided until the forecast study (Task 3.1) is accomplished and recommendations provided (Task 3.2). These preconditions are scheduled to be fulfilled after month 6. The ultimate assignment of these person months and the corresponding budget allocation will be decided by the appropriate consortium body, in accordance with the consortium agreement.

Objective

- To enable ECCSEL to form a world-class CCS research infrastructure
- To establish the inventory of ECCSEL: to locate and describe existing facilities, and determine and quantify the needs for upgrades and new laboratories
- To carry out conceptual studies for technical planning, structuring, and budgeting
- To accomplish the initial logistical planning of ECCSEL

Description of work

The purpose of this work package is to establish a viable plan for implementing ECCSEL. The implementation plan shall cover the initial phase and the (early) advanced phase (cf. Figure 7) in time spells of 5 to 10 years. For the purpose of planning, the former phase shall be considered intermediate. It is required to pass activities from the preparatory phase to a fully operational CCS infrastructure, ECCSEL.
As basis for the planning a top-down approach will be adopted to provide appropriate forecasts relating the infrastructural needs, in due consideration of research topics and related activities reflecting the scientific and commercial potential. This approach will be a structured process (Delphi or similar) with involvement of true specialists.
Important aspects to consider are quality, uniqueness and the ability to attract (genuine) interest from the CCS community in making use of ECCSEL. In this undertaking, due regard shall be given to a) the vision of ECCSEL (Section 1.1.2), b) the stated targets (Section 1.1.5) and c) the forming of the ECCSEL Research Infrastructure (Section 1.1.6).

The *ECCSEL RI Development Plan* drafted during ECCSEL PP1 will be applied in the planning of the structured process. In establishing the implementation plan, the demand for expanding the consortium in order to meet the objective will be considered, backed by Task 4.4 of ECCSEL PP1, .

The following tasks will be executed under this work package:

- Task 3.1: Forecasting future needs and opportunities
- Task 3.2: Providing recommendations of the necessary inventory required to form the initial and the

early advanced ECCSEL infrastructure (including CAT-1 fact sheets)
- Task 3.3: Conceptual planning studies for CAT-3 laboratories, pilots or test sites
- Task 3.4: Contribution to the ECCSEL Business Plan

CAT-1 refers to existing operational research facilities (owned by individual partners) on an "as is" basis
CAT-2 refers to existing research facilities that will need upgrading. These facilities will be owned by individual partners or there will be a mixed ownership with ECCSEL, depending on contractual obligations and investment schemes (agreed prior to or during the early advanced phase). These facilities will become operational and applicable to the R&D community
CAT-3 means non-existing, but strategically important new, big laboratories to be constructed and owned by ECCSEL

Task 3.1: Forecasting future needs and opportunities

Under this task, a structured process will be prepared and conducted, comprising the following prospective actions:
- planning of the structured process (Delphi or similar)
- forecasting scientific needs in time spells – advanced phase
- identification of the needs to be met by CAT-1 or CAT-2 facilities
- evidencing and ranking of the scientific and commercial potential for new CAT-3 facilities along with a consideration of the scientific and technological relevance, uniqueness and expected impact (cf. Task 3.3)
- assessment of the topical research challenges that CAT-3 facilities will meet and address

The outcome of this process will form the basis for the subsequent tasks 3.2 and 3.3.

To conduct the forecasting event, a group of experts from the consortium and invitees from the stakeholders and third-party institutions will form a panel generating ideas in the format of a Delphi study. The results provided by WP3 of ECCSEL PP1 will be used in the planning of the event. The ultimate aim is to identify (and justify scientifically) one or more big new CCS laboratories, pilots or test sites (CAT-3, i.e. unique, complex and advanced units) to be built on the basis of multi-national funding and to be operated under ECCSEL ownership. Emphasis will be placed on research needs relating to second generation (and third generation) CCS technology. In order to justify the huge investments, the scientific and commercial potential should be attested.

Task 3.2: Providing recommendations of the necessary inventory required to form the initial and the early advanced ECCSEL infrastructure (including CAT-1 fact sheets)

This task aims at prioritising the initial stage of inventory forming ECCSEL (2015) prior to the advanced phase. A number of criteria will be taken into account, such as:
- need defined by the R&D community
- need identified by the forecast study (Task 3.1)
- scientific/technical capacity and originality
- availability in terms of time and access rights and costs
- commitment of stakeholders
- geography, etc.

Close cooperation with other work packages (funding, legal) will insure overall consistency of the inventory.

Detailed fact sheet templates will be provided to describe the facilities. The fact sheets will be based on the infrastructure questionnaires elaborated during ECCSEL PP1 and will form the basis for a searchable database. They will describe the scientific/technical capacity of the facility as well as operational/ organisational constraints and conditions.
- For each CAT-1 facility, a fact sheet will be established allowing the R&D community to formulate R&D project proposals including the use of the ECCSEL infrastructure.

- For each CAT-2 facility, the necessary upgrades or modifications will be analysed and recommendation provided through brief conceptual studies, including scientific, technical and economic (funding) aspects (using 1st order approximations). For each identified facility an upgrading plan will be elaborated, which will be put to execution after the start of ECCSEL in early 2015.

Task 3.3: Conceptual planning studies for CAT-3 laboratories, pilots, test sites

- Among the highest ranked CAT-3 laboratories (pilots or test sites) identified under Task 3.1, preferably three (maximum five) cases shall be selected for further outlining and scrutiny under this task. The selected cases shall be subjected to a conceptual planning study aimed at envisaging the feasibility by objective, concept, technological relevance, investment level (1st order approximation), possible scientific/technological impact, with inclusion of considerations of siting and funding (CAPEX, OPEX).

For the purpose of this study the following notion shall apply:

- A case recognised as a CAT-3 laboratory (pilot or test site) shall comprise unprecedented scientific and/or technological features with the capabilities that are deemed essential to meet the expectations for second generation and third generation CCS technology. It shall set new standards to CCS research on a global scale. Furthermore, the investment in a CAT-3 laboratory (pilot or test site) is assumed to exceed the level of funding that can be expectedly provided by a single source (nation or region). For this reason multi-national funding is deemed necessary (cf. Sections 1.1.1 and 1.1.6). This implies that each case subjected to scrutiny under this task shall be perceived and treated as a pan-European asset, owned and operated by ECCSEL. Last, but not least, a recommendation shall be drawn from the conceptual planning study of this task, as to whether the CAT-3 case should proceed to further engineering studies in ECCSEL – tentatively in 2015, or later.

Task 3.4: Contribution to the ECCSEL Business Plan

A summary of the outputs from the above tasks will be provided in this task, aimed at forming a foundation for the ECCSEL Business Plan (WP1). This input shall specifically address the following items of the structure shown in Section 1.2.2 ECCSEL Business Plan: Paragraph 10 and 12 d.

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D3.1.1	Forecast – future needs	5
D3.1.2	ECCSEL Research Infrastructure - Implementation Plan	15
D3.2.1	Inventory of ECCSEL (CAT-1, CAT-2 and CAT-3)	9
D3.2.2	Template(s) of Fact sheet(s) for CAT-1 description	14
D3.2.3	Fact sheets for CAT-1 facilities	10
D3.2.4	Upgrading plans for CAT-2 facilities	12
D3.3.1	Conceptual studies for CAT-3 facilities	15
D3.4.1	Contribution to Business Plan (Draft/Version 1/Final)	8/14/20

Milestones

Mile. no	**Milestone name**	**Exp. date (month)**
M3.1	Forecast future needs	5

Work package number:	WP4				start date of event:			M1		end date of event:				M24	
Work package title	Innovation														
Activity Type	SUPP														
Participant number	1	2	3	4	5	**6**	7	8	9	10	11	12	13	14	15	
Participant short name	NTNU	SINTEF ER	SINTEF	PGI-NRI	IFPEN	**TNO**	DLR	Ciuden	BGS	BRGM	OGS	CERTH/ISFTA	ETH Z	ENEA	RCN	SUM
Person month per participant:	1	2	1	1	1	**6**	1	1	2	1	1	1	4	1		24

Objective

Objective

- To increase the potential for innovation
- To increase the impact of innovation
- To enable ECCSEL to deliver knowledge products

.

Description of work

The purpose of this work package is to ensure that specific innovation processes will be pursued as part of the project, and subsequently in the implementation of ECCSEL (by 2015 and beyond), aimed at creating better and more efficient ideas, processes, technologies and products.

Innovation may be initiated either by 1) technology push, or 2) market pull. Whereas the former is traditionally recognised as manufacturer innovation, the latter is often effectuated by end-users in order to meet specific new needs. Whereas radical and revolutionary innovations tend to emerge from research and development, the more incremental innovations are prone to emerge from practice.

In ECCSEL, the integration of different laboratories is expected to have an impact on the ability of the consortium to drive innovation. For this reason, ECCSEL will provide a venue for confronting ideas to broaden the communicative basis within the consortium and with industrial players around the world. This may result in strategic advantages, such as:

- Novelty, by offering services that nobody else can offer
- Competence, by extending the level of expertise within CCS research beyond the state-of-the-art

Furthermore, management of complexity in current CCS research is another matter for innovative concern. Owing to the need for derisking of second generation (and third generation) CCS technology, and for meeting the safety and HSE regulations in due time, future demands will require advanced research facilities. As these facilities are believed to become exceedingly complex, costly and complicated, more simplistic solutions must be devised. Hence, in the planning of ECCSEL, innovative processes are required also to improve the research processes, and reduce the initial investments and operational cost of ECCSEL.

Emphasis will be placed on the following tasks:

- Task 4.1: Technology push – Developing a management tool for innovation
- Task 4.2: Market pull – Seeking market involvement
- Task 4.3: Market up-take of knowledge products under the ECCSEL hallmark

Specific work:

 Pag. 578

Task 4.1: Technology push – Developing a management tool for innovation

Although innovation can be achieved in many ways, much attention is given to formal research and development for "breakthrough innovations." In line with the notion of Innovation (in Section 1.1.8), an innovation process shall be conducted in which emphasis shall be placed on specific needs (to be identified and evidenced in WP3) and on the following structuring components:

1) targets (cf. Sections 1.1.1, 1.1.2, 1.1.3, 1.1.5 and 1.1.6)
2) alignment of actions to targets
3) participation in teams
4) monitoring of results
5) communication and access to information

This process will

- build on the outcome of Tasks 3.1, 3.2 and – in particular – Task 3.3.
- require extended communication among partners.
- develop a management tool for innovation to facilitate items 3, 4 and 5 of the structuring components, listed above.
- carry out continuous incremental innovation to address crucial aspects of ECCSEL – particularly the potential for reducing the overall expenditure pertaining to research and development.

Task 4.2: Market pull – Seeking market involvement

Market-pull, recognised as end-user innovation, is considered the most important and critical source for innovation in the commodity market. However, as CCS is not yet commercialised, market pull may be less pronounced in the context of ECCSEL. In order to drive a successful innovation process, a systemic approach is needed to assess the potential for innovation from research and also from a market pull perspective. In this context the process will

- involve industries, authorities and NGOs on a consultative basis in the planning of research and required facilities to become part of ECCSEL.
- gather information on specific needs and concerns, as articulated by third parties, conducted in cooperation with WP5.

Task 4.3: Market up-take of knowledge products under the ECCSEL hallmark

In the planning of ECCSEL, this task will take into account the development of new knowledge products. In this process, possible spin-offs will be considered to provide specific knowledge products, for instance by adding value to data arising from actions carried out under ECCSEL. Hereby, the reporting on lessons learnt turned into best practices is of significant relevance.

Under this task

- the concept of specific knowledge products will be addressed and developed.
- the potential for knowledge products will be assessed along with the hallmark of ECCSEL.
- the possibility and financial implications of organising (on a regular basis) topical education and training events will be assessed.

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D4.1.1	ECCSEL knowledge management tool	6
D4.2.1	Innovation score card	6
D4.2.2	Market pull inventory	8, 22
D4.3.1	Report on knowledge products under the hallmark of ECCSEL (Draft/Final)	9/18

 Pag. 578

Work package number:	WP5				start date of event:		M1				end date of event:				M24
Work package title	Communication and Networking – seeking Stakeholder Engagement														
Activity Type	SUPP														
Participant number	1	2	3	4	5	6	7	**8**	9	10	11	12	13	14	15
Participant short name	NTNU	SINTEF ER	SINTEF	PGI-NRI	IFPEN	TNO	DLR	**Ciuden**	BGS	BRGM	OGS	CERTH/ISFTA	ETH Z	ENEA	RCN
Person month per participant:	1	1	1	1	2	2	1	**6**	1	2	1	1	1	1	1

Note: the participant rows also carry a final column: (blank) / SUM / 23.

Objective

- To make efforts to engage in relevant knowledge markets
- To attract the interest from relevant institutions and industrial players seeking involvement in ECCSEL in actions devoted to integrating activities and joint research
- To provide appropriate communication strategies and communication planning
- To ensure science outreach and public awareness/understanding of the societal potential of CCS

Description of work

In this work package, proper communication and networking are crucial components for ECCSEL to achieve its stated objectives and targets, and to realise its vision and the description of forming ECCSEL (Sections 1.1.1, 1.1.2, 1.1.3, 1.1.5, 1.1.2, 1.1.6, respectively). Communication strategies and communication plans particularly apply to the preparation of events for approaching stakeholders to obtain firm commitments, especially with regard to soliciting and negotiating funding and stakeholder engagement.

Under the more general term *networking* with the intent of improving awareness of the potential of the CCS research infrastructure, a targeted approach needs to be planned to ensure proper communication. The purpose is to foster a culture of co-operation between the partners and the scientific communities that may become beneficial to ECCSEL and help develop a more efficient and attractive European Research Area. This may eventually accelerate the deployment of CCS in Europe and worldwide.

Emphasis under this work package is placed on the following tasks:

- Task 5.1: Providing appropriate communication strategies and communication plans for networking, solicitation and negotiations (branding the ECCSEL hallmark)
- Task 5.2: Networking

Specific work:

<u>Task 5.1:</u> <u>Providing appropriate communication strategies and communication plans for networking, solicitation and negotiations (branding the ECCSEL hallmark)</u>

This task will set a communication strategy for the extensive fund-raising of the project, as required to establish ECCSEL by 2015, to upgrade facilities during the first year of operations, and to build new highly advanced CCS laboratories in the following years (in time spells of 5 years). The communication strategy shall cover a consecutive plan for soliciting and negotiating commitments by governments, funding agencies, regional or structural funds, banks and industries.

The communication strategy shall duly reflect the budgeted amounts required to develop ECCSEL as a pan-

European research infrastructure pursuant to the project idea, the vision of ECCSEL, its objective along with its specific targets, and the description of forming ECCSEL, as pointed out in Sections 1.1.1, 1.1.2, 1.1.3, 1.1.5 and 1.1.6, respectively, and in accordance with input from WP3. The communication strategy shall target – case by case – the various funding bodies foreseen to provide financial support, as indicated in Section 1.1.1, for

- the upgrading of existing facilities,
- new laboratories, and
- operation and access

The task shall furthermore provide the required communication plan for soliciting and negotiating funding, for networking (in Task 5.2) and for branding the ECCSEL hallmark. The rationale is that communication needs to be customised, as the message may vary – owing to what is deemed relevant and important to the addressee. This work shall include descriptive communication targeting the funding bodies, governments, politicians, industries and NGOs on a case-to-case basis.

Task 5.2: Networking

Networking will (particularly) target

- the European and global CCS community (ERA, EERA, ZEP, IEA-GHG, ECRI, CCS-PNS, GCCSI, CSLF etc.)
- stakeholders, authorities, regulators and industries
- international presence, recognition and/or cooperation – aiming at synergistic approaches with third parties outside Europe – especially in China, USA and Australia. Once identified, the most suitable or interesting countries for ECCSEL outreach, a pan-European plan will be proposed to achieve further cooperation and engagement.
- The networking outcomes will provide a strategic view for communication and dissemination needs to accomplish ECCSEL.

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D5.1.1	ECCSEL Communication Strategy for Fund-raising (Draft/Version 1)	7/10
D5.1.2	ECCSEL Communication Plans for Soliciting and Negotiating Commitments – and branding the hallmark of ECCSEL (Draft/Version 1)	10/16
D5.2.1	Pan-European Outreach plan	14
D5.2.2	Communication targeting Synergy in collaboration with China, USA and Australia	16

Milestones

Mile. no	**Milestone name**	**Exp. date (month)**
M5.1	Outline communication strategy and plan	3
M5.2	Communication strategy document – selected target groups	14
M5.3	Communication plan document – approaching selected target groups	16

Work package number:	WP6				start date of event:			M1				end date of event:				M24
Work package title	Project Management and Coordination															
Activity Type	MGT															
Participant number	**1**	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Participant short name	**NTNU**	SINTEF ER	SINTEF	PGI-NRI	IFPEN	TNO	DLR	Ciuden	BGS	BRGM	OGS	CERTH/ISFTA	ETH Z	ENEA	RCN	SUM
Person month per participant:	**10**															10

Objective
• To ensure proper performance and coordination of ECCSEL PP2

Description of work

The Project Coordinator will be empowered by the General Assembly to manage the project in terms of its legal, financial and administrative aspects. This implies that the Project Coordinator will have the sole authority of interacting with the General Assembly and the Scientific Officer nominated by the European Commission. Project reports will be produced in close cooperation with the WP-leaders, drawing upon resources assigned to the various work packages.

Emphasis is placed on the following tasks, all led by NTNU:

- Task 6.1 Operational management
- Task 6.2 Financing
- Task 6.3 Reporting

Task 6.1 Operational management

This task covers all the work related to the practical continuous management of the project. Efforts will be made to

- implement and monitor the fulfilment of the Consortium Agreement by all partners.
- monitor the compliance by partners with their obligations under the Grant Agreement.
- compare on a regular basis the work progress against the agreed work plan, including provision of deliverables against the agreed deadlines, attainment of milestones etc.
- report any deviations to the General Assembly and take necessary actions.
- carry out risk assessment of the project, including contingency plans and measures for remediation.
- facilitate internal project communication, especially with the WP-leaders and Task leaders.
- organise all meetings (with the whole consortium, General Assembly, Steering Board, Project Management Group etc) and workshops (with the consortium and other bodies included in the project description).
- establish and maintain continuous and close communication with the European Commission through the responsible Scientific Officer of the Commission.
- undertake the necessary steps regarding potential integration of new partners to the Consortium.

Task 6.2 Financing

Efforts under this task will be made to:

- administrate the financial contribution from the Commission, including distribution of share among partners, and to monitor all transactions.
- document and report all financial transactions of the partners to the Commission as specified in the Grant Agreement.
- establish and maintain a project master plan.
- follow-up on cost and work performance.
- carry out regular control of accounts versus project budget.
- provide the financial report to be submitted to the Commission as agreed in the contractual rules. The financial report will be presented to the General Assembly for approval before submission to the Commission.

Task 6.3 Reporting

Efforts under this task will be made to

- establish a reporting structure that allows for monitoring of work performance.
- provide the Commission periodic reports for each reporting period and a final report, in order to assist the Commission in monitoring work and results. The reports will be prepared by the Coordinator based on the inputs from the WP-leaders and other ECCSEL-PP2 management bodies (see management structure).

Deliverables

Del. no.	**Deliverable name**	**Delivery date (month)**
D6.1.1	Project master plan including full transparency of resources, schedule and cost/performance	3
D6.2.1	Mid-term report to the European Commission (Month 12)	12+60 days
D6.3.1	Final report to the European Commission	24+60 days
D6.4.1	Public executive summary	24+60 days

Milestones

Mile. no	**Milestone name**	**Exp. date (month)**
M6.1	First GA meeting/consortium workshop (kick-off meeting)	2
M6.2	Project planning and reporting tools ready	3
M6.3	Second GA meeting/consortium workshop	8
M6.4	Third GA meeting/consortium workshop	16
M6.5	Final GA meeting/consortium workshop (final meeting)	24

1.3.4 Table 1.3 e: Summary of staff effort

Part. No	Short name	WP1	WP2	W3	W4	W5	WP6	Total
1	NTNU	7	3	4 + 35*	1	1	**10**	61
2	SINTEF ER	7	2	3	2	1		15
3	SINTEF	**7**	1	4	1	1		14
4	PGI-NRI	1	1	3	1	1		7
5	IFPEN	5	2	**7**	1	2		17
6	TNO	2	2	3	**6**	2		15
7	DLR	1	1	3	1	1		7
8	CIUDEN	2	1	4	1	**6**		14
9	BGS	2	1	4	2	1		10
10	BRGM	1	1	3	1	2		8
11	OGS	1	**10**	3	1	1		16
12	CERTH/ISFTA	1	4	2	1	1		9
13	ETH ZURICH	1	1	4	4	1		11
14	ENEA	1	2	3	1	1		8
15	RCN	3	1			1		5
	Total	42	33	85	24	23	10	217

Note *A monetary allocation corresponding to approximately 35 person months is temporarily set aside in the Coordinator's budget for later allocation among the beneficiaries in WP3. This implies that 35 person months remain to be assigned to the beneficiaries in WP3. The reason is that the need for specific capabilities to carry out specific conceptual planning studies in WP3, Task 3.3, cannot be decided until the forecast study (Task 3.1) is accomplished and recommendations provided (Task 3.2). These preconditions are scheduled to be fulfilled after month 6. The ultimate assignment of these person months and the corresponding budget allocation will be decided by the appropriate consortium body, in accordance with the consortium agreement.

2 Implementation

According to plan, the project will be operational throughout 2013 and 2014. Its operations will be based on the same partners and consortium as the ECCSEL PP project. ECCSEL PP2 will conclude its work in due time before establishment of ECCSEL, intentionally in 2015.

2.1 Management structure and procedures

The project will be implemented with a lean management structure backed by firm operational procedures and decision rules, as set out in the Consortium Agreement.

2.1.1 ECCSEL organisation structure

The cooperation within ECCSEL PP2 will be managed by the Project Coordinator with a light administration. The project operational and financial management structure of the project is outlined in Figure 9 .

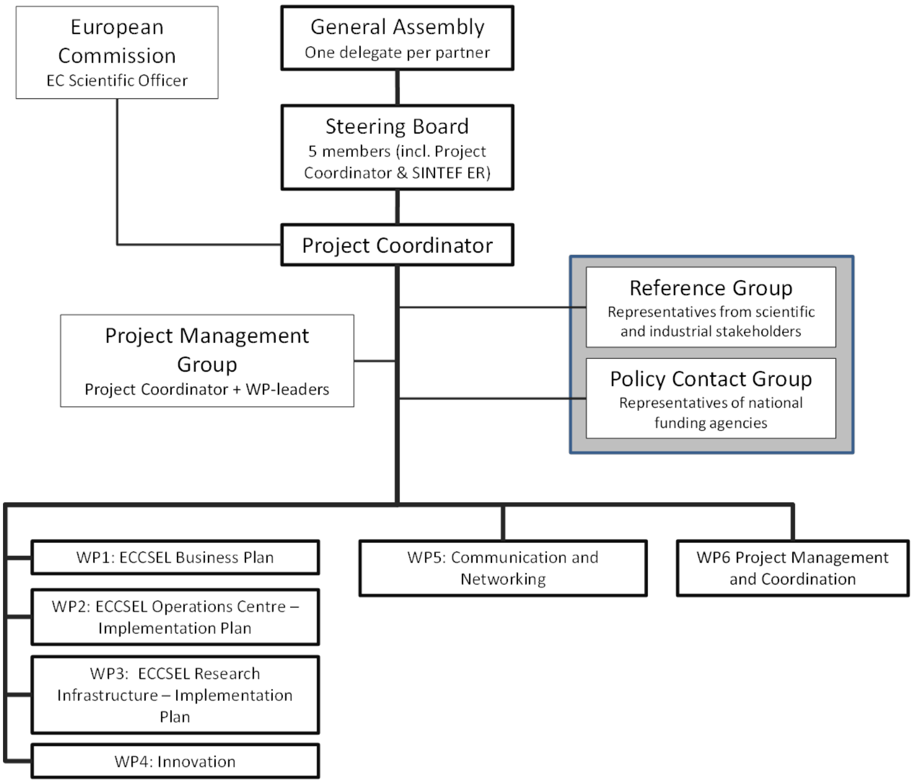


Figure 9: Organisation chart for ECCSEL PP2. Operational and financial management structure

Hence, the project is organised with a clear-cut management structure following the line of influence from the highest level (General Assembly) to working level (Work Packages).

Apart from the working level, the project has three levels for decision making: one operational, one strategic and one regarding formalities, as depicted in Figure 9. This management structure has proved successful in several integrated projects executed under the EU-based framework programmes 6&7.

General Assembly

All parties signing the Consortium Agreement will become full and equal members of the General Assembly (GA). The Project Coordinator will propose the chair of the GA, and the GA will consent. The GA shall meet at least once per year adjacent to the annual project meetings, and GA members and the Project Coordinator have the right to call for extra GA meetings if deemed necessary. The Scientific Officer of the European Commission will be invited to attend all GA meetings.

The General Assembly is the ultimate decision-making body on formal aspects relating to the project, such as:

- Content, finances and intellectual property rights
- Proposals for changes to Annex I of the Grant Agreement – to be accepted by the European Commission
- Changes to the Consortium Plan (including the Consortium Budget), evolution of the Consortium (entry of a new Party to the Consortium and approval of the settlement on the conditions of the accession of such a new party, withdrawal of a party from the consortium and the approval of the settlement on the conditions of the withdrawal, declaration of a party to be a defaulting party, remedies to be performed by a defaulting party, termination of a defaulting party's participation in the consortium and relating measures, proposal to the European Commission for a change of Coordinator, proposal to the European Commission for suspension of all or part of the project, proposal to the European Commission for termination of the project and the Consortium Agreement).

Voting in the GA is by 2/3 majority in all decisions except for critical decisions which require unanimous approval. Critical decisions are decisions deemed crucial to reach the stated overall objective of the project or decisions on issues that may endanger the completion of the project.

The progress and the results of the project will be presented by the Project Coordinator to the GA at the GA meetings. The GA will approve all deliverables of the project. In particular, the GA will be instrumental in all decisions that relate to the Implementation Strategy Plan for ECCSEL all along its development.

Steering Board

The Steering Board is the decision-making body with respect to strategic issues and the practical performance of the project – including possible sanctions (if appropriate). It covers all steps and decisions necessary to fulfil the work plan, and for keeping the deadlines and milestones. If necessary the Steering Board will take steps to handle deviations.

The Steering Board will have 5 representatives (including the Project Coordinator and SINTEF ER), who will be proposed by the Project Coordinator and approved by the General Assembly. The Project Coordinator shall act as Chair of the Steering Board. Decisions in the Steering Board are by 2/3 majority.

The Steering Board will meet regularly, generally every 6 months, throughout the project period, either physically or via video-/telephone conferences. Agenda and necessary documents will be provided by the Chair in due time.

The Project Coordinator

The role of the Project Coordinator is to sign the Grant Agreement with the European Commission and to obtain from each participant a signed accession to the grant agreement (forms A). On this basis the Project Coordinator shall be responsible for the execution of the project.

The Project Coordinator is the only partner authorised to exchange information with the European Commission (Scientific Officer) in any event that may concern the project and/or its Consortium. The Project Coordinator has the overall responsibility for the progress of the project and for the quality of its deliverables. All deliverables and any formal report pertaining to the project shall be submitted to the European Commission by the Project Coordinator.

The Project Coordinator will form a Management Team empowered to execute the project on a day-to-day basis according to duties as stated under WP6 (Project Management).

The Project Coordinator furthermore undertakes to

- **manage the financial contribution from the Commission**. The respective share shall be distributed among the partners according to the Consortium Agreement and Steering Board decisions, and the Project Management Group shall monitor all financial transactions and inform the Commission about the financial administration as agreed in the Grant Agreement.
- monitor the **compliance by participants** with their obligations under the Grant Agreement.

- provide the Commission with **periodic reports** for each reporting period as well as a final report, in order to assist the Commission in approving the fulfilment of the Grant Agreement. The content of these reports shall comply with the Grant Agreement and the reporting guidelines for EC-FP7.
- **review and submit reports** and other deliverables to the Commission by electronic means.

Link to the Commission

The Project Coordinator shall constitute the single interface with the Commission. However, if deemed necessary, the Steering Board may represent the Consortium towards the Commission in pressing issues.

Project Management Group (PMG)

The Project Management Group is composed of the Project Coordinator (i.e. Project Manager) and the assigned WP-leaders. The Project Management Group will meet regularly, generally every 4 months, throughout the project period, either in person or via video-/telephone conferences. Agenda and necessary documents will be provided by the Project Coordinator in due time in advance of all meetings. Meetings in the Project Management Group are chaired by the Project Coordinator.

Reference Group

The Reference Group will ensure that ECCSEL develops in line with industrial and scientific research needs. The Reference Group consists of scientific experts from R&D-providers, technology providers, and energy providers (including processing industry as appropriate). The role of the Reference Group is to give advice during the project period from the point of view of an external stakeholder on core aspects relating to the future research laboratory infrastructure, such as

- scientific development and consequences for the infrastructure
- user community needs
- cooperation with other projects and networks

The rationale for getting involved in the Reference Group is to obtain direct insight to the work of ECCSEL, and/or to consider this as an opportunity to influence the process and decisions thereof.

For the Consortium, the rationale for including the Reference Group is to trigger involvement from important CCS players in Europe that might become future users of ECCSEL in the Implementation Phase, seeing this as an opportunity to get important insights from other types of organisations and new countries that are not represented in the Consortium.

Policy Contact Group

The Policy Contact Group will be open to the funding agencies (or representatives of ministries) of all countries participating in ECCSEL. The Research Council of Norway (RCN) will be central in supporting ECCSEL with regard to practical arrangements – especially for formal invitations – relating to Policy Contact Group meetings.

Main tasks and responsibilities of the Policy Contact Group are (per partner country)

- to provide information and updates regarding upcoming research infrastructures, including possible funding schemes, timeline (e.g. road maps) and decision-making processes
- to give input to the financial strategies of ECCSEL
- to contribute in discussions dealing with future needs and the development of ECCSEL via possible building blocks
- to provide factual input for decisions via review processes and recommendations with regard to the design and site location of key facilities, legal framework and governance structure.

 Pag. 587

It is foreseen that the Policy Contact Group may transform into a Stakeholder (Interim) Council at a later stage, when the infrastructure building blocks, legal, governance and administrative matters are further developed, and when core countries have made firm funding decisions for ECCSEL.

Work Package Leaders

Work Package Leaders shall be assigned by the Project Coordinator. All other necessary decisions on the allocation of manpower and other resources to the planned activities may be taken by the Work Package Leaders in order to execute the work and make sure that the deliverables conform to the project plan and otherwise are provided according to instructions from the Project Management Group. The Work Package Leaders shall ensure good communication and collaboration between the subordinated task leaders, and they will work closely together with the Project Coordinator in the Project Management Group.

Consortium Agreement (CA)

The participants will enter into a Consortium Agreement, in which all relevant issues needed for the proper execution of the project are described in detail. Relevant issues are the responsibilities (of the General Assembly, Steering Board, Project Coordinator, WP-leaders, and individual participants), liabilities, handling of defaulting parties, confidentiality, resolution of conflicts, etc.

2.2 Individual participants

1. The Norwegian University of Science and Technology (NTNU)

NTNU (The Norwegian University of Science and Technology) is a fully integrated university with emphasis on technology and engineering. It is the main technical university in Norway with over 80% of all master- and PhD-degrees awarded in science and technology. Over the last 30 years NTNU and the research institute SINTEF have jointly developed a research area covering 8,000 square metre hosting a 40 million Euro research facility, where 750 people work on mitigating emissions like CO_2, NOx, SOx and other greenhouse gases. This includes removing such emissions from oil and gas production processes and from use in industry, buildings and transport.

NTNU is and has been involved in a series of national projects (BIGCO2, BIGH2, BIGCLC, BIGCCS) and EU projects (ENCAP, DYNAMIS, DECARBit, iCap) and has been the coordinator of the FP6 funded ENGAS-RI (Environmental Gas Management Research Infrastructure).

NTNU is also the coordinator of ECCSEL (European Carbon dioxide Capture and Storage Laboratory Infrastructure – www.eccsel.org) put on the official ESFRI Roadmap in 2008. NTNU furthermore coordinates a new project proposal under Integrating Activities designated ECRI (European CCS Research Infrastructures – Integrating Activities).

Active role: Coordinator and legally responsible for the project, project management function of ECCSEL PP2, secretary of the General Assembly and the Steering Board. Leader of WP6, leader of Tasks 1.3, 1.4, 2.1 and 3.1. Research performer in WP4 and WP5.

Key personnel:

Prof. Dr Olav Bolland is professor in energy and process engineering at NTNU, specialised within power plant engineering and coupling between power cycles and CO_2 capture processes since 1989. He was lead author of the 2005 IPPC Special Report on Carbon Dioxide Capture and Storage. He was, with Dr Nils Røkke, the main organiser of the 2006 GHGT-8 conference in Trondheim, Norway. He is also coorganiser of the biannual Trondheim Conference on CCS. Bolland has published a large number of papers and reports related to CO_2 capture. He is involved, on behalf of NTNU, as partner and work package leader in the FP6 projects ENCAP, DYNAMIS and the FP7 project DECARBit.

 Pag. 587

Dr Morten Grønli is laboratory director of the thermal engineering laboratory at NTNU. He has more than 15 years of experience within the combustion and bioenergy field and has experience in managing research projects as well as laboratory infrastructures at NTNU. Dr Grønli has been project manager of ENGAS RI, and is the project coordinator for ECCSEL Preparatory Phase I.

Morten Øien (Master of Law) has since January 1997 worked as a legal adviser at NTNU. He has substantial experience working with international RTD contracts and IPR, particularly within framework programmes. Prior to joining NTNU he worked for many years as a private practicing lawyer.

Liv Randi Hultgreen is assistant professor in Marine Engineering. She has 8 years of experience in project management at NTNU, and is project manager for ECCSEL Preparatory Phase I.

Prof. Dr Hallvard F. Svendsen is professor in Chemical Engineering. He has more than 110 refereed journal papers and conference publications on CO_2 absorption and multiphase reactor modelling. He is project leader of several national research projects on CO_2 capture and supervises presently 12 PhD students in this field. He was member of the CASTOR project Executive Board, heads the NTNU activity in the CAPRICE, CESAR and CLEO projects, and is coordinator of the iCap project. Presently he is referee to about several international scientific journals, and is member of the editorial board of one journal.

Prof. Dr May-Britt Hägg is professor in Chemical Engineering, with a professional background from academia and industry. She leads the Membrane Research group, Memfo, which counts about 16 researchers, post docs and PhD-students. Her focus of research is membranes for gas separation, material development and process simulations. She has 6 patents, has published around 50 papers in peer reviewed journals, and has held around 100 presentations at international conferences. Hägg has also chaired 3 international conferences, and has participated in 8 EU-projects.

2. SINTEF Energi (SINTEF ER)

SINTEF Energy Research (a legal entity affiliated to SINTEF) is a contract research institute focused on thermal power generation, conversion technologies, and the supply, distribution and end-use of energy. Over the last two decades it has established a sizeable group of people working on various topics relating to CCS technologies. In this area SINTEF ER has developed a considerable level of expertise pertaining to CCS, mainly related to capture techniques in power cycles, gas handling, gas pre-treatment, transport of CO_2, as well as low-temperature processing. In collaboration with NTNU, SINTEF ER has more than 30 years of experience in numerical simulation of combustion processes and experimental capabilities (advanced laser diagnostics for combustion measurements). Of special relevance are a novel high pressure oxy-combustion facility (HIPROX) and a 150kW CLC cold pilot that is going to be extended with a hot pilot. Experience has particularly been gained on oxy-combustion and hydrogen combustion in CO_2 capture processes through various projects under the Norwegian research programme CLIMIT, and the EU projects ENCAP, DYNAMIS, ECCO and DECARBIT – led or coordinated by SINTEF ER.

SINTEF ER possesses world-class expertise in refrigeration and cryogenics, including modelling and simulation capabilities covering components, working media and systems, and is i.a. responsible for advanced cryogenic air separation units in DECARBit. SINTEF ER was also in lead of the WP2 Capture Technologies in the Sino-European COACH project (2006-2009), much devoted to pre-combustion concepts, notably polygeneration in a Chinese context.

SINTEF ER is the coordinator of the national strategic R&D project BIGCO2 and the International CCS Research Centre BIGCCS. The BIGCCS Centre is considered to form the largest single R&D project portfolio in the world addressing the CCS chain from CO_2 capture to underground storage.

Active role: Member of Steering Board. Leader of Tasks 1.1, 2.5 and 4.2. Research performer in WP3 and WP5.

Key personnel:

Dr Nils Røkke is President of Climate Change Technologies within SINTEF and Director of BIGCCS, the International CCS Research Centre at NTNU and SINTEF. He has also been coordinator of the EU FP6

 Pag. 589

DYNAMIS and the EU FP7 DECARBit project, and Project Manager for the ENCAP EU FP6 project contracted by Vattenfall. He is Chairman of major CCS projects (e.g. the BIGCO2 project and the Enabling Remote Gas project), member of the EU ZEP Advisory Council, member of WG1 in ZEP, and is leading the ZEP Long Term R&D plan within capture. Dr Røkke was Chair of the GHGT-8 in Trondheim 2006, Chairman of the European CCS conference in February 2009, and Chair of TCCS-5 (2009) and TCCS-6 (2011) in Trondheim.

Dr Marie Bysveen is the Combustion Group Team Leader of the department of Thermal Energy, and has 20 years of experience in combustion research, management of R&D projects and process engineering. She has been working on fuel technology, especially on the use of hydrogen and natural gas in combustion engines. Dr Bysveen is the manager of BIGCLC – probably one of the largest R&D projects in Europe on Chemical Looping Combustion – and she is the present Coordinator of the EU FP7 DECARBit project.

Dr Sigurd Sannan has a PhD in theoretical physics from University of California, Santa Barbara. He has several years of international experience from research and teaching at research institutes and universities both in the US, Europe, and in Asia. Dr Sannan has worked as a research scientist at SINTEF ER since 2002, and has specialised in combustion modelling and simulation with a focus on the development of a novel high-fidelity design tool for gas turbine combustors.

Dr Jens Hetland is a senior research scientist who has also industrial experience in oil & gas processing and manufacturing. He was leading an action on coal-based CO_2 capture technologies in China (the Sino-European COACH project) and has been appointed an international expert to the Asian Development Bank and the Chinese Government – the National Development and Reform Committee (NDRC) in providing recommendations for the first large-scale CCS demonstration in China (IGCC-CCS) 2009-2010. He is a member of the Editorial Board of Elsevier Journal of Applied Energy.

3. SINTEF (SINTEF)

Stiftelsen SINTEF is part of the SINTEF Group; one of the largest research groups in Europe. Stiftelsen SINTEF has more than 1200 employees with international top-level expertise in science and technology. The annual turnover is 1600 million NOK (~ 200 M€) originating from industrial research contracts as well as European and National research projects. SINTEF is an independent and non-commercial corporation. Profit from contract research is invested in new research, scientific equipment and competence.

SINTEF Materials and Chemistry (MC) is the division of SINTEF that will be involved in ECCSEL PP2. This division has around 420 employees, about 90% of these are scientists and technicians. The Material and Chemistry division has extensive activities in the fields of CO_2 capture and transport, and experience from several national and European R&D programmes within FP5, FP6 and FP7, as coordinator and/or core partner.

Active role: Leader of WP1. Leader of Task3.2. Research performer in WP2, WP3 and WP5.

Key personnel:

Dr Richard Blom is Research Manager at SINTEF MC. He has been working in the field of catalysis and sorption for the last 20 years. For the last 10 years, his main interest has been the development of materials and processes for CO_2 separation technologies. He has long term experience as a project leader and coordinator for CCS related projects. He has more than 70 scientific publications

Dr Rune Bredesen is Research Director at SINTEF MC. He has over 30 years experience in materials research. For the last 20 years, his main activity has been directed to energy technology. He has been the Coordinator of several European Projects. Presently he manages the Capture project of the International CCS Research Centre BIGCCS. Bredesen is a member of several international scientific committees and has about 60 publications in international journals and conference proceedings. He is member of the Editorial Board of Chemical Engineering Journal.

Dr Cato Dørum is senior research scientist at SINTEF MC. He has 10 years experience in FE-based material and fracture modeling, and experimental mechanics. He participates in several projects dealing with

 Pag. 589

development of methodologies for prediction of initiation and propagation of fracture, and has a key role in several projects related to CO_2 transport at SINTEF Materials and Chemistry.

Dr Partow Pakdel Henriksen is Research Manger at SINTEF Materials and Chemistry, working mainly on material development for energy and environmental technologies. She has been concentrating on CO_2 capture technologies (membranes, adsorption and absorption) for the past 11 years. Prior to her work for SINTEF, she was employed by ABB Environmental / ALSTOM Norway in the area of Air Pollution control for power plants and various industries in air pollution technologies. She is the leader of the CO_2 strategy group at SINTEF Materials and Chemistry.

Dr Thor Mejdell is senior research scientist, and he has been involved chemical engineering for more than 25 years. He has a PhD from NTNU (1990) within process control and modelling, and has been working on CO_2 post-combustion capture since 2003. He has coordinated the department's activities in the CASTOR, DYNAMIS and ULCOS projects within the European FP6 and the CESAR project in FP7. He has also been heavily involved in the SOLVit project and is presently responsible for pilot plant activities at the new facility at Tiller, Trondheim, Norway.

Øyvind Hennestad has since 2000 been the Company Lawyer of SINTEF. He has over 20 years of experience within legal management of R&D projects, and management of Intellectual Property rights. Hennestad has been involved in several EU projects, supporting SINTEF as Project Coordinator on legal issues from the EU FP4.

4. Panstwowy Instytut Geologiczny – Panstwowy Instytut Badawczy (PGI-NRI)

Polish Geological Institute – National Research Institute, founded in 1919, manages multi-disciplinary research on the geological structure of Poland in order to use the knowledge for purposes of domestic economy and environmental protection. Besides research in all fields of modern geology, the Institute fulfils the role of a geological and hydrogeological survey of Poland, securing economic stability to the country in areas of both mineral (including hydrocarbons, conventional and unconventional) and groundwater resources management, environmental monitoring, CCS and geothermal. PGI-NRI is leading, since 2008, National Programme "Assessment of formations and structures suitable for safe CO_2 geological storage including monitoring plans". The programme is to provide information necessary for future permits on exploration of CO_2 storage sites all over the country and characterise selected storage sites using archive data and laboratory analyses. PGI has provided expertise to the first Polish demo project Bełchatów and other CCS projects which are under planning. It is also involved in planned pilot CO_2 injection (sandstone Jurassic aquifer) supported by all major power companies operating in Poland. The research facility will be constructed within PGI (wells/monitoring). By now research injection permit has been obtained (27 kt CO_2) and contract negotiations completed.

Active role: Research performer in WP1, WP2, WP3, WP4 and WP5.

Key personnel:

Adam Wójcicki, Ph.D. is a geophysicist, involved in CCS activities supported by the EU FP6 since 2004 (CASTOR, EU GeoCapacity, CO2NetEast) and domestic projects (e.g. WebGIS CCS atlas of Poland). Since 2008 working at PGI-NRI, integrating national projects and activities on CO_2 geological storage led by PGI-NRI. This includes coordination of the national programme „Assessment of formations and structures for safe CO_2 geological storage, including monitoring plans". He provides expertise and studies to stakeholders interested/involved in CCS activities in Poland, including the Polish pilot injection project and demos. Involved in CCS networking activities supported by the EU FP7 (CGS Europe, ECCSEL PP). Member of ENeRG network, involved in activities of CO2NET, cooperating with CO2GeoNet network since 2008.

Marek Jarosiński is Associate Professor of PGI-NRI. His principal expertise is within tectonics and geodynamics. Supervising PGI-NRI involvement in CCS demo project Bełchatów and other PGI-NRI projects. Head of the Department of Geological Mapping, where all CCS, hydrocarbon and geothermal projects are carried out.

Ewa Szynkaruk is managing the project on PGI-NRI involvement in the demo CCS project Bełchatów, storage part. The project includes supervising and elaboration of results of field works (seismic and gravity surveys, two exploration wells), and constructing models of structures - potential storage sites, together with risk analyses and elaborating monitoring plans.

Anna Feldman-Olszewska is a sedimentologist, her principal expertise is in evaluation of Jurassic sandstone aquifers for the purposes of CO_2 storage, including studies and analyses of rock samples. Participates in the National Programme and PGI-NRI project supporting the Bełchatów demo project.

Monika Konieczyńska is Head of Environmental Protection Division in PGI. Coordinating PGI-NRI involvement in the pilot injection project within the field of surface monitoring.

Wojciech Wołkowicz is an environmental geologist. His expertise includes studies on CO2 natural analogues and (by now) baseline surveys on CO2 content within soil, air and groundwater. Key monitoring specialist in the pilot project.

5. IFPEN Energies nouvelles

IFP Energies nouvelles is a public-sector research, innovation and training center active in the fields of energy, transport and environment. Its mission is to provide public players and industry with efficient, economical, clean and sustainable technologies to take up the three major challenges facing society in the 21st century: climate change and environmental impacts, energy diversification and water resource management. It boasts world-class expertise.

IFP Energies nouvelles sets out 5 complementary, inextricably-linked strategic priorities that are central to its public-interest mission. **Renewable energies**: producing fuels, chemical intermediates and energy from renewable sources. **Eco-friendly production**: producing energy while mitigating the environmental footprint. **Innovative transport**: developing fuel-efficient, environmentally-friendly transport. **Eco-efficient processes**: producing environmentally-friendly fuels and chemical intermediates from fossil resources. **Sustainable resources**: providing environmentally-friendly technologies and pushing back the current boundaries of oil and gas reserves

As an integral part of IFPEN Energies nouvelles, its graduate engineering school prepares future generations to take up these challenges.

Active role: WP leader of WP3,Task leader of Task 1.2 and 3.4. Research performer in WP2, WP4 and WP5.

Key personnel:

Gaële Valet (Business Law and Contracts Division, IFP) has 15 years of experience in the legal management of European Projects, including the negotiation of consortium agreements and specific agreements for user rights. Gaële Valet has participated in the DESCA model as an FP contract expert, in particular for drafting the provisions relating to the management of intellectual property and access rights to results.

Dr Andreas Ehinger (Scientific Management Unit, IFP) has a scientific background in geophysics (PhD). He has 15 years of experience in project and R&D management. During the last 5 years he has been involved in CCS research, in particular as coordinator of the French CCS R&D program, acting on behalf of the Agence Nationale de la Recherche. Currently he is in charge of IFP's European and international collaboration; he manages e.g. IFP's contribution to the EERA program on CO2 capture and storage.

Dr Hervé Quinquis has a PhD in structural geology and geophysics (1980). He joined Shell International in 1981 where he occupied various positions in Oil &Gas exploration around the world (UK, New Zealand, Brunei, Gabon). He joined IFPEN Energies nouvelles in 1999 as Business Development Manager.

His current activities are directly oriented towards the acceleration of the deployment of the CCS technologies and the development of advanced technologies addressing CO2 storage in particular. He is a member of AAPG and EAGE and has been involved in the organisation of numerous international events including CCS forums, workshops and conferences. He has also participated actively in the elaboration of the EERA CCS program and is IFPEN focal point for the newly formed Tri4CCS research alliance between

IFPEN SINTEF and TNO. He is a member of the Executive Committee of CO2Geonet. He will be the IFPEN representative within the secretariat of the European CCS project network starting early 2012.

6. Nederlands Instituut voor Toegepast Natuurwetenschappelijk Onderzoek (TNO)

TNO is the largest fully independent Research, Development and Consultancy organisation in the Netherlands, with a staff of over 4,200 and a total annual turnover of close to 700 million Euros. TNO's primary tasks are to assist and support trade and industry, including SMEs, governments and others in innovation and solving problems by rendering services and transferring knowledge and expertise. TNO participates in many EU programs aiming at technological development. TNO is organised in seven thematic core groups. Researchers from three of these core groups have been involved in CCS for nearly 20 years. The core group Industrial Innovation has been pioneering in CO_2 capture and clean combustion technologies and materials studies for transport. While the core group Energy has been involved in areas such as underground CO_2 storage, decision support systems, HSE studies, the core group Built Environment has been covering the climate effect of energy transition by means of in-situ and remote earth observation techniques. TNO coordinates the Dutch CATO-2 CCS study that started 2 years ago (2009) and will last for a minimum of 2 years, involving over 90 million Euros in research investments both from government and industry. The Geological Survey of The Netherlands, part of TNO Energy, is involved in the prequalification study of some 12 CCS pilot plants both on- and off-shore the Netherlands, in aquifers and in depleted oil and gas fields.

Active role: Leader of WP4. Leader of Tasks 3.5, 4.1 and 5.2. Research performer in WP1, WP2.

Key personnel:

Emile Elewaut (Geoscientist) is Director International Affairs at TNO – Energy. He is also account manager for the European Commission projects and activities. Since 2007 he is the Executive Director of the European Economic Interest Grouping of European Geological Surveys and was the Secretary General in Brussels for EuroGeoSurveys from 2001 to 2004. A former CCS expert from 1992 until 2001, he is now involved in long term strategy planning, contract evaluation and alliance management for TNO (developing strategic alliances between different research organisations and universities worldwide).

Rens Kloppenburg is Attorney at Law at TNO Corporate. He has specialised on European Corporate and Commercial law issues.

Kees van Strien graduated in Economy and is presently a controller at TNO Energy. He has extensive experience in setting up integrated research laboratories between the TNO organisation and different Universities.

Dr Sven van der Gijp is currently manager of the group Separation Technology of TNO Industrial Innovation, Delft, the Netherlands. This research group focuses on CO_2 capture and sour gas treatment. Van der Gijp is executive board member of two European projects in the field of CO_2 capture, CESAR and DECARBIT. In addition, he is member of the general assembly of the Dutch platform on CCS, CATO-2. Van der Gijp has a MSc in catalysis and a PhD in Material Science.

Peter van Os is Project Manager at TNO Science & Industry with a technical background in Embedded System Development. 20 years of experience as a Hard- and Software engineer, System Engineer and Project Manager for projects in the field of industrial inspection and robotics. Currently: Project Coordinator of the EU FP7 project CESAR.

7. Deutsches Zentrum für Luft- und Raumfahrt e.V (DLR)

The Institute of Combustion Technology (DLR-VT) is part of the German Aerospace Centre. The expertise of the Institute applies to fundamental and applied research in technical combustion processes aiming at: 1) Reduction of pollutants, like soot, NOx, and unburned hydrocarbons; 2) Flame stability, linked to ignition, extinction, and thermo acoustics; 3) Combustion fundamentals, like characterisation of fuel properties especially with respect to future alternative fuels.

Active role: Research performer in WP1, WP2, WP3, WP4 and WP5

Key personnel:

Dr Peter Kutne (PhD in physical chemistry) has been working since 2004 at the DLR on the application and development of laser measurement techniques for combustion diagnostics. Kutne is member of the workgroup "IGCC with Pre-combustion Capture" from the COORETEC initiative of the Federal Ministry of Economics and Technology, and has since 2005 been working as a project leader for several projects on CO_2 reduction

Dr Manfred Aigner (PhD in Mechanical Engineering) is an ordinary Professor at the University of Stuttgart and has been in charge of the DLR Institute of Combustion Technology since 1998. Before this, he worked 13 years for ABB power plants, last position Vice-President Gas Turbine Basic Development. Beside his work in the institute he is highly engaged in coordination of regional, national and international research related to CCS: -EC 5FWP: EAG Non-Nuclear Energy (Member and Vicechair) and E-WoG (energy rel. work. group); -G8 workshop for energy research 2005: German delegate for fossil based systems; -Cooretec programme: advisory board and Co-Speaker combined cycle pp; -Iniator of the pub.-priv.-part. KW21 in Baden-Württemberg -IEA 2005; since 2006: Member Technology Taskforce of EC-Technology platform Zero Emission Power plant.

8. The Fundación Ciudad de la Energía (CIUDEN)

CIUDEN is a research and development institution created by the Spanish Administration in 2006 and fully conceived for collaborative research in CCS thus contributing to the strengthening of the industrial and technological base in Europe. CIUDEN´s main objectives are the research, development and demonstration of efficient, reliable and cost effective CCS and CCT through the design and operation of a large scale integrated test facility for advanced technologies on CO_2 capture (coal power) plus a pilot for geological storage of CO_2 in saline aquifers. The aim of the latter is to quickly develop Spanish know-how on geological storage of CO_2 in saline aquifers for environmental safety and technological and economically viability. CIUDEN TDC (Technology Development Centre) will offer outstanding opportunities to test at a more suitable scale on CCS through its full fuel preparation unit, 20MWth PC boiler and 30MWth circulating fluidised bed (CFB) boiler, full flue gas depuration train, CO_2 cleaning and purification unit (CPU) and its transport rig. CIUDEN participates in the several important forums, associations and platforms related with energy, fossil fuels and CO_2.

Active role: Leader of WP5. Leader of Task 5.1. Research performer in WP1, WP2, WP3 and WP4.

Key personnel:

Modesto Montoto San Miguel, is the Director of the CO2 Geological Storage Programme of CIUDEN since May 2007. He has been working for the University of Oviedo as Professor, as Vice-Rector for Planning and Development, as Dean of the Faculty of Sciences and as Director of the Department of Petrology. His main area of Research is Petrophysics, where he created an internationally recognized workgroup, within the University of Oviedo.

Pedro Otero, Technical Director of CIUDEN, formerly Head of Technical Department of 1312 MW Compostilla PS., has worked for the cement industry and for more than 25 years in power generation, participating in more than 20 projects of applied research. BS in Chemistry (Chemical Engineering) by U. of Santiago de Compostela; MS in Engineering & Environmental Management and MBA by the Industrial Organization School (Madrid).

 Pag. 594

Fernando Torrecilla Molina, Director of Public Outreach and International Communication at CIUDEN. Has been involved in a variety of cabinets of science policy in Spanish Governments in order to improve communication between the scientific community and society and promote contacts with journalism in scientific and technical communication. He focuses on the communication technology side of newest Spanish science facilities

Tomás Coca, project engineer at CIUDEN Technology Center was the Worksite Manager of the erection of CIUDEN´s facilities and Coordinator of CIUDEN´s team during the construction. As Chemical Engineer by the University of Nottingham and MSc on Water technologies by Cranfield University, he has extensive experience on the water and refining sector.

Manuel Gómez, project engineer of CIUDEN with experience in process engineering. Integrated Design of Chemical Plant, Postgraduate course at Leeds University and MSc in Chemical Engineering at University of Cantabria.

Daniel Fernández Poulussen, Degree in Geology. 3 years of experience in technical management for the CO2 Geological Storage Programme of the Fundación Ciudad de la Energía (CIUDEN). He is currently working on the Spanish EEPR-Project for the CO2 Geological Storage Programme of CIUDEN.

Nelly Castilla, Legal Counsel, Fundación CIUDEN. She has worked in the energy field for 5 7 years in particular for European and Spanish research centerscentres where she has been dealing with legal issues related to R&D projects and in particular with IPR issues. She is currently providing legal support to CIUDEN CO2 TDP Capture projectprogramme.

Dr. Francisco Muñoz, is Assistant Professor, Chem. and Env. Eng. Dept. University of Seville and junior researcher at CIUDEN. His professional career has been focused on R&D projects related to pollutants control and abatement, and operation and maintenance of pilot plants in the framework of international and national R&D projects.

Belén Fernández, Institutional and Political Relations Technician at CIUDEN. Graduated in Political Science and Sociology, specialized in International Relations. Extensive experience with Public Administrations and currently involved in the "Research and Civil Society Dialogue: towards a low-carbon society" European project..

9. British Geological Survey (BGS)

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and a component body of the Natural Environment Research Council (NERC), one of the UK's seven Research Councils. The BGS is the United Kingdom's premier centre for earth science information and expertise, employing around 800 staff and operating a series of state-of-the-art research laboratories with an international reputation for long-term, process-based research in support of model development and performance assessment particularly related to CO2 sequestration and radioactive waste disposal. BGS coordinated the ground-breaking Joule 2 project in the mid-1990s and has subsequently taken a leading role in CCS research via a number of characterisation, storage capacity estimation, performance assessment and site monitoring projects. BGS also provides advice to the UK Government in developing the UK legislative framework for CO2 storage.

Active role: Deputy leader (storage) of Tasks 3.2 and 4.2. Research performer in WP1, WP2 and WP5.

Key personnel:

Shaun Reeder is Head of Science Facilities with responsibility for the management of all BGS's laboratories (analytical geochemistry; mineralogy, petrology and biostratigraphy; physical properties; and fluid processes research) and science facilities (marine, drilling, geophysics, hydrogeology and image analysis).

Jonathan M Pearce has over 15 years of experience in the geological storage of CO2, leading and undertaking a range of research activities in the areas of CO2-fluid-rock interactions, near-surface

 Pag. 594

monitoring and assessing impacts of leakage. He has provided advice to industrial and national project developers on a number of CCS projects internationally and across Europe.

Dr Jon F Harrington is a senior research scientist with specialist expertise in the transport and mechanical properties of low permeability materials and extensive experience in research-quality testing. He is Facility Leader for the Fluid Processes Research laboratories and project manager for numerous scientific studies.

Dr Helen J Reeves is an engineering geologist with 13 years' post graduate experience. She is currently Team Leader for geo-engineering properties and processes research and Facility Leader for the Physical Properties laboratories. She is also currently acting Head of Science for the Land Use & Development programme.

Simon J Kemp is a mineralogist with over 24 years' experience of mineralogical investigations and an international reputation in clay mineralogy and X-ray diffraction (XRD) analysis. He is Facility Leader for the Mineralogy, Petrology and Biostratigraphy laboratories.

Dr Michael H Stephenson has extensive experience of research in petroleum geology and biostratigraphy. He is Head of Science for Energy at the BGS with responsibility for managing a large program of research into carbon capture and storage, clean coal, renewables, oil and gas and advanced seismic techniques.

Dr Nick J Riley MBE is coordinator of the European Research Network of Excellence on Geological CO2 storage and President of its legal entity (the CO2GeoNet Association). He is Head of Science Policy Europe & Grants at the BGS, with responsibility for developing and initiating BGS's scientific collaboration in Europe.

Christopher Luton is Head of IPR at BGS. He is a lawyer with specialism in intellectual property management, commercialisation of research outputs, contract negotiation and company set-up.

10. Bureau de Recherches Géologiques et Minières (BRGM)

BRGM, France's leading public institution in the Earth Science field, has three main activities: scientific research, support for government policy, and international cooperation and development assistance. BRGM has been among the pioneers in research on CO_2 geological storage, participating from 1993 in the first European research project (Joule II) and in the first commercial CCS operations worldwide (Sleipner, Weyburn, In Salah, etc.). BRGM also carries out research activities in natural CO_2 fields, such as Montmiral in France, and at natural CO_2 seepage areas in Italy, Germany and France. Its fields of expertise are site selection and characterisation, predictive modelling, risk analysis, monitoring and safety management, thus addressing a wide range of the issues related to CO_2 geological storage. BRGM has been the manager of the CO_2GeoNet European Network of Excellence on the geological storage of CO_2, initiated in 2004 through an EC FP6 contract, now a legally registered Association under French law. As a continuation BRGM is currently the coordinator of the FP7 coordination action CGS Europe that brings together research institutes working on CO_2 geological storage from across Europe.

Active role: Deputy leader (storage) of Task 3.3. Research performer in WP1, WP2, WP4 and WP5.

Key personnel:

Dr Isabelle Czernichowski-Lauriol (PhD in Geosciences and Engineering Degree in Geology) has since 1993 been involvedin many European projects on CO_2 geological storage and has been managing the BRGM research activities in this field. She has been CO_2GeoNet Network Manager under the FP6 contract. She is currently President of the CO_2GeoNet Association and coordinator of CGS Europe. She has responsibilities in the ZEP Technology Task Force, the CO2NET Board, IEA GHG Executive Committee and EERA initiative.

Dr Hubert Fabriol (PhD in Applied Geophysics) currently manages the Safety and Impacts of CO_2 storage unit at BRGM. He has been involved in CO_2 storage research since 1993 (projects Joule II, SACS, Weyburn, GRASP, CO2ReMoVe, CO_2GeoNet). He has coordinated the 'Géocarbone Monitoring' project funded by the French Agency for Research. He is member of the CSLF Risk Assessment Task Force and the IEA GHG monitoring network. He gave advice to the French Ministry of Environment for the London Convention and OSPAR discussions on CO_2 sub-sea bed geological storage, the transposition of the European directive, etc.

Marie Gastine obtained an environment engineering degree of Politecnico di Milano and an engineering degree of Ecole Centrale Paris. She joined BRGM in 2007 and has been working on CO_2 Geological storage flow modeling. She has been involved in different European project (CO2GeoNet, CGS Europe, COMET). Since 2011 she participates in the ZEP communication task force.

11. The National Institute of Oceanography and Applied Geophysics (OGS)

The mission of The National Institute of Oceanography and Applied Geophysics (OGS), a national Italian institute under the control of the Ministry of University and Research, is to promote, coordinate and perform, in collaboration with other national, international, and European institutions, studies and research on the Earth and its resources related to: applied geophysical and environmental disciplines; marine sciences; seismicity, hydrodynamic and geodynamic phenomena.

The institute, with offices in Trieste, Udine and Rome and a staff of about 270 (about 100 on temporary contracts), has a long tradition in geophysical exploration, on land and at sea, as well as in physical oceanography, marine biology and Earth observation. OGS coordinated or participated in more than 70 EU-funded research and demonstration projects in the fields of Energy, Environment and Marine Sciences, among these CO2NET2, Castor, INCA-CO2 , CO2GeoNet, Geocapacity, CO2ReMoVe, MOVE-CBM, RISCS, Sitechar, CO2CARE, CGS Europe, ECO2 and ECCSEL all dealing with CO_2 geological storage. At national level, OGS participates in all running projects on CO_2 geological storage (of ENI, ENEL, Carbosulcis) and manages the Secretariat of the Italian CO_2 Club. Moreover, OGS holds the Secretariat General of the CO2GeoNet Association, the European network of Excellence on the Geological Storage of CO_2.

Active role: Leader of WP2. Leader of Tasks 2.2, 2.4. Deputy leader of Task 3.3. Research performer in WP1, WP4 and WP5.

Key personnel:

Alessandro Crise, degree in Physics, OGS permanent staff since 1981, is presently the Director of the Department of Oceanography. Author of numerous scientific papers published in highly rated peer-reviewed journals, he is partner of major European projects focused on operational oceanography and biogeochemical modelling of the Mediterranean Sea (among others, MFSTEP, CIRCE, MERSEA, SESAME, MyOCEAN, SESAME, the forthcoming PERSEUS). Dr Crise is member of relevant Italian and international committees on marine sciences (ESF Marine Board, POGO) and operational oceanography (e.g. EuroGOOS board, MOON). Moreover, he acts as referee for scientific journals and several institutions including the Italian Ministry for University and Research, the European Commission, the French Research Agency, IFERMER, The British National Environmental Research Council and Italian PNRA.

Dr Franco Coren, PhD in environmental geophysics, started his career as researcher in 2D and 3D multichannel seismic data processing and interpretation. In 1997 he started a research group in the field of airborne laser scan and SAR (synthetic aperture radar) remote sensing with peculiar attention to interferometry at OGS. Principal Investigator in two European Space Agency projects, he is advisor for the State Attorney Board and has held teaching activities at United Nation Industrial Development Organisation of Trieste. From 1996 to 2006 Coordinator of research group CARS – Cartography and Remote Sensing, presently he is Head of Department of Geophysics of Lithosphere.

Dr Paola Del Negro, biologist, master's degree in Aquaculture and PhD in environmental science, is leading the OGS research group “Marine Biogeochemistry and Ecosystems”. Her main expertise is in marine microbial ecology and processes, and ecosystem functioning under different environmental stresses (hypoxia, anoxia, chemical contamination, CO_2 increase, pH decrease). These research taks were mainly performed in the Adriatic Sea (coasts, open waters and lagoons), in the Ross Sea (Antarctica) and in natural CO_2 leaking sites (Panarea-Italy). She has also been involved in several FP7 CO2 related projects as RISCS (Research into Impacts and Safety in CO_2 Storage), ECO2 (Sub-seabed CO2 Storage: Impact on Marine Ecosystems) and MedSeA (Mediterranean Sea Acidification in a changing climate.

Dr Cinzia De Vittor holds a BSc in Biological Science, a master in Aquaculture and a PhD in Environmental monitoring and methods. Her research focuses mainly on the biogeochemical cycle of carbon in the marine environment and fluxes of organic and inorganic carbon, nitrogen and phosphorous at the sediment-water interface. She participates in some CO_2 related projects, as RISCS (Research into Impacts and Safety in CO_2 Storage), ECO2 (Sub-seabed CO_2 Storage: Impact on Marine Ecosystems) and Eurofleet - PaCO2 (The Panarea natural CO_2 seeps: fate and impact of the leaking gas). She has been scientific coordinator, for the OGS-BIO department, of the Pre-injection off-shore baseline survey project in an area closed to Porto Tolle (Italy), identified as a potential CCS site.

Dr Michela Vellico, an Environmental Engineer with a PhD in Applied Geophysics and Hydraulics, has been working at OGS since 2003. Her main expertise is in remote sensing techniques and their use for CCS. She has been involved in the following EC projects: CO2 GeoNet (testing the use of remote sensing methodologies in the leaking sites of Latera and Laacher See), Geocapacity (providing datasets to the European WebGIS of storage sites, and storage capacity calculation), Enhygma (applying remote sensing techniques to hydraulic risk prevention). She has also contributed to national projects related to CCS (for ENEL and Cesi Ricerca).

Davide Deponte, degree in Electronic Engineering, is responsible for management and development of electronic instruments in the Oceanogaphy department. During the last 10 years, he has been involved, in all the main projects of the department, as responsible for time series data acquisition, starting with PRISMA1 and leading up to VECTOR. Since 1998, he has contributed to the development of automatic meteo-oceanographic buoys for coastal monitoring projects. More recently, he has been the coordinator, for the oceanographic part, of the project 'CO2 Pre-injection Off-Shore Baseline Survey', performed by OGS for ENEL.

12. Centre for Research and Technology Hellas / Institute for Solid Fuels Technology and Applications (CERTH/ISFTA) is a legal non-profit entity, under the auspices of the General Secretariat for Research and Technology of the Greek Ministry of Education. CERTH/ISFTA is the main Greek organisation for the promotion of research and technological development aiming at the improved and integrated exploitation of solid fuels and their by-products. CERTH/ISFTA is actively involved in clean coal technologies and CCS technologies and represents Greece in the Carbon Sequestration Leadership Forum, the Global CCS Institute and in the European Technology Platform on CCS. The Institute participates, amongst others, in several EU-funded research projects on the monitoring of CO_2 in natural analogues, the underground coal gasification for CCS, capture technologies, as well as public awareness of CCS.

More specifically the current projects of the Institute are as follows: a) FP7 Project RISCS ("Research into Impacts and Safety in CO_2 Storage") leading the WP – Naturally-leaking sites in southern Europe (Assessing potential impacts in the terrestrial environment – southern Europe) through the conduction of sampling, field measurements and geochemical, biological, and botanic analyses of natural CO_2 seeps in Greece and Italy (Florina, San Vittorino, Latera), b) RFCS Project UCG-CO_2 ("Study of Deep Underground Coal Gasification and the Permanent Storage of CO_2 in the Affected Areas"), c) FP7-SCIENCE-IN-SOCIETY-2011-1 Mobilisation and Mutual Learning Action Plan on societal challenges towards the development of renewable energies and CCS for a low carbon society, d) RFCS project Modelling and experimental validation of Calcium Looping CO2-capture process for near-zero CO_2 emission power plants (CAL-MOD), e) FP7–INFRASTRUCTURES–2010-1 European Carbon Dioxide Capture and Storage Laboratory (ECCSEL) project and f) EUROFLEET FP7 Panarea natural CO_2 seeps: fate and impact of the leaking gas (PaCO_2) project. Furthermore CERTH/ISFTA leads a National Network with members from the Electricity sector as well as the Cement Industry. In addition, CERTH/ISFTA has recently completed a techno-economic study related to the feasibility of a CCS demo project in Northern Greece for the Public Power Corporation of Greece.

Active role: Leader of Task 2.3. Research performer in WP1, WP3, WP4 and WP5.

Key personnel:

Dr Nikolaos Koukouzas is a Geologist and holds a MSc and a PhD in Industrial Mineralogy. He has more than 20 years of experience in power production, CO_2 emissions, carbon capture and storage technologies, industrial mineral applications, coal mining, coal combustion by-products utilisation, co-combustion of coal with biomass related topics. He was appointed to the European Commission, DG Energy & Transport, as Detached Expert in Coal Technology (1999-2003). Presently, he is the Director of Research in CERTH/ISFTA, managing the research activities of the Institute. Dr Koukouzas was involved in the Project Management Group of Enhanced Capture of CO2 (ENCAP) Project, and he is scientifically responsible for various on-going and completed EU and national Projects (FENCO ERANET, RISCS, C2H, UCG-CO2, ECCSEL, Greece-Czech Republic and Greece-USA bilateral projects). He is the author of over 150 publications in scientific journals and conference proceedings.

Vassiliki Gemeni has a Master in Applied Environmental Geology. For the last three years she has been working as a scientific researcher in CERTH/ISFTA, involved mainly in CCS R&D projects. Her recent scientific activities include on-going European projects such as FP7 RISCS ("Research into Impacts and Safety in CO2 Storage") and UCG-CO2.

Fotini Ziogou is a Chemical Enginer and holds a Master's Degree in Business Administration. She has been working for 7 years in the French multinational company AIR LIQUIDE HELLAS as a Production Engineer of air and CO_2 liquefaction plants in North Greece and supervising engineer at the Florina natural CO_2 deposits for the commercial exploitation of CO_2 as an industrial gas. Since 2006 she has been working for CERTH/ISFTA as a Scientific Co-operator implementing European and national R&D projects dealing with CCS technologies (ENCAP, FENCO - ERA.NET, Greece-Czech and Greece-USA bilateral projects etc.). She currently participates in the on-going FP7 RISCS project.

13. Swiss Federal Institute of Technology Zurich (ETH Z)

Founded in 1855, ETH Zurich is a science and technology university with an outstanding research record. ETH Zurich is the study, research and work place of 20,000 people from 80 nations (25% of which are women). About 4000 professors in 16 departments teach about 16,000 students (3,500 of which are Ph.D. students) mainly in the engineering sciences and architecture, system-oriented sciences, mathematics and natural sciences areas, and carry out research that is highly valued worldwide. Twenty-one Nobel Laureates have studied, taught or conducted research at ETH Zurich, which underlines the excellent reputation of the institute. Maintaining and developing its top standing in the international competition among top universities is an important task of ETH Zurich.

ETH Zurich orients its research strategy around global challenges such as climate change, world food supply and human health issues.

ETH is a member of CO2NET and CO2NET2, the specialised Thematic Network sponsored by the EC under FP5 and FP6, moreover ETH operates in the European Energy Research Alliance (EERA), in DECARBit and in ECCSEL (European Carbon dioxide Capture and Storage Infrastructure), in the framework of FP7.

Active role: Leader of Tasks 3.3 and 4.3. Research performer in WP1, WP2 and WP5.

Key personnel:

Prof. Dr Marco Mazzotti has been a professor of process engineering at ETH Zurich since May 1997. He has a Ph.D. in Chemical Engineering from the Politecnico di Milano. His research activity deals with adsorption-based separations and chromatography, and with crystallisation and precipitation processes. Mazzotti has been coordinating lead author of the IPCC Special Report on Carbon Dioxide Capture and Storage (2002-2005). He is also an active member of the AIChE, of the Working Party on Crystallisation of the EFCE, and vice-President of the International Adsorption Society. He was the chair of the 9th International Conference on Fundamentals of Adsorption FOA9 (Italy, May 20-25, 2007), and of the 18th International Symposium on Industrial Crystallisation (Switzerland, September 15-16, 2011). His refereed publications include more than 180 journal articles, 20 articles in books and 6 book chapters.

Dr Alba Zappone received her PhD at the University of Milan in 1993. Since then she has been working in the field of laboratory measurements of physical parameters of rocks. During the last years, she has devoted her attention to the topic of seismicity induced by fluid injections (geothermal plants and CO2 storage sites). In 2010 she joined the group of Prof. Mazzotti and works in projects in the fields of CCS.

14. Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

ENEA is the Italian national agency for new technologies, energy and sustainable economic development. Its two fundamental tasks are to conduct research in these areas and to diffuse the results nationally. More particularly, ENEA's activities involve: i) research, development and testing of innovative technology and equipment, and transfer of innovations to industry; ii) development of technologies, equipment and components designed to exploit renewable energy sources and to save energy, and stimulation of demand for them; design, construction and testing of demonstration plants. ENEA, with a general mandate from the Italian Parliament operates according to the directives from the Ministry of the economic development – together with that of environment and of research – in national and international programmes on energy saving and sustainable use of fossil fuels, mainly supporting the Italian industry; furthermore, ENEA acts as advisor and supports the above mentioned Ministries.

In this context ENEA is involved in CCS technologies, where it operates in strict coordination with its controlled company SOTACARBO (located in Sardinia), covering all the aspects of CCS, from CO2 capture to storage, from generation of energy – eventually combined with hydrogen – to system integration, and also the fields of communication and dissemination of results.

In Italy there are several programmes for promoting Research and Innovation in CCS, focused on basic research, industrial and pre-competitive research, demonstration and dissemination: ENEA is the main actor in this context, working in strict cooperation with its controlled company SOTACARBO. Moreover, ENEA (Dr Girardi) operates in the International Flame Research Foundation (IFRF), in CSLF (technical group), in the European technological platform ZEP (Task Force "Technology), the European Energy Research Alliance (EERA), the European "Coal & Steel Committee" (COSCO), and in the IEA implement agreement. Dr Girardi is the national representative in CCS EII Team of SET Plan.

Active role: Research performer in WP1, WP2, WP3, WP4 and WP5.

Key personnel:

Giuseppe Girardi (ENEA). Graduated in Mechanical Engineering from University of Rome, he joined ENEA in 1978. He has directed the Measurement Methods Laboratory, and then the Diagnostic & Control Section of the Engineering Division, operating in basic and industrial oriented research activities. During the last decade he has been head of the Energy Plants and Processes and manager of Clean Coal/Zero Emission Project at ENEA. Now he is responsible for sustainable fossil fuels and CCS programmes at ENEA, and manages several programmes on CCS technologies (pre, post and oxy combustion), in cooperation with industrial entities (ENEL, Techint, Carbosulcis), universities and research organisations. He is VicePresidente of Sotacarbo, and member of several Italian and international organisations.

Stefano Giammartini (ENEA). Degree in Nuclear Engineering at University of Rome "La Sapienza" in 1981. Researcher in ENEA since March 1984. Responsible for the Nuclear Laboratory of the Engineering Department in ENEA from October 1993 to June 1997. Responsible for the "Combustion Technology" Laboratory since June 1997 to December 2001. Responsible for the Sustainable Combustion Processes Laboratory of ENEA from 2010. He has been the coordinator of several research projects financed by ENEA, the Italian Industry and Scientific Research Ministry and by EC, related to technologies for sustainable use of fossil fuels. He has been member of the Board of the Italian Section of the Combustion Institute

Dr Paolo Deiana (PhD in mechanical design) is responsible for a working group operating on coal gasification with CO_2 capture and storage (ECBM and saline aquifers technologies) at ENEA-Cascadian centre as well as at SOTACARBO research centre in Sardinia. He is responsible for a pre-combustion CCS project funded by the Ministry of Economic Development, and is involved in a national initiative aimed at realising a new demonstration plant in Sardinia.

Dr Antonio Calabrò (Graduated in Nuclear Engineering) is responsible for a team working in the energy processes analysis and simulation. He is an expert in thermal and chemical process analysis, modelling and simulation. He coordinates several projects on hydrogen and energy production from coal with CO_2 capture, as well as the design and realisation of the Coal Zero Emission experimental plant (ZECOMIX).

Dr Eugenio Giacomazzi (PhD in Theoretical and Applied Mechanics). He has participated in several national and international projects in combustion and space propulsion systems and teaches classes on turbulence and combustion modelling at the Aerospace Engineering School of Rome.

Stefano Stendardo (ENEA) (Master degree in Mechanical Engineering, and PhD on Mathematical-Physical Modelling within Chemical Engineering). Expertise in experimental and modelling of fluidised bed reactors with respect to CO_2 capture with solid sorbent. He worked as a researcher at the Joint Research Centre of The European Commission within the Clean Coal and Biomass (CLEANCAB) action. In his current job at ENEA, he is involved in both experimental and modelling activities in the field of carbon capture.

Claudia Bassano (ENEA) (Chemical engineer). Since 2006 researcher at ENEA Energy Dept, is currently involved in activities in the field of CCS technologies related to experimental plant design and managing. She is also an expert on modelling and simulation of coal to liquids plants and power plants integrated with CO_2 capture systems. At the moment, she is a PhD student in chemical engineering, preparing a thesis focused on coal-to-liquid technologies. She is the author of several publications in the field of energy production and hydrogen from coal and biomass.

Dr Guido Troiani (ENEA) received his PhD in fluid-mechanics from the Faculty of Engineering of the University of Rome “La Sapienza” (2004). He was employed as a post-doc researcher at ENEA research center in the field of turbulent combustion in 2006, and is now a researcher in combustion and fluid-mechanics at ENEA. His main topics of interest are the interactions between turbulence and combustion, flame chemiluminescence emissions, fractal aspects of flame fronts and heavy particle dynamics from a theoretical and experimental point of view.

15. Research Council of Norway (RCN)

The Research Council of Norway (RCN) is Norway's official body for the development and implementation of the overall national research strategy. The Council is responsible for enhancing Norway's knowledge base and for promoting basic and applied research and innovation in order to help meet research needs within society. RCN also works actively to encourage international research cooperation.

The Research Council serves as an advisory body on research policy issues, identifies research needs and recommends national priorities. Through the establishment and implementation of targeted funding schemes, RCN facilitates the translation of national research policy objectives into action. The total budget (2011) amounts to NOK 6922 million (around 890 M€). RCN also serves as a meeting place for researchers, funders and users of research findings. A staff of about 400 people are employed in the Research Council.

RCN is responsible for the funding of R&D, Research Centres within Environmentally Friendly Energy and research infrastructure. In collaboration with the state-owned company Gassnova, RCN organises the R&D&D program CLIMIT, with a total funding of 23 M€ in 2011. Climit supports technology for Carbon Capture and Storage (CCS) applied to fossil fuel based power generation and industrial point source emission. Two new research centres, designated Centres for Environmentally Friendly Energy within CCS, have been sponsored by Climit since 2009. These are the International CCS Research Centre (BIGCCS) at SINTEF, Trondheim, and the SUbsurface CO_2 storage - Critical Elements and Superior Strategy (SUCCESS) at CMR Bergen.

RCN is also responsible for the national long term financing initiative for research infrastructure, with a 360 M€ budget over a 10 years period. This amount is allocated for investments in new research structures and major upgrades to facilitate high quality science in meeting the needs of the society, the business sector and the high calibre research in a more efficient manner.

Pag. 601

Active role: Contributing as advisor in WP1 and WP2 - with guidance, anchoring and strategic negotiation related to the following tasks: Legal framework and governance structure, Political and institutional support, Financing strategy and legal issues through the policy contact group.

Key personnel:

Åse Slagtern (Senior Adviser) has experience from SINTEF as a researcher, project manager and Research Director for Department of Hydrocarbon Process Chemistry. She has also experience from front-end engineering in Aker Solutions related to CO_2 management and gas technology. Although she started to work in the Research Council of Norway in 2011, she has prior experience from collaboration with the Research Council through projects, programme committees and boards in previous industrial projects and EU projects. In RCN she will coordinate the funding of CCS research.

Jon Børre Ørbæk (Senior Adviser) has experience from polar, atmospheric and climate research as well as research infrastructure networks funded by the EC. He is now coordinating the national research policy with respect to ESFRI within the Research Council of Norway.

Pag. 601

2.3 Consortium as a whole

Consortium capabilities

The consortium represents the **core of CCS research in Europe**. It is committed to **provide the prerequisites** necessary for bringing up the **new research infrastructure, ECCSEL**, to the level of legal and financial maturity required to implement it. The partners agree that the **quality** of this preparatory work will **reflect the capability, skill and experience of the consortium** as a whole. Hence, the **consortium** is designed so as to be **adequately sized** and to have the **appropriate composition** for its duty.

The 15 partners have experience from previous EU-projects – partly in joint undertakings. In particular, all partners assigned to be in charge of the work packages have **prior experience from the coordination of integrated EU projects**, whereby the professional management of the present project is deemed to be ensured. Partners assigned to be in charge of the underlying tasks are **selected according to the merits** of the partner institutions and of the persons involved.

Furthermore, the human resources made available to the project cover the **full range of proficiencies**, such as scientific, legal, financial and R&D management skills.

The consortium comprises **eleven research institutes**, **two universities**, and **two national research councils/agencies**. **10 partners belong to EU** member states (Poland, France, UK, Germany, Italy, Spain, The Netherlands and Greece) and **5 partners to associated countries** (Norway and Switzerland).

The rather high number of partners is considered to allow for **effective execution of the project**. It is expected, however, that the **consortium will grow** when ECCSEL enters the implementation phase, as members of the Reference Group are expected to apply for partnership.

Involvement of Stakeholders

The **Reference Group** comprises R&D-providers and industrial players that support the development of CCS in Europe. **Two national agencies** (the Research Council of Norway and ENEA, Italy) are part of the Consortium.

The ECCSEL consortium is in receipt of an official **Letter of Intent from** from the UK, Italy, Spain, France, Switzerland, Italy and Norway. These nations have stated explicitly are in support of the project, although yet without firm commitments.

A link to **relevant industrial players** is guaranteed through the participation of members of the consortium of the present project who take part in large national R&D projects and Centres of Excellence, as well as through partnership in the ZEP-TP, EERA (European Energy Research Alliance), CSLF (Carbon Sequestration Leadership Forum), IPCC, and national networks and initiatives.

Scientific and territorial complementarities

As indicated in Table 2.2, the Consortium covers all scientific areas pertaining to CCS in a complementary way.

Table 2.2 *Scientific areas covered by the ECCSEL PP Consortium.*

Participant	Post-combustion processes	Pre-combustion processes	Oxy-combustion processes	Transport	Storage
NTNU	✓	✓	✓	✓	✓
SINTEF ER		✓	✓	✓	
SINTEF	✓	✓	✓		
PGI-NRI					✓
IFPEN	✓		✓	✓	✓

 Pag. 603

TNO	✓	✓	✓	✓	✓
DLR		✓	✓		
CIUDEN	✓		✓	✓	✓
BGS					✓
BRGM					✓
OGS					✓
CERTH/ISFTA			✓	✓	✓
ETH Zurich	✓	✓			✓
ENEA	✓	✓	✓	✓	✓
RCN	Not relevant				

Hence, the consortium is deemed **complementary also in terms of country of origin**. Access to country-specific information is considered essential to pursue the vision of ECCSEL (Section 1.1.2) in terms of financial schemes and legal issues. It is, furthermore, anticipated that the strong involvement of the Reference Group will increase the territorial balance, as ten countries are represented in the consortium (see Figure 10).

Figure 10: *Territorial distribution of the participants in the ECCSEL PP consortium*

2.3.1 Subcontracting

Subcontracting is not foreseen.

 Pag. 603

2.4 Resources to be committed

Research capacity relates to the interaction between education, research and innovation, represented by the knowledge triangle (Figure 12).

Consistent with the stated objectives (Section 1.1.3), assessment of capacities and capabilities as needed by ECCSEL is an integral part of the work plan of this preparatory project (ECCSEL PP2, 2013-2014). Efforts are required to ensure that the objectives and specific targets – as set out in Section 1.1.3 – will be achieved pursuant to the vision as articulated in Section 1.1.2.

2.4.1 Budget distribution

The total budget for the present project (ECCSEL PP2) is 3.53 million Euros, whereof the EC contribution is expected to 2.50 million Euros. The remaining 1.03 million Euros will be necessary to cover the indirect costs related to project work not financed by the EC.

About 89% of the costs will be assigned to cover work expenses, while the remaining 11% are assigned to meet travelling and subsistence expenses. The members of the Reference Group and the Policy Contact Group (PCG) will cover their own costs accrued from their engagement in ECCSEL PP2, both in terms of man hours and travel expenses.

About 93% of the work expenses is dedicated to support and coordination activities (WP1-WP5), and about 7% is allocated to the management of the project (WP6).

A monetary allocation corresponding to approximately 35 person months (374 500 Euros) is temporarily set aside in the Coordinator's budget for later allocation among the beneficiaries in WP3. This implies that 35 person months remain to be assigned to the beneficiaries in WP3. The reason is that the need for specific capabilities to carry out specific conceptual planning studies in WP3, Task 3.3, cannot be decided until the forecast study (Task 3.1) is accomplished and recommendations provided (Task 3.2). These preconditions are scheduled to be fulfilled after month 6. The ultimate assignment of these person months and the corresponding budget allocation will be decided by the appropriate consortium body, in accordance with the consortium agreement.

2.4.2 Other commitments

Two national agencies (RCN and ENEA) will uphold their roles as active participants in the project, although RCN will not be reimbursed by ECCSEL PP2.

In order to strengthen the promotion of ECCSEL, NTNU has decided to appoint a new position as project director. As this position will be paid by NTNU, only direct involvement by the project director in ECCSEL will be reimbursed by the project on account of NTNU.

The financial contribution from the Norwegian Government to ECCSEL will be based on a proper international quality assessment of the outcome of the preparative phase 2, to which the Research Council of Norway will contribute in the form of guidance, anchoring and strategic negotiation (see Support letters from funding agencies in Appendix)

The establishment of ECCSEL will be based on existing laboratories and equipment to form – in the initial phase – a cluster for experimental CCS research. In the advanced phase major upgrades and new highly laboratories will be built. These new laboratories (pilots or test sites) will require huge investments to be provided by multi-national funding sources. In recent years several partners have made significant investments in their research facilities, and they are desirous of continuing to do so in meeting the future demands. Examples of facilities that will potentially become part of ECCSEL are listed below – subject to consented and transparent selection criteria:

- CO_2 capture test facility at Tiller (SINTEF/NTNU, Norway)
- New packed column for solvent characterisation (IFP, France)
- Post-combustion coal based pilot plant at Brindisi, (ENEL, Italy)
- Oxy-combustion test facility at El Bierzo (CIUDEN, Spain)

 Pag. 605

- High pressure oxy-combustion test rig (DLR, Germany)
- Pulverised coal test facility at Amyantaion-Filotas (CERTH, Greece)
- Rock Mechanical & Geophysical Property (S&P-wave) Testing System (BGS, UK)
- Tri-axial flow cell for gas injection/displacement in ECBM applications (ETH Zurich, Switzerland)
- MONTMIRAL natural CO_2 field for CO_2 storage (BRGM, France)
- PANAREA (off-shore) and LATERA (on-shore) CO_2-leaking natural laboratories (OGS, Italy).

 Pag. 605

 Pag. 606

3 Impact

Pursuant to the call, the **scope of the project is to complete the preparatory phase** leading to the construction of a new CCS research infrastructure of European laboratory facilities and test sites devoted to CCS. The aim is to bring the project of this new research infrastructure (ECCSEL) up to the level of legal and financial maturity, as required for its implementation.

Although the immediate impact of the project (per se) will be rather limited, the **end result will have a huge impact**, as ECCSEL PP2 will **pave the ground for a new type of research infrastructure** to be formed in 2015 which will provide a **clear added value**.

3.1 Expected impacts listed in the Work Programme

The Work Programme states as follows:

> *research infrastructures play an increasing role in the advancement of knowledge and technology and their exploitation. [---] By offering high quality research services to users from different countries, including from the peripheral and outermost regions, by attracting young people to science and by networking facilities, research infrastructures help structuring the scientific community and play a key role in the construction of an efficient research and innovation environment*.

ECCSEL responds directly to the overall objective of the Work Programme: ECCSEL intends to **optimise the use and development of the best CCS research facilities in Europe**, and to create in the field of science and technology a **new research environment of pan-European interest** needed by the European scientific community.

The Work Programme furthermore lists the following expected impacts (under its section 1.2.2 *Construction of new infrastructures (or major upgrades) – preparatory phase*). The bullet points in italics (below) are extracted from this part of the Work Programme.

- *How the project may help the new research infrastructure – identified in the periodic updates of the ESFRI roadmap – to reach the level of technical, legal and financial maturity required to enable the construction work to start.*

ECCSEL was first posted on the roadmap by the European Strategy Forum on Research Infrastructures (**ESFRI[8]) in December 2008** (cf. Figure 11), and it was then the only new entrant within the energy domain.

The process behind this important event includes a close scrutiny of the European position, and a broad consultation with regard to the obvious gaps that need to be closed within existing European research laboratories and their recent availability.

The project is made up by **proficient European research institutions and laboratories**. The partners are **desirous of creating a new research infrastructure of pan-European interest**. From this base, joint efforts will be made mainly to complete the prerequisites for establishing ECCSEL, which requires a legal framework, governance structure, financing strategies, infrastructure development and technical work.

Figure 11: The ESFRI Roadmap 2008

[8] Formed in 2002 by the European Commission as the strategic instrument of the EU, ESFRI aims at developing the scientific integration of Europe and strengthening international outreach. Its members are the EU Ministries for Research. The mission of ESFRI is to support a coherent and strategy-led approach on research infrastructures (RIs) in Europe, and to facilitate multilateral initiatives that lead to better usage of RIs, at EU and international level. The first ESFRI roadmap was published in 2006. (http://ec.europa.eu/research/esfri).

 Pag. 606

Emphasis will be placed on the **structuring of future capacities, capabilities and operations** needed to **remain at the forefront of the advancement of research**, thus **enabling industry to strengthen its knowledge base** and its technological know-how.

Throughout its operational life, the ECCSEL research laboratory infrastructure will **offer**

- **access** to world-class laboratory facilities by prominent researchers and reputable industrial players
- **profound CCS expertise**, enhancing the thematic discussions and activities of ECCSEL
- extensive **analytical skills**, allowing and delivering new knowledge that will have the maximum beneficial impact on the field.

In this way the project will have a significant role to play in **fostering cooperation among partners and stakeholders within the European (and global) CCS society**.

- *Contribution to the technological development capacity and to the scientific performance and attractiveness of the European Research Area.*

The scope of the project is limited to accomplishing the preparatory phase, as required to form a new European research infrastructure. This preparatory work builds on a **vision of ECCSEL** as a future distributed research laboratory infrastructure devoted to CCS.

Main elements of this vision are based on the **state-of-the-art in science and technology combined with future needs and opportunities**. Success means that all **steps and actions must be addressed, understood and made operational**.

Three challenges that need to be addressed in order to scale up CCS research in Europe are **cost, coordination and cross-fertilisation of ideas**.

Subordinate to the **objective** of the project (Section 1.1.3), a subset of **specific targets** set out in Section 1.1.5 will be used to **define criteria for choosing direction** of the scientific and technological development – including **capacities and capabilities** required to form ECCSEL.

Adherence to these targets will affect the **quality** and quantity of the planning, which will have later impacts on the **scientific performance and attractiveness** of the European Research Area, as it relates to promotion and cross-fertilisation of new research ideas.

Research along the CCS chain will be promoted in order to integrate work that is currently organised in capture/ transport/ storage silos. **Research efforts within specific discipline areas may be pooled** in order to **overcome institutional barriers** that separate researchers within the same disciplines. A main purpose of ECCSEL is to **facilitate interaction between researchers from different organisations** in order to create new **synergies and motivation**.

Once ECCSEL becomes operational it will **draw upon expertise from its consortium** to set up and integrate its operations. ECCSEL will make use of analytical approaches to **add value to raw data, knowledge and experience** arising from projects, in order to **yield best practices from lessons learnt** and to **accelerate the deployment of CCS** in Europe and worldwide.

It is through the providing of tangible information and the sharing of advanced laboratory equipment at the present critical stage in technology development that issues of **techno-economic viability** can be quickly addressed and **solutions for commercial deployment** be devised. This kind of **derisking of the commercial CCS development** – still at laboratory scale – will increase the public confidence in CCS.

The increased research within Europe will be met via **cross-institutional and transnational access** to laboratories and facilities that must be coordinated within and between countries. ECCSEL will **foster commitment to common research objectives** and **priorities** between researchers, industry and EU demonstration projects.

Duplication of efforts and/or poor utilisation of resources shall be **avoided** by adjusting research priorities according to industrial needs and EC strategy.

- *Contribution to the Innovation Union commitment (n.5) to complete or launch by 2015 the construction of 60% of the priority European research infrastructures currently identified by ESFRI*

ECCSEL **contributes to the innovation** objectives in two different ways:

1. by **establishing and operating a world-class CCS research infrastructure** aimed at offering transnational access and conducting joint research, thus enabling researchers to generate substantial knowledge which can lead to **new innovative solutions**, such as more efficient products, processes and services relating to CCS, and thereby help to **address societal challenges** – especially the issues of **climate change** and **security of energy supply**. Innovation is reflected in the stated objective and the scope of the specific work packages, as well as in the expected impact statements.
2. by **increasing the potential for innovation** within ECCSEL and its affiliated research facilities, in particular by **reinforcing links with companies** that drive innovation. This includes activities and partnership with industry such as **transfer of knowledge** and other dissemination activities. ECCSEL will also carry out activities involving industrial researchers, and it will include industrial players in **reference group**s and for **peer review**.

Hence, the project contributes directly to commitment (n.5) by preparing all necessary aspects needed to form the new research infrastructure, ECCSEL, by 2015. This will require a **new approach to funding CCS research laboratories** to achieve future goals in a **cost-effective** manner.

The expected operations of ECCSEL will be considerable. ECCSEL will coordinate the funding of new and upgraded research laboratories to an **estimated value of 250 million Euros** provided by European, regional and national agencies. Industrial funding will be additional.

- *Increasing the potential for innovation of RIs*

Innovation is the creation of better or more effective products, processes, technologies, or ideas that are accepted by markets, governments, and society. Innovation differs from invention or renovation in being a substantial positive change rather than a modest incremental change.

In this project, a specific **work package designated "Innovation"** has been defined as part of the project. This work package addresses innovation and innovative ways of doing research within the research laboratories.

A key task of ECCSEL will be the facilitation of knowledge sharing between members, and from members to stakeholders, and funding bodies such as (inter alia) European governments, the European Commission, project proponents, and industry.

In prioritising research activities to be carried out in ECCSEL, two main directions are emphasised, i) the **academic research** (generic/fundamental) and ii) **innovation** (i.e. applied, operational, pre-normative research).

Projects belonging to the latter direction will be ranked according to their potentiality and capability for **reducing the overall energy penalty** and **lowering the levelised cost** of the CCS chain, and also for **ramping up the speed and capacity needed for CCS to become material**. These aspects are all research topics that call for **cost-effectiveness, increased research and innovation**.

Increased costs may be expected to take the form of high CAPEX and OPEX for new and/or upgraded laboratories and equipment. In this context, ECCSEL is prepared to

- allow for **resources and budgets to be pooled** in order to meet these higher costs. Cost sharing between ECCSEL partners may allow for reduced contributions from single sources.
- provide a **mechanism to create research facilities that would otherwise be unaffordable to any single institution**, thus increasing the breadth and depth of research that will be performed.

3.1.1 Education and innovation

ECCSEL also responds to Commitment n. 4, as referred to in the Work Programme: "*Opening of Member State operated RIs to the full European user community*". This will enable researchers to make decisive **contributions to the grand societal challenges in energy supply and climate change** via actions.

For ECCSEL to reside within the knowledge triangle (Figure 12), it is necessary to place emphasis on education and innovation. Hence, ECCSEL will make research facilities and services **systematically available for higher education and training**. This will in turn have a significant **impact on the skills and capabilities** of the **next generation of engineers and researchers** specialising in topics related to CCS. As these persons will subsequently make use of their experience and new knowledge, they will contribute to enhance the European knowledge base – scientifically and technologically. In any case, they will contribute to the ability of developing industry and **bringing forward CCS for successful utilisation** by society. In this manner, the value created via ECCSEL may become quite substantial.

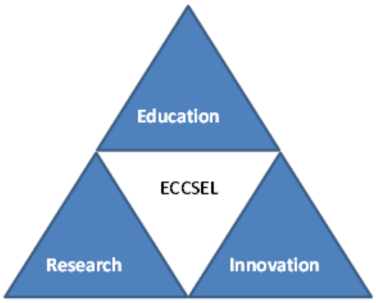


Figure 12: The knowledge triangle[9]

3.1.2 Stakeholder engagement

ECCSEL also responds to the Work Programme with regard to stakeholder involvement and engagement. Reference is given to Section 1.1.7 ECCSEL Business Plan (developed in WP1), and activities specially addressed in WP5 Communication and Networking – seeking Stakeholder engagement.

3.1.3 Socio-economic impact of ECCSEL

The project addresses socio-economic issues in various ways, such as **knowledge, scientific and technological development, education and training, knowledge transfer and collaboration** within the consortium, transnationally within Europe and internationally, especially in consideration of Australia, China and USA. In addition, the successor of the project (**ECCSEL) will have a significant impact on the employment in Europe**. First, ECCSEL will contribute to employ graduates (at MSc and PhD level) trained in facilities belonging to ECCSEL, and students using ECCSEL. Secondly, it will provide **knowledge and innovation for industries to commercialise**, which will **create job opportunities** among technology providers, energy providers and industry.

The impact of knowledge can be measured by the number of publications of **scientific papers** in impact factor journals and other periodicals, as well as the value granted to external researchers through the open access policy. Likewise, the impact of development can be recognised via the **number of national and international patents**, and also by the **number of technologies developed and transferred** (including prototypes, methodologies and designs). Finally, the impact of knowledge transfer and collaboration is identifiable via the **number of collaborative projects**, the volume of **research contracts** and competitive funding and/or international grants.

Furthermore, a successful **socio-economic analysis** (i.e. an analysis proving a solid base for investment in ECCSEL) can only be **derived from an excellent business case**. The business case has been duly developed and included in the ECCSEL Business Plan (WP1).

3.2 Strategic impact

3.2.1 Impact of EU policy on CCS

In meeting the upcoming urgency and need for technological development and improvement within CO_2 capture, transport, and storage (CCS), it becomes obvious that **moving the frontier** in technology from the state-of-the-art **is far beyond the capacity of a single nation**. Therefore, the principal aim of the Work Programme – through establishing the European Carbon Dioxide and Storage Laboratory, ECCSEL, – is to **ensure that the policy goals** of the European Union **can be achieved** as concerns the safe and swift commercial deployment of CCS within Europe by 2020 and beyond.

[9] Source: A vision for strengthening world-class research infrastructures in the ERA, Report of the Expert Group on Research Infrastructures. 2010

 Pag. 610

Through its mission, ECCSEL will **support industrial initiatives of implementing CCS,** pursuant to the **European roadmap** and the **SET-Plan**. From a SET-Plan perspective, ECCSEL will promote efficiency within the European Research Area (ERA) and it will link to the European Energy Research Alliance (EERA). Furthermore, as indicated in Figure 13, the new *CCS Research Infrastructure* (ECCSEL) jointly with the new *CCS Integrating Activities* (i.e. current ECRI-IA proposal) and the *CCS Demo Sectretariat* (CCS PNS) may have and reciprocal impact on knowledge and capacity building in the interaction between research and the commercial deployment of CCS.

ECCSEL responds to the expressed **needs for further technological development** to ensure that CCS can be deployed on a large scale in Europe and elsewhere, to **cut the global emissions of greenhouse gases by 50-80% by 2050**. According to climate modelling this tremendous reduction is necessary to limit global warming by 2°C – as pronounced by the UN and the IEA (cf. the Blue Map scenario of Figure 14 – and the CCS trajectory of Figure 2). Although the reduction must be regarded as an **unprecedented challenge** in terms of funding resources, **ECCSEL responds directly to the core of this issue**.

The European and international impact of accelerating the development of CCS for commercial use complies to the **dedication of significant and specific CCS legislation** (i.e. the CCS Directive and amendments to other Directives), the granting of significant funds to CCS commercial demonstration (EERP and NER300) and numerous CCS research projects, as well as the inclusion of CCS within the European emissions trading system (EU ETS).

ECCSEL is considered to have a **key role to play in achieving this acceleration**. The most obvious reason is that granting access to a **pool of test facilities** on a **time-sharing basis** will **enhance the intensity and value of experimental research**.

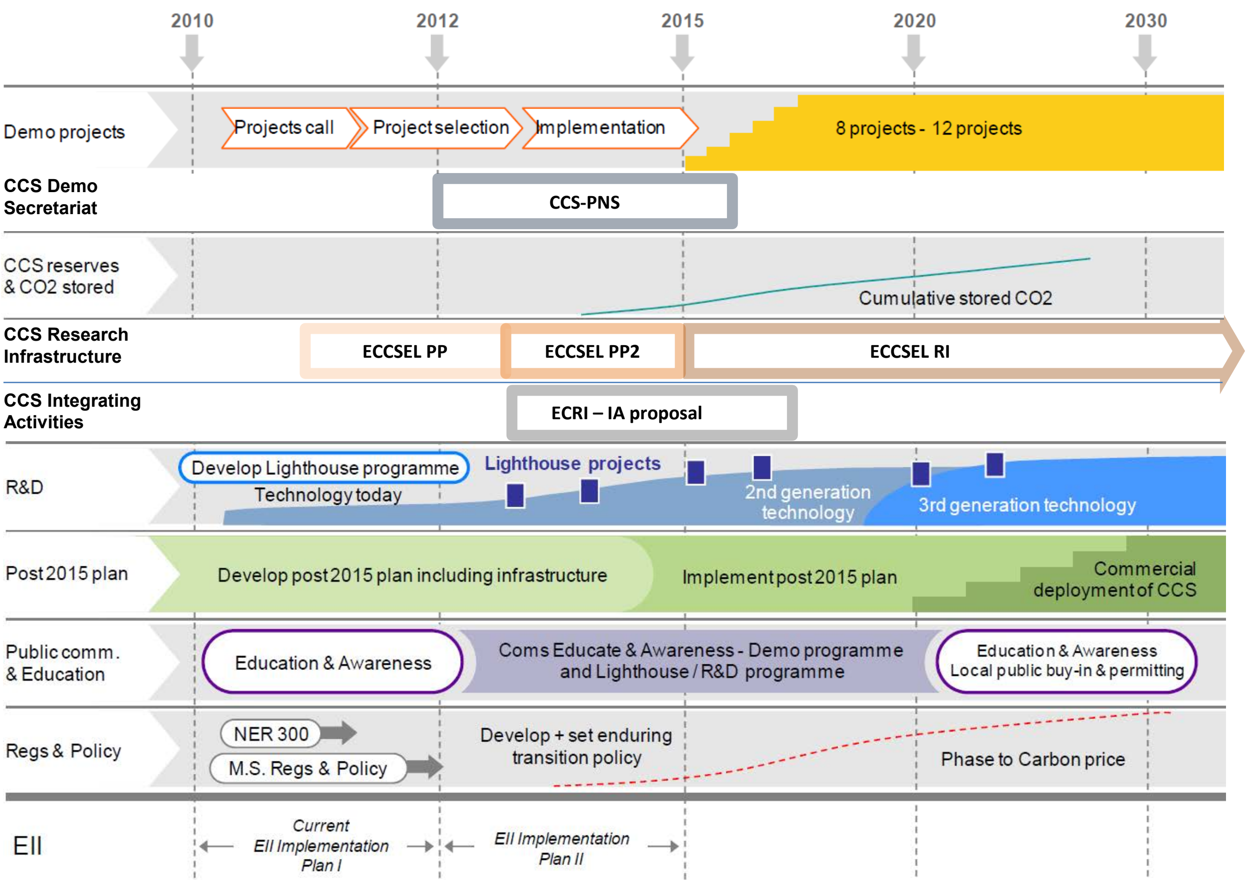


Figure 13: Positioning the ECCSEL initiative in the technology roadmap of the ZEP jointly with the proposed ECRI-IA project and the new CCS-PNS project. (Source: The CCS EII implementation plan 2010-2012, Zero Emission Platform – manipulated to fit the intended purpose of this proposal)

Seen as a **toolbox for joint programming** within the EERA CCS Joint Programme, ECCSEL may boost innovation through joint and extended use of new research laboratory infrastructure, and also respond to the industrial needs via ZEP and other European CCS initiatives.

 Pag. 610

 Pag. 611

In this respect ECCSEL undertakes a critical role to ensure that the targets of the EII Implementation plan and those of the Roadmap can be achieved in due course.

3.2.2 Impact on the European approach

The idea of ECCSEL is to **enable excellent researchers** from all regions of Europe (and, where appropriate, from third countries) to **undertake research** that requires the **most advanced equipment and facilities**. The partners are open to discussing **further inclusion of research facilities** from other nations if it can be justified that this will add value to the results (synergy).

The project will imply a European approach, rather than a local or national approach, as ECCSEL is based on a **pan-European collection of CCS research laboratories** and test sites, and it will direct significant investments into new advanced research laboratories devoted to CCS (cf. Figure 7). ECCSEL will therefore benefit from having a pre-existing collection of internal CCS expertise.

On a medium-to-long term basis the project (ECCSEL) will have additional impacts on

- **European competition**, contributing – as a world-class CCS research laboratory infrastructure – to accelerate CCS towards industrial exploration and deployment
- **innovation**, by forming a breeding ground for invention, exploration and pre-commercial testing of CCS techniques and technologies
- the **regulatory framework**, pertaining to safety and environmental aspects of CCS and also the working environment (i.e. HSE issues)
- **mobility and joint programming** of European CCS resources

Moreover, via its consortium, ECCSEL will be capable of collecting relevant **information on institutional research projects world-wide** – and on the majority of all CCS-focused networks and groups.

ECCSEL will also be well positioned to **assess all strategic impacts on or of CCS in a societal context**.

3.2.3 Impact on the issue of climate change

The United Nations ranks ***climate change* as the most severe issue of our time**. Nonetheless, in some nations the issue of *security of energy supply* appears to represent an even more severe concern. Since energy demand is believed to grow in the foreseeable future, these issues can hardly be combined unless a larger part of the **global energy is provided with less greenhouse gas emissions**.

CCS is seen as a key technology in tackling climate change. The IEA anticipates that CCS will contribute 19% of the emissions reductions required world-wide by 2050 (Figure 14). The IEA further anticipates that the level should be as high as 24% within OECD Europe.[10] (It should be noted, however, that in OECD Europe this does not solely apply to the power sector, as **50% of the reductions must be achieved within industry**.)

IEA analyses also tell us that without CCS, the overall cost of reducing emissions to 2005 levels by 2050 will increase significantly.

Against this back-drop the impact of ECCSEL is deemed to be significant.

Furthermore, in order for ECCSEL to have the expected impact in Europe, **concepts for mitigating the CO_2 emission in industrial processes** must become an essential **part of ECCSEL**.

Figure 14: IEA scenario for abatement of world energy-related CO_2 emissions (Source: IEA 2010, Energy Outlook)

[10] IEA Technology Perspectives, 2010, page 333

 Pag. 611

3.2.4 Impact on national and international networks

Structural Funds – including the **European Regional Development Fund** (ERDF) – have made the financing of infrastructures for knowledge-based development a top priority. It is hoped that more partners from the **convergence regions** where ERDF is available may wish to build new facilities to extend the scope of research.

One expected impact of this project is that discussions with research groups in Convergence Regions will lead to a **broadening of the partnership** and facilities to be managed by ECCSEL.

In terms of other national and international activities, the ECCSEL Operations Centre will be well placed to interpret, understand and engage with the CCS groups involved in experimental research actions.

3.2.5 Impact - external factors

The outcome of ECCSEL, and the success of the project, will rely heavily on the participation, openness, and trust of the partners and stakeholders. Potential obstacles will be analysed as part of the risk assessment (see Section 3.4.1) and the impacts these obstacles may have.

3.3 Dissemination and/or exploitation of project results, and management of intellectual property

The **outcome of the project** will mainly result from structural planning, legal and financial strategies, operational issues, recommendations and pre-engineering studies intended mainly to support the technical planning and budgeting. The intangible results will be summarised and presented in the **ECCSEL Business Plan**. The results also comprise assessment of assets viable for the subsequent CCS research infrastructure – ready to be established in 2015 – subject to appropriate funding and partner agreement.

Intellectual property will be handled as background information vested in the partner that is entitled to such intellectual property rights. As the nature of the project is mainly preparatory, it is not expected that ECCSEL PP2 will raise any new IPR issues. However, should this happen, it will be handled according to the rules set out in the consortium agreement.

Furthermore, the intangible results will per se have only minor interest for the public domain. They will, however, be highly appreciated by the stakeholders as presented in the prospectus (ECCSEL Business Plan) and the implications of the planned services. **Dissemination** will therefore be **made part of a communication plan targeting the specific stakeholders** to **ensure proper understanding** of the message, thus **seeking further engagement**.

The results will be exploited in two directions: i) for the **planning of operations** and further investments in laboratory, research facilities and installations, ii) for **funding** – by attracting sponsors, investors and users of ECCSEL and its services.

3.4 Risk and contingency plans

It is necessary to distinguish between **risks pertaining to the preparatory phase** per se and **risks that may occur during implementation and operation** of hardware. In this context, risks and contingency plans apply to the former – relating to the project and its execution.

3.4.1 Risk assessment

The Project Coordinator will be responsible for identifying risks (by name and brief description) and for assessing the actual mitigation action - either accepting, preventing or reducing the risk. This action must be taken in due consideration of the resulting impact(s) of each risk identified.

Risk assessment also includes a contingency plan suggesting (if required) adequate corrective actions. This approach will be pursued to assess risks pertaining to the planning phase (ECCSEL PP2).

Pag. 613

3.4.2 Technical and commercial risk

The technical risk of the project itself (i.e. ECCSEL PP2) is considered **fairly low,** since the handling of hardware (if any) will be rather limited. The risk will, however, **grow as ECCSEL shifts towards implementation** and later operation.

Pursuant to the vision (Section 1.1.2), the prevalent **risk for ECCSEL to fail is deemed to be the commercial risk** – made up mainly by the **financial and political risks**. The reasoning is that a fairly large portion of private and public funding is required in order to comply with the vision. If this funding is not sufficiently secured at the end of the project, ECCSEL will either be postponed or abandoned.

It is widely accepted that CCS as a climate mitigation option is not profit-driven. Hence, **CCS is and remains a policy issue**. This implies that raising the required funding requires **political support** at a high level of leverage. Hence, the **political risk is deemed rather high**.

The relationship between risk level and impact has been further assessed and ranked, as depicted in Figure 15.

3.4.3 Contingency plans

The project makes efforts to prepare for coping with problems arising from the creation of a pan-European CCS research infrastructure. Problems such as loss of **partner commitments** - despite obligations stated in the Consortium Agreement - may endanger the survival of the infrastructure subsequent to the preparatory phase. Loss of **commitment of member states**, triggered by factors not in the hand of the consortium (e.g. financial, economic, public perception) may jeopardise future investments.

To reduce these risks, a proper communication plan is the key for internal and external communication with the stakeholders.

Pag. 613

Pag. 614

3.4.4 Risk and contingency table

ID	Risk name	Risk description	Mitigation Action	Accept, prevent, reduce	Probability	Impact	Contingency
1	Technical failure	The technical risk of carrying out ECCSEL PP2	None	Prevent – stick to the stated objectives and targets	Low	High	Close coordination of the project, proper reporting
2	Commercial setup	The prevalent risk of the project is that the establishment of ECCSEL will fail owing to lack of funding (private and public)	Revisit the project ideas, vision, objective and targets. Improve communication plans	Prevent or reduce via proper planning and communication	Medium-high	Very high	Accept delay. Improve planning and the focal point in communication (specific to addressee)
3	Political support	There is a risk that ECCSEL will not be established owing to lack of political support or lack of leverage	Engage in proper lobbying to convey the message (communication plan)	Prevent or reduce via proper communication strategy	High	High	Accept delay. Improve communication strategy and core message
4	Partner commitment	The project may fail if one or more partners withdraw from the project or do not commit to ECCSEL (i.e. do not commit to pursue by signing the legally binding contracts)	The ambition of ECCSEL may be reduced (in capacity/capability), or it may be compensated by more efforts placed on the remaining partners	Reduce	Medium	Medium	New partner may be approached to replace the withdrawing partner(s)
5	Member States Commitments	Loss of commitment of Member States, triggered by factors not in the hand of the consortium (e.g. financial, economic, public perception) may jeopardise future investments.	None. Project will fail.	Accept (or prevent by proper communication)	Medium	Very high	If only one or two MSs decline, the project may survive without involvement of partners of these MSs
6	Commitment by Associated Countries	Loss of commitment of Associated Countries	The project may be pursued as a European project.	Accept	Medium	Medium	None

Pag. 614

Pag. 615

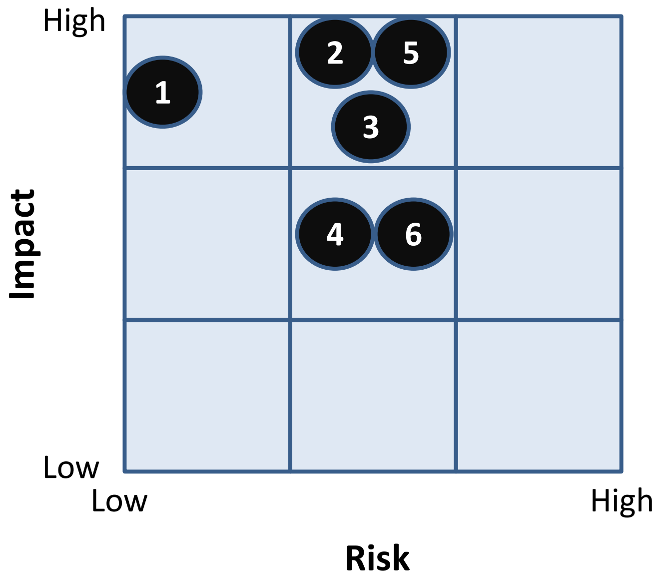


Figure 15: Assessment of the risks and impacts following the numbering presented in the Risk and contingency table under section 3.4.4.

Pag. 615

4 Ethical issues

In pursuing the objectives of ECCSEL PP2, **no fundamental rights are contravened**. The undertakings of the project consist mainly of **legal, strategic, structuring** and some **technical work** which will **not involve human subjects, personal data or animals**. The work will be performed in ten European countries, as indicated in Figure 10. The focus is on setting up a European CCS research infrastructure. The technologies to be addressed in this context will **not be used for any kind of military purpose or terrorism**.

Nonetheless, ethics will be included as a continuous topic to ensure that **ethical challenges are discussed** and that the required guidance is provided. The project shall be conducted based on the basic values: **honesty, generosity, courage and solidarity** and in accordance with **applicable laws and regulations**. This is the responsibility of the Steering Board, the Project Coordinator and the individuals that constitute the project organisation at all levels.

Obviously, as the project will devote **efforts to the planning of new CCS techniques** aimed to reduce the level of greenhouse gas (GHG) emissions. It will have a **positive ethical impact** relating to the *issue of climate change*. In particular, ECCSEL conforms to the Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy issued by the Commission in 2006. CO_2 capture and storage is seen as a **main avenue to achieve the reduction targets** for the medium to long-term mitigation of GHG emissions. As such, the technology has the **potential to improve the competitive edge** of European industries, and respond to the *issue of security of energy supply*, based on own – or alternative – fossil resources. By most people these impacts may be considered positive – also as an ethical issue.

Further ethical issues may arise owing to a growing concern of **depletion of fossil fuel reserves** and limited knowledge as concerns **consequences of underground storage of captured CO_2**. As international regulations gradually become stricter pursuant to the climate change issue, large efforts are put into **investigating the basis for these concerns**. CCS concepts are prone to attract more interest, and new concepts are explored for low-carbonaceous power generation. Today, even environmentalists and several NGOs promote CCS as a better choice than alternative concepts suitable to large-scale power generation and industrial point sources.

Still, **ECCSEL acknowledges a fair amount of uncertainty with regard to the above issues**. This uncertainty represents an **opportunity to inform about technical progress** made within the frames of political decisions to grant the achievement of safe CO_2 storage.

4.1 Ethical issues table

	Research on Human Embryo/ Foetus	**YES**	**Page**
*	Does the proposed research involve human Embryos?		
*	Does the proposed research involve human Foetal Tissues/ Cells?		
*	Does the proposed research involve human Embryonic Stem Cells (hESCs)?		
*	Does the proposed research on human Embryonic Stem Cells involve cells in culture?		
*	Does the proposed research on Human Embryonic Stem Cells involve the derivation of cells from Embryos?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

Pag. 617

	Research on Humans	YES	Page
*	Does the proposed research involve children?		
*	Does the proposed research involve patients?		
*	Does the proposed research involve persons not able to give consent?		
*	Does the proposed research involve adult healthy volunteers?		
	Does the proposed research involve Human genetic material?		
	Does the proposed research involve Human biological samples?		
	Does the proposed research involve Human data collection?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

	Privacy	YES	Page
	Does the proposed research involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?		
	Does the proposed research involve tracking the location or observation of people?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

	Research on Animals	YES	Page
	Does the proposed research involve research on animals?		
	Are those animals transgenic small laboratory animals?		
	Are those animals transgenic farm animals?		
*	Are those animals non-human primates?		
	Are those animals cloned farm animals?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

Pag. 617

 Pag. 618

	Research Involving Developing Countries	YES	Page
	Does the proposed research involve the use of local resources (genetic, animal, plant, etc)?		
	Is the proposed research of benefit to local communities (e.g. capacity building, access to healthcare, education, etc)?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	
	Dual Use	YES	Page
	Research having direct military use		
	Research having the potential for terrorist abuse		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	X	

 Pag. 618

 Pag. 619

5 Consideration of gender aspects

The project is devoted to the planning and preparatory work required to set up a distributed research laboratory infrastructure (ECCSEL) and to initiate pre-commercial operations. Hence, the project will deal essentially with the facilitation of knowledge sharing and information about the future needs of European CCS research.

Under this commitment, the project does not – per se – deal with the gender equality issue on scientific terms. However, as women still represent a low percentage (roughly 15%) of industrial researchers within the European Union, and because industrial and technological research within energy and electrical engineering exhibits the lowest participation of women (next to civil engineering), it is desirous to seek involvement of women within European CCS research projects (the stakeholder) and within the ECCSEL cluster including its Operations Centre, aimed at promoting gender equality.

Moreover, in consideration of information intended for public outreach to be made available by ECCSEL, it will be kept in mind that the perception of technology, environment and risk issues in a societal (and geopolitical) context is prone to vary by gender – as evidenced by recent European perception studies on CCS. This experience calls for special attention when establishing communication strategies about CO_2 capture, transport and storage.

Essential to creating awareness towards CCS is the providing of relevant and objective knowledge via public information, targeting the attitudes and concerns that tend to occur between the genders.

 Pag. 619

 Pag. 620

Appendix

Letters of Intent (LoI)
from supporting
Research Councils and Ministries

 Pag. 620

Pag. 621

Royal Norwegian Ministry of Petroleum and Energy
Royal Norwegian Ministry of Education and Research

Project Coordinator ESFRI FP7/PP ECCSEL project
Dr. Morten Grønli
Norwegian University of Science and Technology
7491 TRONDHEIM

Deres ref	Vår ref	Dato
	200903481-/TLD	21.11.2011

Norwegian statement with respect to the ECCSEL Preparatory Phase II Proposal

This letter is to express the intent from the Ministry of Education and Research and the Ministry of Petroleum and Energy to support the ECCSEL Preparatory Phase II Proposal. We fully trust that the University of Science and Technology (NTNU), as coordinator of this proposal, is well qualified to lead the preparation work of this important new infrastructure, together with the strong international consortium as presented in the proposal.

Carbon capture and storage (CCS) is a central part of the Norwegian government's policy on energy and climate change. A cornerstone of this target area is the planning of a full-scale carbon capture and storage project at Mongstad on the western coast of Norway together with the ongoing construction of TCM (CO_2 Technology Centre Mongstad) and support of CCS research and development programs and Research Centres.

ECCSEL was proposed for the ESFRI roadmap by the Norwegian Ministry of Education and Research on the background that Norway has leading research groups and significant relevant existing research infrastructure in the field of Carbon Capture and Storage (CCS).

In line with the *Governmental White Paper for Research* (April 2009), Norway is a strong host candidate for the ECCSEL research infrastructure. There is a broad political consensus in Norway to contribute to the general knowledge base with respect to climate change and mitigation issues. The *White Paper on Climate Policies* (2007) especially emphasizes a significant increase in Norwegian research spending on renewable energy research and CCS over the coming years. As a result the Research Council of Norway has established 2 new *Centers for Environmental Friendly Energy* within CCS in Norway in 2009. These are the *International CCS Research Centre* (BIGCCS) at Sintef, Trondheim,

Postadresse: Postboks 8119 Dep, 0032 Oslo
Kontoradresse: Kirkeg. 18 Telefon: 22 24 90 90* Telefaks: 22 24 95 40
Org. nr.: 872 417 842

Pag. 621

Pag. 622

and the *SUbsurface CO2 storage - Critical Elements and Superior Strategy* (SUCCESS) at CMR Bergen. In addition three new research centres were established that will study the interactions between technology and society and will examine Norway's energy policy challenges from a social science perspective. CCS research is also funded under our funding instruments on CCS technology development and research infrastructure.

The Ministry of Education and Research and the Ministry of Petroleum and Energy foresee that ECCSEL, as a distributed pan-European research infrastructure, will contribute to a significant increase in CCS research and research infrastructure upgrade in Europe. In agreement with the overall objectives of the FP7 Capacities program for research infrastructures, and in accordance with our "National Strategy for Research Infrastructure" the Ministries support optimized use and development of the best infrastructures of pan-European interest. The financial contribution from the Norwegian Government to the construction phase of this project will be based on a proper international quality assessment of the outcome of the preparative phase II, to which the Research Council of Norway will contribute with guidance, anchoring and strategic negotiation.

Kari Balke Øiseth
Director General

Ove Flataker
Director General

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

**MINISTÈRE
DE L'ENSEIGNEMENT SUPÉRIEUR
ET DE LA RECHERCHE**

Paris, 20 november 2011

**Direction générale
pour la recherche
et l'innovation**

Dr. Gabriele FIONI

Deputy Director General
Scientific Director

DGRI /GF/2011 n° 978

Dear Prof. Rokke,

I am pleased to confirm our support to the preparatory phase of the ECCSEL project funded by EU, to which France participate through IFPEN and BRGM.

Carbon capture and sequestration is a very important topic to limit the impact of human generated greenhouse gases and it is our duty to assess and enhance this technology.

The current works will provide scientific, technical and industrial elements that will be essential for taking a decision on the construction of the infrastructure in a few years from now.

I thank you for your efforts for making this preparatory phase a success.

Yours Sincerely

Gabriele FIONI

Prof. Nils A. Røkke
Vice President Climate Technologies
Stiftelsen SINTEF,
box 4760 Sluppen,
NO-7465 TRONDHEIM, NORWAY

Pag. 624

NATURAL ENVIRONMENT RESEARCH COUNCIL

Polaris House
North Star Avenue
Swindon SN2 1EU
United Kingdom

Telephone (01793) 411500
Main Fax (01793) 411501
www.nerc.ac.uk

SINTEF Gas Technology
Nils A Røkke
Kolbjørn Hejes vei 1A
7465 Trondheim
Norway

16 November 2011

Dear Dr Røkke

LETTER OF INTENT

European CO_2 Capture and Storage Laboratory Infrastructure (ECCSEL) Phase 2

ECCSEL (http://www.eccsel.org/) is a vehicle for a pan-European infrastructure for carbon dioxide capture and storage. ECCSEL consists of a wide range of partners across Europe with expertise in CCS, each of whom will commit existing, upgraded and new laboratory infrastructure to a co-ordinated consortium that will promote research into efficient and cost effective CCS technologies. A principal aim of ECCSEL is to aid defragmentation of European CCS research and to create a common plan for research initiatives and investment in world-class laboratories.

The consortium is being led by a core group comprising the Norwegian University of Science and Technology (NTNU, Norway), SINTEF (Norway), Institut Français du Petrole (IFP, France), TNO (the Netherlands) and DLR (Germany). The British Geological Survey (BGS), a component body of the UK Natural Environment Research Council (NERC), will be one of 20 or so partners who will contribute to the infrastructure consortium.

ECCSEL will address all science areas relevant to CCS research, including conversion, material science, cryogenic processes, absorption and storage - the latter being BGS's core expertise. BGS already operates a series of state-of-the-art laboratories that have specific focus on the provision of long-term process-based knowledge in support of CO_2 sequestration and radioactive waste disposal. These laboratories form the core of BGS's newly proposed 'centre of excellence' for physical properties and processes. The specific laboratory expertise that BGS will contribute to the ECCSEL infrastructure includes:

Transport Properties Research: Study of fluid movement in ultra-low permeability media under simulated in situ conditions of stress, pore pressure, temperature and chemical environment. Key equipment includes: high pressure and high temperature isotropic and triaxial permeameters; heavy duty shear-rigs; and a high temperature, high pressure geochemical flow reactor.

Rock Engineering: Investigation of specialist geotechnical rock engineering and geomechanical properties related to strength, deformability, density and geophysical properties used to improve the understanding of material behaviour and processes related to performance assessment. Significant new investment planned on a new Rock Mechanical, Geophysical (S & P-wave) & Thermal Properties Testing System.

Geomicrobiology: Study of biological processes involved in the transport of contaminants in a variety of rock types applicable to the safe long-term storage of CO_2. New investment in a Biological Flow Apparatus (BFA) will be used to examine the impacts of CO_2 on biofilms in targeted lithologies.

Hydrothermal Research: Study of fluid-rock interactions and processes over a range of temperatures and pressures typical of the upper few kilometres of the Earth's crust. The laboratory is

INVESTOR IN PEOPLE

Pag. 624

Pag. 625

equipped with a wide range of high-pressure batch and column reactors capable of investigating CO2-fluid-rock reactions occurring within the reservoir and cap rocks under *in situ* conditions.

Hydrates Research: Investigation of how CO2 hydrate behaves within sediments and the impact the hydrate has on the physical properties of the sediments under the high pressure/low temperature conditions found on the bed of deep oceans or under permafrost.

Mineralogy, Petrology and Biostratigraphy: Study and characterisation of the mineralogical composition and texture of geological and allied materials in order to understand the processes and conditions under which they have formed. The laboratory posses a full range of state-of-the-art equipment including: ESEM, SEM, electron microprobe, XRD, physisorption system and thermogravimetric/differential thermal analysis system

The first 'Preparatory Stage' of the ECCSEL project started in January 2011, with 1.5m Euro funding from the EU FP7 'Capacities' programme, and runs until December 2012. A bid for FP7 funding for a continuation of the Preparatory Stage (ECCSEL PP2), led by NTNU, is due for submission by 23 November 2011. This stage of the project will formalise arrangements for delivery of the ECCSEL partnership, taking forward legal framework, governance, and funding arrangements explored during the first preparatory phase and developing them into an operational framework. Assuming funding is secured, ECCSEL PP2 is likely to start in January 2013 for two years, with an estimated budget of 2.5m Euro. Once the second Preparatory Stage has been concluded, the actual implementation stages (i.e. science projects and open access to facilities) will commence.

Through BGS, NERC has already been very active in the first phase of the preparatory project, utilising our expertise in IPR, Contracts, Finance, business support, as well as providing considerable technical and scientific policy input. BGS wishes to continue its involvement by contributing to a wide range of WPs designed to deliver the second preparatory stage that will lead to formal establishment of the ECCSEL consortium.

This statement of intent does not offer any specific commitment of funding by NERC to the construction and operational phases of the ECCSEL infrastructure.

Yours sincerely

Phil Heads
Interim Director, Strategy & Partnerships

cc Professor John Ludden
Dr Michael Schultz

Pag. 625

 Pag. 626

HELLENIC REPUBLIC
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY
INTERNATIONAL S&T CO-OPERATION DIRECTORATE
EUROPEAN UNION SECTION
14-18, Mesogeion Avenue
GR-115 10 Athens
Tel. +30 2107458 000
Fax: +30 210 7714 153

Athens, 22/11/2011
Ref. no. 13795

Dr. Ing. Morten Grønli

Norwegian University of Science and Technology
Department of Energy and Process Engineering
7491 Trondheim
Norway

Reference: Letter of Support – European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL)

With reference to the publication of the European Commission FP7 call FP7–INFRASTRUCTURES–2012-1, the General Secretariat for Research and Technology of the Greek Minstry of Education (GSRT) wishes to express its support to the project European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) Preparatory Phase II.

ECCSEL addresses the need for a high-class wide European research infrastructure for carbon dioxide capture and storage (CCS). This requires a strategic upgrading of existing research infrastructures in this important area, development of new unique laboratories, and the strengthening of networks between the existing European laboratories. The foreseen overall research infrastructure will foster the European competitiveness within CCS technologies and reinforce the role of Europe in the forefront of research in an important sector of the green economy.

 Pag. 626

 Pag. 627

The consortium is being led by a core group comprising the Norwegian University of Science and Technology (NTNU, Norway), the Research Council of Norway (RCN, Norway), SINTEF (Norway), Institut Francais du Petrole (IFP, France), TNO (the Netherlands), DLR (Germany), the British Geological Survey (BGS), the Polish Geological Institute – National Research Institute (Poland), Fundacion Ciudad de la Energia (CIUDEN, Spain), Istituto Nazional di Oceanografia e di Geofisica Sperimental (OGS, Italy), the Italian National agency for new technologies, Energy and sustainable economic development (ENEA, Italy) and the Swiss Federal Institute for Technology Zurich (ETH-IPE, Switzerland).

CERTH/ISFTA will represent Greece in the preparation of this ECCSEL Preparatory Phase II Proposal.

This letter does not offer any specific commitments of funding by GSRT to the construction phase of the ECCSEL infrastructure.

The Secretary General for Research and Technology

Konstantinos Kokkinoplitis

 Pag. 627

Pag. 628

MINISTERIO
DE CIENCIA
E INNOVACIÓN

SECRETARÍA DE ESTADO DE INVESTIGACIÓN

DIRECCIÓN GENERAL DE COOPERACIÓN INTERNACIONAL Y RELACIONES INSTITUCIONALES

SUBDIRECCIÓN GENERAL DE INSTALACIONES Y ORGANISMOS INTERNACIONALES

Dr. Astrid Lilliestrale
Norwegian University of Science and Technology
Department of Energy and Process Engineering
7491 Trondheim
Norway

Madrid, November 19th 2009

Dear Dr. Lilliestrale,

Concerning the interest of the Spanish institution "Fundación Ciudad de la Energía" to eventually become an active part in the preparatory phase of the ESFRI project entitled

> ECCSEL, under the 7th Framework Programme, Capacities Workprogramme, Part 1 - Infrastructures, Call Identifier FP7-INFRASTRUCTURES-2010-1,

for which you are the Current Coordinator, I am pleased to transmit, on behalf of the Spanish Ministry of Science and Innovation (MICINN), my support to the participation of Fundación Ciudad de la Energía in the ECCSEL team, and express my conviction that their competence in the field will contribute to the success of this challenging European initiative.

The Fundación Ciudad de la Energía, as a qualified Spanish agent in this scientific field, receives hereby the support of MICINN for participating in the preparatory phase of the ECCSEL project, in the understanding that this support does not mean in any aspect a decision on the financial contribution from the Spanish Government to the construction phase of this project.

Sincerely yours,

Benjamin Sánchez Gimeno
Assistant to the Deputy General for International
Large Facilities and Organizations

MINISTERIO DE CIENCIA E INNOVACIÓN
Dr. Gral. de Cooperación Internacional y Relaciones Institucionales
Subdirección General de Instalaciones y Organismos Internacionales

MINISTERIO DE CIENCIA E INNOVACIÓN
DIRECCIÓN GRAL. DE COOPERACIÓN INTERNACIONAL
SUBDIRECCIÓN GRAL. DE INSTALACIONES Y ORGANISMOS INTERNACIONALES
20 NOV. 2009
~~Entrada~~
Salida Nº 291

CORREO ELECTRÓNICO
sgioi@micinn.es

Calle Albacete, 5
5ª Planta Norte
28071 Madrid
TEL.: 91603 71 44
FAX: 91603 70 99

Pag. 628

 Pag. 629

Ministero dell'Istruzione, dell'Università e della Ricerca

Direzione Generale per l'Internazionalizzazione della Ricerca

Prot. 888

Prof. Iginio Marson
Presidente
OGS, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale
Borgo Grotta Gigante 42/C
34010 Sgonico (TS)

Reference: Letter of support to the **ECCSEL** Preparatory Phase proposal

With reference to the publication of the European Commission FP7 call INFRA-2010-2.2.4, the MIUR (Ministero dell'Istruzione, Università e Ricerca) hereby wishes to express its support to the project **ECCSEL** (European Carbon Dioxide and Storage Laboratory).

ECCSEL addresses the need for a high-class wide European research infrastructure for CCS (Carbon dioxide Capture and Storage). This requires a strategic upgrading of existing research infrastructures in this important area, development of new unique laboratories, and the strengthening of networks between the existing European laboratories. The foreseen overall research infrastructure will foster the European competitiveness within CCS technologies, and reinforce the role of Europe in the forefront of research in an important sector of the green economy.

ECCSEL Preparatory Phase, with 15 partners (and some other 20 R&D providers, companies and national funding bodies contributing in the Stakeholder Contact Group) and 13 participating countries, is coordinated by the Norwegian University of Science and Technology (NTNU).

The MIUR confirms that Prof. Iginio Marson of OGS will represent Italy in the preparation of this preparatory phase proposal.

This letter does not entail any commitments of funding by MIUR at this stage in the construction phase of the ECCSEL infrastructure.

Roma, 25 novembre 2009

IL DIRETTORE GENERALE
Dott. Mario ALI
Mario Ali

 Pag. 629

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of the Environment,
Transport, Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research Section

SFOE, sig, CH-3003 Bern

Mrs. Dr. Astrid Lilliestråle
Norwegian University of Science and Technology
Dept. of Energy and Process Engineering
N-7491 Trondheim
Norway

Your reference:
Our reference: sig
Contact person: Gunter Siddiqi
Bern, May 19, 2010

LETTER OF INTENT

European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL)

Dear Dr Lilliestråle,

In my capacity as deputy head of the Section Energy Research of the Swiss Federal Office of Energy within the Swiss Federal Department of the Environment, Transport, Energy and Communication, I would very much like to express the strong support of the Swiss Federal Office of Energy for the participation of the Swiss Federal Institute of Technology in Zurich (ETH-Z) in the European Carbon Dioxide Capture and Storage Laboratory Infrastructure.

With the launch of the European Industrial Initiative on Carbon Dioxide Capture and Storage (CCS) this summer, we believe the time has come to ensure that the European Laboratory Infrastructure is set up to allow the research and development into key and critical questions on CCS. The Swiss Federal Office of Energy believes that the skills and competencies of the ETH in Zurich and its related Swiss federal research organizations will provide extremely useful and constructive input into the building, launch and operation of the ECCSEL. In particular, Professor Marco Mazzotti of the ETH in Zurich is spearheading a major Swiss research initiative into CCS. He and his team from a variety of federal research institutes, cantonal universities and universities of applied science are in a uniquely well qualified position to successfully contribute to the ECCSL.

This statement of intent does not offer any specific commitment of funding by the Swiss Federal Office of Energy to the construction phase of the ECCSEL infrastructure.

Yours sincerely,

Swiss Federal Office of Energy SFOE

Previdoli

Pascal Previdoli
Deputy Head

Mühlestrasse 4, CH-3063 Ittigen
Postal address: CH-3003 Bern
Phone +41 31 322 56 11, Fax +41 31 323 25 00
contact@bfe.admin.ch
www.bfe.admin.ch

Doc 003866679

SEVENTH FRAMEWORK PROGRAMME
FP7–INFRASTRUCTURES–2012-1
Integrating Activity

Proposal Part B

Proposal full title: **European CCS Research Infrastructures – Integrating Activities**

Proposal acronym: **ECRI**

Type of funding scheme: Combination of Collaborative Projects and Coordination and Support Actions - Integrating Activities (CP-CSA-INFRA)

Work programme topics addressed: **INFRA-2012-1.1.18. Carbon Capture and Storage (CCS) facilities for energy research**

Co-ordinating person Dr. Morten Grønli
Co-ordinator organisation name Norwegian University of Science and Technology
Co-ordinator email morten.g.gronli@ntnu.no
Co-ordinator phone +47 73 59 37 25
Co-ordinator mobile +47 918 97 515

List of participants

No.	Participant organisation name	Short Name	Country
1 (Coord)	NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY	NTNU	Norway
2	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE,L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	ENEA	Italy
3	UNIVERSITATEA BABES BOLYAI	BBU	Romania
4	BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	BRGM	France
5	CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS	CERTH	Greece
6	DELFT UNIVERSITY OF TECHNOLOGY (DUT)	DUT	Netherlands
7	EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE ZÜRICH	ETH Zurich	Switzerland
8	FONDAZIONE INTERNAZIONALE PER LA RICERCA SULLA COMBUSTIONE - ONLUS	IFRF	Italy
9	FUNDACIÓN CIUDAD DE LA ENERGÍA	CIUDEN	Spain
10	IFP ENERGIES NOUVELLES	IFPEN	France
11	ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE OGS	OGS	Italy
12	MATGAS 2000 AIE	MATGAS	Spain
13	MIDDLE EAST TECHNICAL UNIVERSITY	METU-PAL	Turkey
14	NATURAL ENVIRONMENT RESEARCH COUNCIL	BGS	UK
15	PANSTWOWY INSTYTUT GEOLOGICZNY - PANSTWOWY INSTYTUT BADAWCZY	PGI-NRI	Poland
16	SINTEF ENERGI AS	SINTEF ER	Norway
17	SINTEF PETROLEUMSFORSKNING AS	SINTEF-PR	Norway
18	STIFTELSEN SINTEF	SINTEF	Norway
19	THE UNIVERSITY OF EDINBURGH	UEDIN	UK
20	THE UNIVERSITY OF NOTTINGHAM	UNOTT	UK
21	TECHNISCHE UNIVERSITAET WIEN	TUV	Austria
22	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	UniRoma1	Italy
23	UNIVERSITAET STUTTGART	USTUTT	Germany
24	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO	TNO	Netherlands

Table of Contents

1. Scientific and/or technical quality, relevant to the topics addressed by the call

1.1 Rationale

ECRI brings together and integrates activities within existing European key research infrastructures pertaining to the field of capture and storage of CO_2 (CCS). Considered as a joint undertaking, ECRI shall offer a comprehensive inventory of advanced research facilities covering three main areas of CCS research:

i) Energy conversion

ii) CO_2 Separation

iii) CO_2 Storage

The purpose is to provide a wider and more efficient access to high-performing research facilities for European researchers.

1.2 Concept and Objectives

For a sufficient cut of carbon emissions, a rapid decarbonisation on large scale point sources (power generation, industry) is required imposing a radical transformation in the energy sector which can only be achieved through the adoption of new and innovative technologies. CCS (Carbon Capture and Storage) has been widely recognised as a key technology for the transition to an operation of a more sustainable energy system[1]. In Europe, CCS technologies are at the top of all strategic agendas for the energy future[2,3].

However, current CCS technologies do not meet the technical and economic criteria for market introduction. Hence, a significant gap in knowledge and technology exists. On this basis, the concept of ECRI is briefly outlined and envisaged below.

Further development and up-scaling of CCS technologies require a significant additional R&D effort. Cross-border research and development on the level of excellence are necessary elements in the pursuit of achieving the technological innovations needed for the deployment and market entry of CCS. Focal points of on-going R&D efforts are the development of:

- **advanced combustion systems for** IGGC plants and oxy-combustion,
- the **reduction of cost** and **energy penalty** of post-combustion capture processes through the development of **novel separation processes and materials** (solvents, membranes, sorbents),
- the **safety of transport and storage**,
- the assessment of the **long-term behaviour of CO_2 storage** sites, and finally
- the assessment of the overall **environmental impact of the CCS chain**.

---

[1] ***World Energy Outlook 2010 &2011**, International Energy Agency*

[2] ***COM (2007) 713**, A European Strategic Energy Technology Plan (SET-Plan).'Towards a Low Carbon Energy Future', Brussels 22 November 2007*

[3] ***COM (2009) 519**, Investing in the Development of Low Carbon Technologies (SET-Plan), Brussells, 07 Octomber 2009*

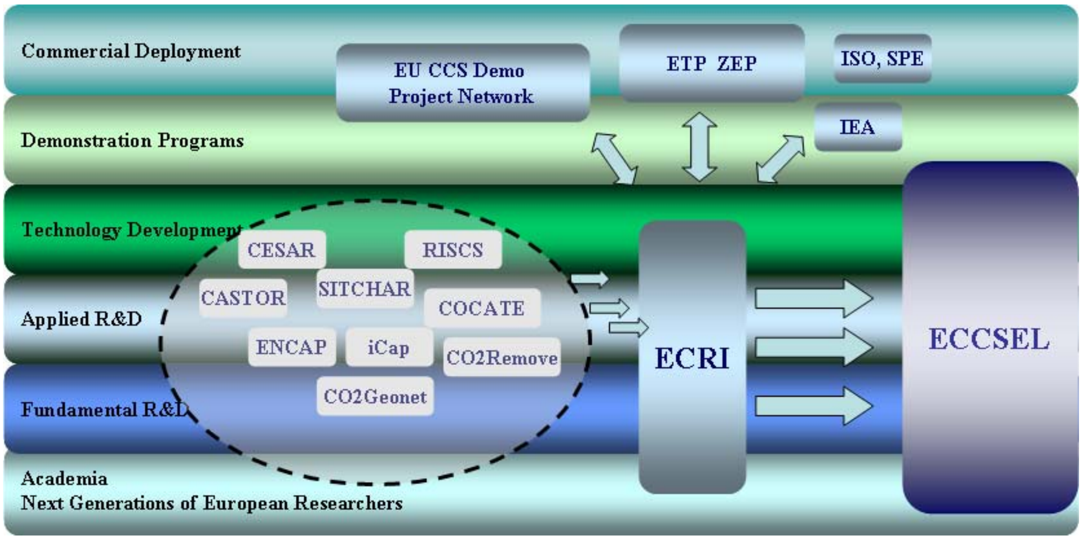


Figure 1.1 ECRI interactions and positioning, ECRI is the launch of ECCSEL[4]

The **ECRI** project responds to the topic: INFRA-2012-1.1.18 Carbon Capture and Storage (CCS) facilities for energy research aiming at:

> *'' Integrating the key research infrastructures in Europe for all aspects of Carbon Capture, Sequestration and Storage as well as of CCS facilities from large point sources such as fossil power plants and storage. Environmental and safety aspects of CCS should be addressed. The project is expected to be complementary to existing activities in the field''*

ECRI's main objective is to bring together and integrate, on European scale, **world-class research infrustrucutre** pertaining **to the field of capture and storage of CO_2** (CCS) in order to promote their coordinated used and development and support research and devepment of of the CCS industry at all stages of development. ECRI is build as Integrated Activity project and combines i) Networking, ii) Joint Research iii) Transnational Access activities. In recognition of the pronounced urgency of CCS - and the growing demand for improvements along the **CCS chain** - ECRI shall pursue these **integrating activities** within **highly-advanced European research facilities** all dedicated to important aspects of CCS.

The technological bottlenecks for further development and remaining challenges for commercialisation and deployment of **CCS technologies** are indentified among different areas of research and numerous scientific disciplines. ECRI aims at addressing these bottlenecks by developing, improving and integrating the use of first class research infrastructures along with a selected portfolio of research activities focused on innovative instrumentation and methods. By this way insights and understanding of the processes and phenomena involved in the different steps of CCS will be obtained thus facilitating technological breakthroughs.

ECRI Research Infrastructures are divided into three groups – *Energy Conversion*, *CO_2 Separation*, *CO_2Transport and Storage* , and cover all aspect of CCS research.

- **Energy Conversion Facilities** integrate a set of high-quality facilities: coal combustion, gasifier and gas turbine test rigs, along with a variety of reactors and world class test rigs for chemical looping combustion.
- **CO_2 Separation Facilities** consist of unique pilot plants for post-combustion solvent technology, laboratory scale test rigs and apparatuses for developing novel solvents, adsorbents and membrane materials for CO_2 capture.
- **ECRI- CO_2 Storage Facilities** consists of a series of installations for core flooding studies and fluid studies at relevant conditions for CO_2 geological storage, facilities for storage site characterization, and unique instrumentation for monitoring CO_2 leakage, for evaluating the effects of CO_2 on marine and terrestrial fields and for assessing the Enviromental Impact and Safety of CCS.

[4] ***ECCSEL:*** *European Carbon dioxide Capture and Storage Laboratory Infrastructure, was proposed by NTNU and SINTEF on behalf of the Norwegian Government, and put on the official roadmap of ESFRI.*

ECRI integrating activities aim to promote targeted research and extended use, including further development, of existing key research infrastructures to ensure that talented European researchers have a wide and efficient access to the most advanced research facilities. At least one third of the EU contribution has been allocated to *transnational access and related services* in order to meet the growing needs of specific knowledge and services required by the European (and global) CCS community.

To summarize ECRI aims at generating a structured and integrated alliance based on complementary, state-of-the-art and excellence of unique infrastructures to serve the needs of the scientific European CCS community and facilitate future research. In detail, ECRI aims are summarized below:

- to create a a focal poit of infrastructures to accommodate CCS research communities
- to provide transnational access for the CCS communities to EU member state infrastructures
- to create a number of expert's special working groups to stimulate innovation
- to combine the interdisciplinary skills from the leading research teams throughout Europe to maximise synergies in the topics of CCS research
- to provide training in specific areas through thematic lectures, and practical training on research infrastructures
- to integrate, enhance and improve on the existing infrastructure
- to coordinate actions with national and international bodies, with academic and industry demands
- to promote best practices, enhance data and knowledge exchange harmonize and organise the way that research is conducted and facilitate interoperability

1.3 Progress beyond the state-of-the-art

Pursuant to the call, ECRI shall combine three categories of integrating activities that will be closely co-ordinated and conducted in a synergistic manner, following the European Integrated Infrastructure Initiative model (I3): *1) Networking, 2) Transnational access and related services,* and 3) *Joint research*. The idea is to promote coordinated and extended use of existing research capacities and to foster further development of the research facilities involved.

The state-of-the-art in the each area concerned, and the advance that the proposed project would bring about in terms of integrated provision of infrastructure related services is stated below.

1.3.1 The Ensemble of Networking Activities

As stated in the call, the purpose of networking is to **foster a culture of cooperation** within the research infrastructure, and between research facilities and scientific communities, helping develop an attractive European Research Area (ERA). ECRI will support and facilitate the exposure and effectiveness of the ERA and the growing needs of the European CCS community. The **Networking activities** proposed under this project **will enhance the possibilities for collaboration in the research community for CCS technologies**. The transnational access at a variety of scales and capabilities means that **researchers will be able to use facilities that are unique in Europe** and not available in their home country.

Under Networking Activities, **knowledge sharing will establish an appropriate balance between the outcome of scientific approaches and applied research, with innovation** ranging from the inherent arrangement of the research infrastructure to commercial exploitation. Hence, networking is **associated with accelerating technology development and dissemination**.

The creation of the **Technical Schools** and the **Researchers Exchange Programme,** the arrangement of **CCS Thematic Workshops,** and the operation of **CCS Special Interest Groups**[5] will allow for the development of a coherent network of researchers in Europe across the CCS chain. At present the work tends to be fragmented and the above tools will allow for true research exchange among the groups. Users will be given the opportunity to present their research in the foreseen workshops and in proceedings published on the **ECRI Website**. Joint projects cam be envisaged involving European research groups fostered through these Networking Activities.

The development of best practice methods as part of NA-WP4 for research and testing within the affiliated infrastructures will ensure a harmonisation of operations at all levels. This will allow direct comparison of results and coherent assessments of the CCS technologies, which will contribute to **high quality research and due diligence**.

Networking activities will enhance the services provided by the **ECRI** infrastructures in several ways:

- **Offering access** in a targeted way by attracting proficient scientists and research teams, subject to consolidated planning and coordination
- **Providing academic training** in specific areas through thematic lectures, and practical training in the research infrastructure funded by ECRI
- **Encouraging collaboration** by funding overseas exchange of visiting researchers between ECRI institutions
- **Raising awareness of ECRI** and its programme amongst all organisations and individuals. Special attention will be given to potential users of ECRI for transnational access (TA) and other beneficiaries

[5] **Special Interest Group** (**SIG**) is a community with an interest in advancing a specific area of knowledge, learning or technology where members cooperate to effect or to produce solutions within their particular field, and may communicate, meet, and organise conferences. www.wikipedia.org

- **Disseminating the output** from the ECRI programme within the ECRI partnership and to the wider CCS community
- **Promoting best practices, methods, and protocols** for the efficient use of the ECRI CCS research infrastructures.
- **Harmonising and organising the large influx of data** generated by the TNAs to facilitate interoperability
- **Enhancing data and knowledge exchange** among the ECRI partners and with other organisations and the international scientific community through the open access ECRI CCS database

1.3.2 The coherence of the Infrastructures (Transational Access)

The proposed transnational access and research services have been selected on the basis of high quality facilities and the experience and unique expertise that consortium have in CCS research. They have also been selected because they address current bottlenecks for the whole CCS chain development.

The **ECRI network** links **24 leading organizations of CCS research** located in **14 different countries** and well spread over the **entire European region**. When considered as a group, the research facilities provide the most coherent and comprehensive coverage of the three main areas of CCS research. (Energy , Capture , Storage).

The spread of Infrastructure capability is given in the matrix diagram which ranges from small scale laboratories up to pilot and demonstration plants and covers all the steps of CCS value chain.:

i. ECRI -Energy Conversion Facilities and Labs

The integrated set of infrastructures offered in that area features high-quality facilities:

- coal combustion
- gasification of solid fuels
- oxygen-based combustion
- gas turbine combustion system
- various reactors types – including world-class test rigs for chemical looping combustion

Combustion test rigs, capable of handling atmospheric and high pressure combustion, are suitable for the study of **phenomena in oxygen-based combustion atmospheres**, as well as facilities for the study of **gas turbine combustors**. The facilities allow for test conditions similar to industrial applications, with combustion temperatures up to 1400ºC and particle heating rates within the range of $10^4 – 10^5$ K/s. Fuel pre-treatment, flue gas recirculation, and conventional flue gas cleaning equipment are also available. These combustion test rigs can be used for developing new burner concepts and for characterisation of stability and emission performance in unconventional gas mixtures relevant to both the power and industrial process sectors. HCl, SOx behaviour, NOx reduction, high and low temperature corrosion, and slagging/fouling tendencies can be listed among the phenomena to be studied in such facilities.

The energy conversion facilities are supported by well equipped laboratories for the characterisation of fuels, ashes and slag including access to a great variety of (micro-) analytical techniques. Furthermore, the test rigs are operated by experienced scientists and technicians and have state-of-the-art measurement equipment. Special instrumentation for the characterisation of oxy-flames, and conventional techniques for the on-line analysis of major pollutants (NO_X, CO, CO_2) both in flames and in the stack, as well as special probes and in-lab techniques for measuring micro-pollutants (organic and inorganic) complement the infrastructures.

ECRI will furthermore offer **access to the world's largest operating facility** for experimental research in the field of **chemical looping** technology. Research projects in this direction includes performance studies of novel oxygen carriers (reactivity, deactivation, attrition), influence of sulphur components (including slight adaptation of measurement equipment), influence of higher hydrocarbons (including evaporated tar substances), chemical looping combustion of liquid fuels, chemical looping reforming (CLR), and different kinds of hydrodynamics requiring particle related investigations.

ii. ECRI -CO_2 Separation Facilities and Labs

CO_2 separation facilities comprise unique:

- pilot plants for post-combustion solvent technology
- lab-scale test rigs and apparatus for developing novel
  - solvents
  - adsorbents
  - membrane materials for CO_2 capture

New technology and solvents developed in these laboratories can be tested in pilot plants at flue gas conditions corresponding to coal-based power stations. ECRI provides access to pilot plants able to accommodate a maximum loading of 250 kg CO_2 per hour. These pilot plants represent different CO_2 capture techniques that will be further evaluated by the monitoring of all process conditions such as temperature, pressure, flows and content of CO_2, SO_2 and soot formation. Research in this topical direction includes testing of new solvents and materials, scale-up basis for processes, reactor design under steady state and dynamic response, etc. The pilot plants are equipped with the latest technology regarding process monitoring and process measurement. They offer optimal accessibility, smart process data acquisition systems, and user friendly operation with remote control.

ECRI offers state-of-the-art apparatus for **fundamental studies a**t laboratory scale **on CO_2 separation** and characterisation of **solvent**, **sorbents** and **membrane materials**. Research may include studies of absorption kinetics, fundamental studies of solvent degradation, measurement of vapour-liquid equilibrium (VLA) and thermodynamic data at a wide range of pressure and temperature conditions, fabrication and testing of novel membrane materials (polymer and ceramics), measurements of equilibrium isotherms and heat of adsorption including diffusion in nanoporous solids, macropore diffusion in structured materials, stability to SOx and NOx etc. All facilities have been used and proved adequate via numerous projects.

iii. ECRI - CO_2 Storage Facilities and Labs

CO_2 storage facilities comprise equipment for

- studies of core flooding and fluid behaviour at relevant conditions for CO_2 storage
- cap rock characterisation (porosity, permeability, entry pressure)
- identification and monitoring of CO_2 leakag on land and at sea bottom – with unique instrumentation
- assessment of impacts of CO_2 on marine and terrestrial fields

This includes state-of-the-art **geotechnical rock engineering and geomechanical testing** capable of measuring strength (triaxial and uniaxial), deformability, porosity, permeability, thermal properties, geophysical properties and density. Installations for fluid-rock reaction studies cover conditions of temperature and pressure typical of the upper few kilometres of the Earth's crust, with a temperature up to 400°C and pressure exceeding 500 atmospheres. Other facilities allow for the use of advanced techniques for high precision measuring of capillary pressure and relative permeability, e.g water permeability within an estimated error of 10 to 20%.The experimental devices dedicated to entry pressure measurements can be used for performing dynamic methods that proves to be the most efficient way to measure entry pressure values in caprocks. In addition, experimental equipment to simulate reservoir conditions, fluid pressure, temperature, chemistry and fluid flow for the experimental investigation of coupled-reservoir processes is included.

The installations for monitoring CO_2 leakage can be used to perform accurate remote sensing surveys over wide areas, onshore and offshore (especially coastal areas). Data collected can easily be geographically referenced and integrated with similar data collected over the natural field laboratories given access by ECRI, for joint analysis. Access to these laboratories will be offered for joint analyses. The field laboratories include a series of unique instruments and equipment for geophysical imaging of the subsurface (CO_2 migration to the surface). The accuracy of these geophysical methods are needed to understand the interaction of CO_2 with rock formations, and the migration mechanisms, and to predict maximum CO_2 flow rates dissipating to the surface. Novel methods will be proposed within ECRI such as, multichannel seismic reflection, electromagnetic surveys (Ground Penetrating Radar), current measures (Earth Resistivity Tomography) and microgravimetry. The choice of the appropriate method depends on several factors, such as target depth, required resolution, environment characteristics, etc. *The joint availability of all these instruments is unique. It has been demonstrated that combining several geophysical methods is useful in providing a better image of the subsurface at various ranges of depth.* Some installations are also devoted to the simulation of leakage and studies of how CO_2 may impact the ecosystem under controlled conditions. to simulate a leak and study the responses of the ecosystem to CO_2 under controlled conditions.

In the field of CO_2 transport, a unique *CO_2 transport facility integrated with a CO_2 capture plant* forms a part of ECRI. This installation provides industrial scale conditions for the design, maintenance and operation of industrial CO_2 pipelines .The foreseen designed test campaigns can cover research topics on **material selection, impure CO_2 behavior, as well as direct experimental test for safety assessment**

1.3.3 The ensemble of Joint Research Activities

To ensure efficient use of research facilities, ECRI will open issues aimed at improving specific technologies, and shortening the lead time from laboratory to full scale operations. In this pursuit, the collective expertise within ECRI will help create synergy, ensure innovation and cater for equitable outlets from these joint research activities. The partners of ECRI have identified momentous challenges specific to CCS. Many challenges require extensive research to be properly faced and resolved. Problems in the field need to be addressed with adequate methods and technologies.

A key advantage of joint research is that a full range of knowledge, methods and techniques can be mobilised to obtain from the best available instrumentation and data analysis for

- comparative studies
- verification and validation of models and new methodologies
- feedback from the various steps of the development process in simulation and modelling, up to a final full-scale field test.

In ECRI, the **interdisciplinary skills** of **leading research teams throughout Europe are brought together to create synergy within CCS research**. It is assumed that joint research activities will harmonise different methods to make results and benchmarking comparable e.g. by introducing common instrumentation and methods for data processing. Joint research activities will identify differences and the inherent limitations of candidate methods and techniques by comparing with the best methods and techniques available.

Joint research activities (JRA) in ECRI cover, as stated above, the key research areas as already mentioned, notably i) energy conversion, ii) CO_2 separation (capture), and iii) transport and CO_2 storage. Threes specific work packages have been structured as follows:

1) **JRA-1: Advanced measurement and monitoring techniques to improve combustion performance and validation datasets (WP7)**

New measurement techniques and instruments are required for combustion systems operating in CCS pilot and demonstration plants. Specific needs will be identified for quantifying uncertainties of the measurements and for instrumentation exposed directly to **oxy-combustion environments**.

There is a general need for advanced measurement techniques to gain a better understanding of the processes occurring within the flame. New measurement techniques are also required to validate and support the development of CFD models.

The limits of conventional instruments are usually surpassed when exposed to the harsh environment of combustion, owing to

- the inherent temperature peaks in flames that exceed 2000°C
- stability and accuracy as corrosion generally deteriorate probe materials
- safety issues to protect operators and assets.

New concept for measuring in-flame and/or in-reactor FTIR for minor species (nitrogen and sulphur) and new optical probes are required for assessing combustion instabilities through fluctuating signals from flames (e.g. in gas turbine combustors). The latter is important due to the interest in **burning alternative fuels and hydrogen blends, especially in lean premixed gas turbines used for pre-combustion capture applications**. Other challenged addressed in JRA-2 deal with ability to **control and monitor deposition in oxy-fuel coal combustion plants**. Here the different combustion conditions, compared to the conventional coal combustion processes, influence the mineral transformations and thus change the **slagging and fouling potential** of the fuel resulting in severe **corrosion problems o**n the heat exchanger materials. The presence of certain minerals in ash is crucial concerning its slagging potential, e.g. pyrite (Fe_2S), which is generally found in coarse particles and it tends to form sticky spherical particles at high temperatures. Moreover, the presence of hard components in ash, such as quartz (SiO_2), leads to **erosion phenomena** due to abrasion, and has to be quantified in the oxy-combustion ashes. Apart from that, the effect of oxy-combustion on **ash fusibility**, *a key technological factor for slagging potential, has to be thoroughly examined.*

Special attention in ECRI is given to innovative combustion technologies and reactor systems employing the concept of chemical looping combustion[6] (CLC). In such systems, the fuel conversion performance of a dual fluidized beds, as proposed for CLC that incorporate CO_2 capture, depents on the interphasial interactions of gas-solid contacting paterns. Cold flow models are often used to optimise the fluid dynamic characteristics of fluidised bed systems design. A parameter largely neglected so far is the phase contacting pattern of the gas phase versus solids residence time distribution in dual fluidized bed systems. In order to optimize such systems in terms of the gas-solids contacting pattern, measurement methods based on magnetic properties of solids will be developed and implemented in different existing cold flow models.

2) JRA2: Improved methodologies, protocols and instrumentation for the development of solvents, sorbents and membranes for CO_2 separation processes (WP8)

For **solvent systems** both pilot scale and lab facilities are used for testing new methodologies and protocols related to chemical absorption separation processes. For pilot scale facilities reliable on-line measurements of the gas and liquids compositions provides valuable information for assessing the performance of CO_2 absorption plants, ivestigage the operation under dynamic condition, and finaly for validatting and implementing models for real-time process control and optimization. Emission monitoring in amine absorbers is a challenging task, due to the high water content of the gas combined with the very low concentrations of components of interest. At present **no commercial online instrumentation exists** for quantitative online analysis of sub-ppm concentrations of amines, degradation products or nitrosamines. Dedicated methods for analysis of sub-ppm components are only found in relation with ambient air analysis and monitoring and are suitable for non-condensing gases. *In ECRI, pilot plant campaigns will run to develop new systems and methods for on-line process monitoring aiming at:*

i) improving reliability of experimental data and

ii) accuracy of models used for studying the transient and operation of absorber/desorber column

The activity will result into **new measurement methodologies** for process monitoring.

In addition in JRA-2.2 laboratory apparatus modifications for heat and mass transfer model development is investigated with a focus of accurately controlling the interfacial driving forces during chemical absorption. *The aim is to extend mass and heat model to take into account both convective and diffusive mechanism,* **a feature unavailable in any commercial simulator today**.

For **membranes**, *spinning and characterization methods* of novel polymeric materials (e.g. nanocomposites) will be developed. A better understanding of the influence of the membrane's selective layer formation conditions and their influence on the permeability of the membrane will lead *to improved spinning and characterization methods.* For **adsorption process**es one of the key aspects that slows innovation is the lack of equipment designed for fast and high-throughput ranking of materials. In ECRI improved systems that deliver automation in both the running of the experiments and the analysis of the results of nanoporous materials for CCS adsorption applications are envisaged.

[6] **Chemical looping combustion** (CLC) typically employs a dual fluidized bed system (circulating fluidized bed process) where a metal oxide is employed as a bed material providing the oxygen for combustion in the fuel reactor. The reduced metal is then transferred to the second bed (air reactor) and re-oxidized before being reintroduced back to the fuel reactor completing the loop

3) JRA3: Optimisation and comparison of experimental methods for transport properties and surface monitoring tools in CO_2 storage (WP9)

In the context of CO_2 storage, laboratory studies are essential for estimating the chemical and fluid properties of CO_2 in porous media (i.e. geological formations), for both reservoir rocks and cap rocks. However, these studies are scarce and give inconsistent results, when implemented into reservoir simulators, mainly due to the limitations and validity of the experimental techniques used**. Hence, it is important for the petrophysical research community to contact rigorous benchmarking studies, evaluate and standardise the different experimental methods**. In ECRI benchmarking of different techniques and protocols is planned for the following key topics:

i. in-situ pH and dissolved CO_2 measurements at high pressure & temperature

Laboratory tools for measuring in situ pH at elevated pressure and temperature are at very early stages of development.These tools are necessary for evaluating key parameters in-line at the outlet of flooding cells. When conducting experiments to assess the impact of CO_2-rock-water interactions, fluid chemical changes are normally determined on depressurised samples at lab temperature. However, some key parameters needed for constraining inputs to geochemical models are sensitive to changes in pressure and temperature (i.e. pH, CO_2 - solubility and speciation). *In ECRI we seek to develop, evaluate, compare and improve the range of currently available in-situ measurement techniques.*

ii. in-situ CO_2 saturation measurement in rock samples and protocols for gas-water permeability mesuruments

This aspect focuses on experimental methods and protocols for determining flow parameters within a reservoir sequence like relative permeability and capillary pressure curves. Four main protocols exist: steady and unsteady steady state experiments, the semi-dynamic method and the centrifuge method, not including variations within a given method. In addition, local saturation measurements can be added to the data collected, improving and constraining considerably the parameter determination. *Comparison of protocols for estimating CO_2 flow properties will contribute to more relevant input data for CO_2 storage modelling.*

iii. Caprock characterization.

The last aspect deals with the characterisation of very low permeability formations (k_w < 100 nDarcy, 10^{-19} m^2). The movement of fluid can potentially occur by one, or more, of four mechanisms; diffusion, visco-capillary flow (classical two-phase flow), pathway dilation, and hydrofracture. The latter, hydrofracture, is unlikely if reservoir storage pressure is maintained below the sum of the minimum principal stress and tensile strength of the caprock. The caprock sealing efficiency relies on its very low permeability and its high capillary entry pressure (P_E) value, the low permeability also limits advective leakage of CO_2 from the reservoir. A comparative study will be undertaken to determine the merits and pitfalls of using either short- or long-duration testing procedures. This information can then be used to define protocols for characterising the sealing potential of caprocks and increase confidence in the safe long-term storage of CO_2

The **monitoring of CO_2 in the near surface environment is critical** for such issues as: risk assessment; health and safety; leakage detection; remediation monitoring; and carbon credit auditing. Although there are numerous monitoring tools, **detailed inter-comparison is limited**. Instead, **rigorous combined testing of multiple instruments (under different conditions) is needed to**: i) compare sensitivity, spatial coverage and leakage-location accuracy, response times, ease of use, and start-up, running, and maintenance costs; ii) develop protocols and iii) determine the compatibility of different methods which may improve their individual capabilities or reduce costs. *In ECRI testing of different innovative techniques in a number of settings and sites will be performed in order to define which tools are seen as the most appropriate in each case.* The results of these activities will be the **ranking of these tools**, as well as **series of recommendations**. The development of these surveys implies the use of different techniques at every proposed site and, consequently, the sharing of these results.

1.4 S/T methodology and associated work plan

1.4.1 Overall Strategy of the Work Plan

On the one hand, ECRI will identify, address and offer services required to cover the needs for R&D along the CCS chain. This implies networking activities aimed at fostering a culture of cooperation within the research infrastructure and with scientific communities, to help develop a more efficient and attractive European Research Area (ERA). Under these networking activities, ECRI will emphasise the relevance and value of its services relating to facilitation of knowledge via research and scientific approaches - including the ability to draw upon expertise and information from around the world, as well as joint research activities on selected topics. ECRI will divert networking activities towards national key research laboratories and European industries to offer transnational access and involvement in joint research activities aimed at including innovative actions relating to CCS. The following work packages are planned under the category of Networking Activities:

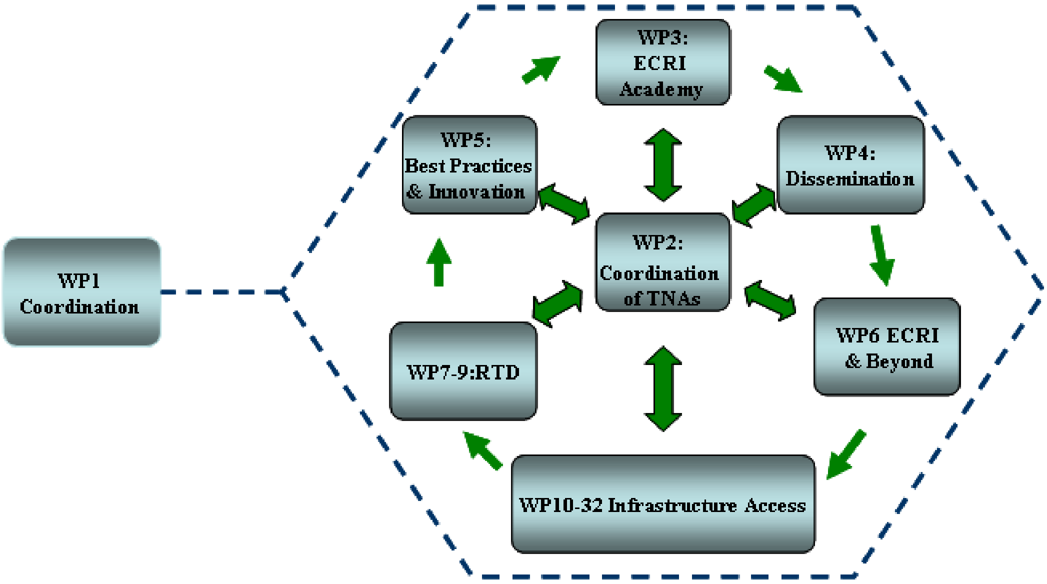


Figure 1.3.1 WP Interdependencies and information flow

Networking activities (WP2-WP6)

ECRI will on the one hand identify, address and offer services required to cover the needs for R&D along the CCS chain. This implies networking activities to foster a culture of co-operation within the research infrastructure and with scientific communities, and to help develop a more efficient and attractive European Research Area (ERA). Under these networking activities, ECRI will emphasise the relevance and value of its services relating to facilitation of knowledge via research and scientific approaches - including the ability to draw upon expertise and information from around the world as well as joint research activities on selected topics. ECRI will divert networking activities towards national key research laboratories and European industries to offer transnational access and involvement in joint research activities aimed to include innovative actions relating to CCS. The following Work Packages are planned under the category of Networking Activities:

- **WP2: Coordination of Transnational Access,** to establish and execute a common framework for handling transnational access with emphasis on flexibility, objectivity, transparency, and quality.
- **WP3: ECRI Academy,** to develop a culture of cooperation between EU research institutions and university partners by providing technical training in key specific areas covering the whole chain of carbon dioxide capture, transport and storage
- **WP4: ECRI Dissemination,** to raise awareness of ECRI and its research policy and disseminate the output of its integrating activities

- **WP5: Best Practices and Innovation along the CCS chain,** to define and promote best practices, methods, and protocols for the efficient use of the ECRI CCS research infrastructures. This will be implemented though the establishment of Special Interest Groups where industrial participation is foreseen.
- **WP6: ECRI and Beyond,** to solicit possible joint actions and contingency for pending research and to identify the impact of ECRI on solving challenges addressed by European CCS road mapping

Joint research activities (WP7-WP9)

Joint research activities (JRA) shall be carried out in order to improve the quality and services provided by the infrastructures. The activities will be combined and closely coordinated and pursued in a synergistic manner with activities under networking and transnational access. These prerequisites translate to innovative approaches (mainly technical and operational), methodology, measurements and recordings, standards and methodology for communication, characterisation, testing and verification, as well as protocols for data acquisition. Improvement of the services also applies to operational procedures, as to how to assess the needs of a specific action for transnational access, how to adapt existing installations to current needs swiftly and with reasonable efforts, and last but not least, how to ensure the required quality and appropriateness of results.

The joint research activities proposed are structured in three work packages, covering key research challenge in the three main areas of CCS research, (energy conversion systems, CO_2 capture, CO_2 Storage) as follows:

- **WP7 (JRA1): Advanced measurement and monitoring techniques to improve combustion performance and validation datasets,** improving the services provided by existing fossil fuel energy conversion experimental facilities by developing advanced measurement/monitoring techniques, and supporting modelling validation and data gathering.
- **WP8 (JRA2): Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes,** improving the services of lab- infrastructure used for the development of CO_2 capture processes in CCS.
- **WP9 (JRA3): Optimisation and comparison of experimental methods for transport properties and surface monitoring tools in CO_2 storage,** focusing on a) benchmarking studies of methods for determination of CO_2 flow property in reservoir and cap rock formations and b) on compassion and improvement of surface monitoring tools for detection of CO_2 leakage using geochemical and biological methods to address issues such as risk assessment, health & safety, environmental remediation monitoring.

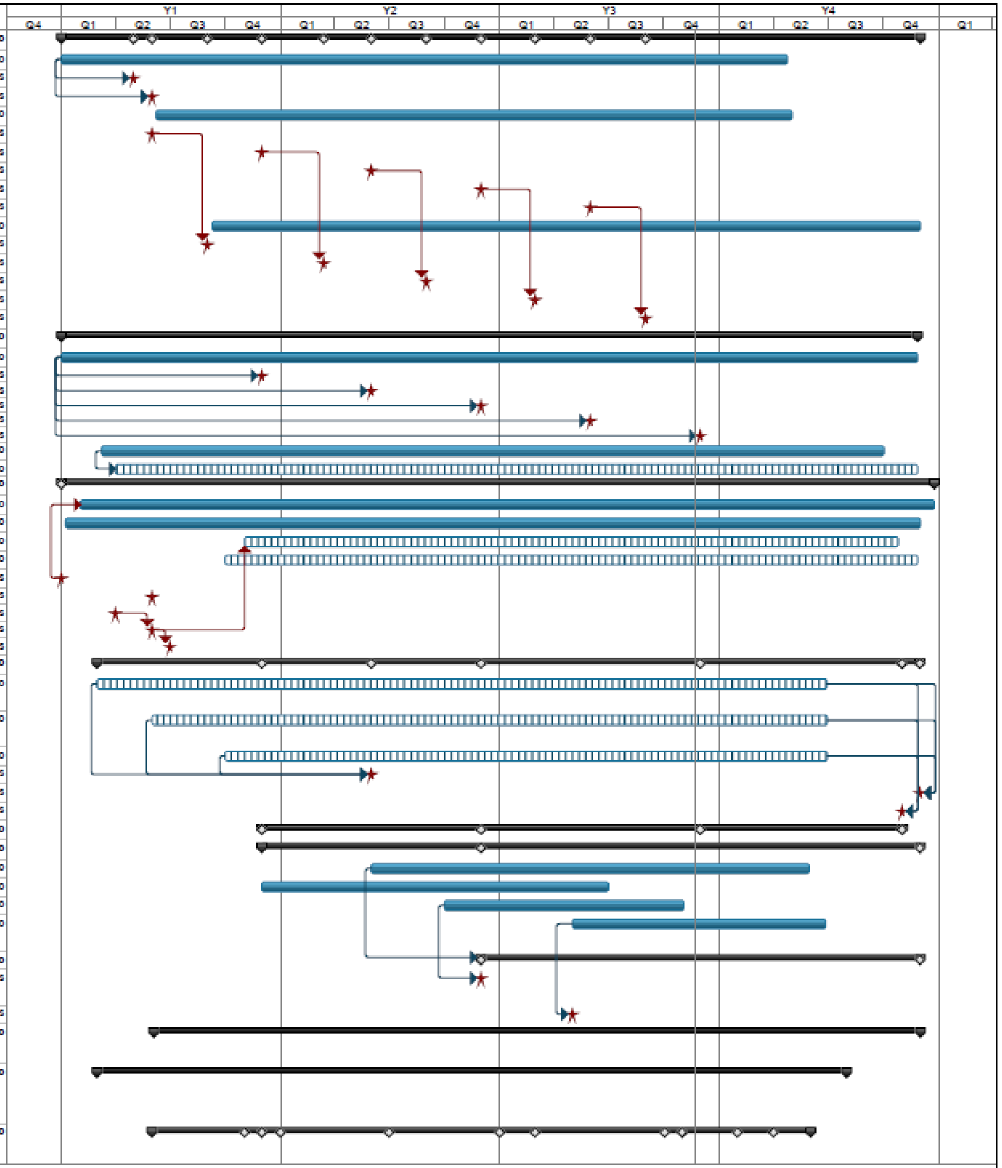
Transnational access and services (WP 10-WP23)

These work packages are at the heart of the infrastructure as they describe the facilities and services provided for technological research along the CCS chain. In each of the work packages, an amount has been allocated for travel and subsistence to each user (ca. 450k€ out of the total budget). This applies to a number of researchers taking part in various research projects during the project period of four years. ECRI will organise its research infrastructure within institutional and national key laboratories in Europe. Although transnational access will be decentralised, the selection of projects, their coordination and the management of the related services, will be coordinated under a common legal framework and governance structure. On this basis, ECRI will provide the necessary functions to ensure efficient operations of the dispersed CCS research infrastructure.

1.4.2 Timing of work packages and their components (Gantt chart)

I) Networking Activities

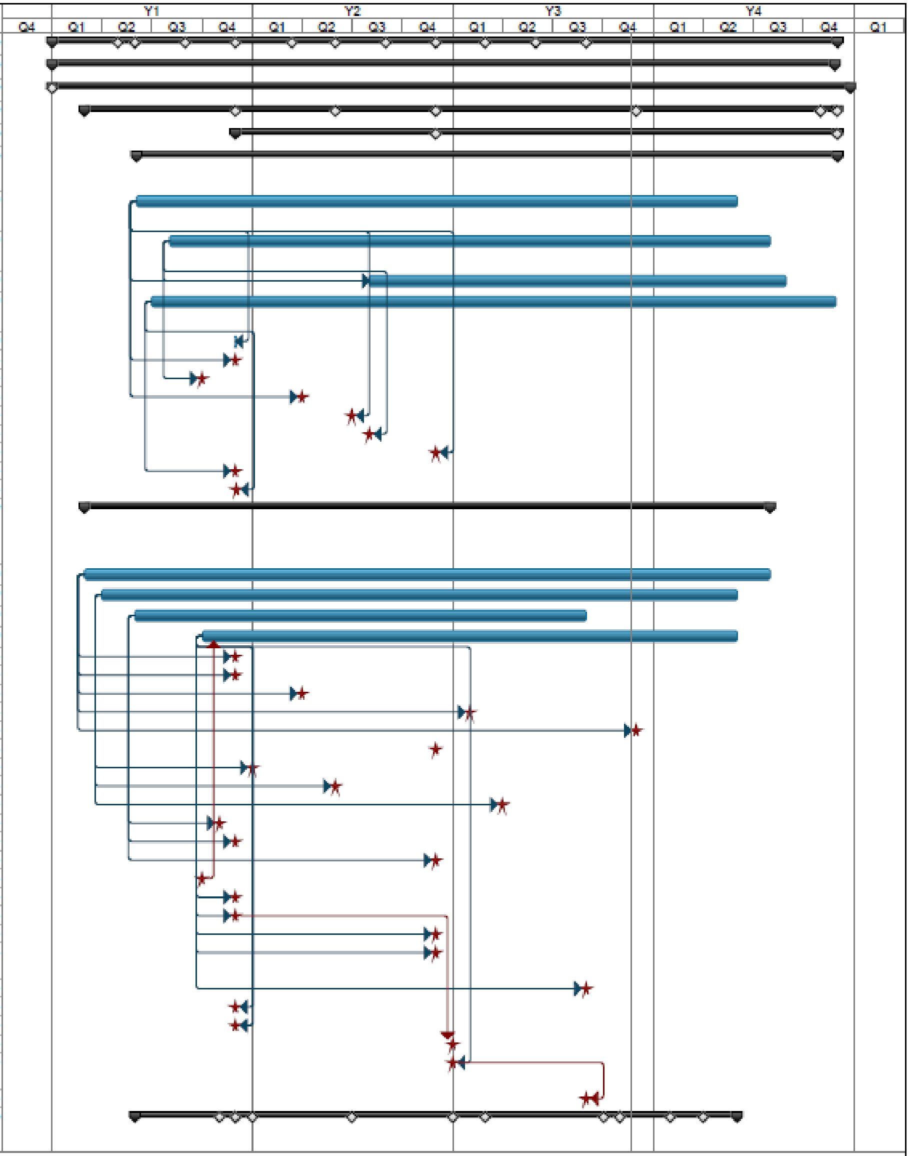
ID	Task Name	Milestone
1	**WP2 NA 1 Coordination of Transational Acces**	No
2	**Taks 1.1 Outreach of New Users**	No
3	M-NA1.1 Report on Application Procedure submitted	Yes
4	M-NA1.2 Report on Proposal Review Procedure submitted	Yes
5	**Task NA2.2 Review and Selection**	No
6	M-NA 2.2.1 Access Calls M6	Yes
7	M-NA 2.2.1 Access Calls M12	Yes
8	M-NA 2.2.1 Access Calls M18	Yes
9	M-NA 2.2.1 Access Calls M24	Yes
10	M-NA 2.2.1 Access Calls M36	Yes
11	**Task NA1.3: Infrastructure Access Coordination**	No
12	M-NA1.3 Access starts M9	Yes
13	M-NA1.3 Access Starts M15	Yes
14	M-NA1.3 Access Starts M21	Yes
15	M-NA1.3 Access Starts M27	Yes
16	M-NA1.3 Access Starts M39	Yes
17	**WP3 ECRI Academy**	No
18	Task 2.1 ECRI CCS Thematic Training Schools	No
19	M-NA1.1Thematic Training School 1,M 6	Yes
20	M-NA1.2Thematic Training School 2,M 12	Yes
21	M-NA1.3Thematic Training School 3,M 18	Yes
22	M-NA1.4Thematic Training School 4,M 24	Yes
23	M-NA1.5Thematic Training School 5,M 30	Yes
24	Task 2.2 Researchers Exchange Programme	No
25	M-NA2.1 Overseas visits	No
26	**WP4 ECRI Dissemination**	No
27	Task NA 3.1 Public Website and Internal Communication	No
28	Task NA3.2 Dissemination Material (UNOTT, NTNU)	No
29	Task NA3.4 Internal Technical Workshops (NTNU, all partners)	No
30	Task NA3.5 Public Technical Thematic Workshops	No
31	M-NA3.1.1 Launch of the public private website	Yes
32	*M-NA 3.1.2 First Researcher Podcast*	Yes
33	*M-NA-3.2.3 Templates for Flyers/brochures sent for review*	Yes
34	*M-NA-3.2.4 Completion of templates for flyers/brochures,posters*	Yes
35	*MNA3.2.5 Circulation of first dissemination material*	Yes
36	**WP5 Best Practices and Innovation along the CCS chain**	No
37	Task NA 4.1: Protocols , Methodologies and Databases for the development of combustion and gasification facilities for CCS	No
38	Task NA 4.2: Protocols, Methodologies and Databases used for the development of new solvent, sorbents and membranes for CO 2 capture	No
39	Task NA 4.3 Protocols , Methodologies and Databases in CO 2 Storage	No
40	M-NA 5.1 ECRI Databases configured and first data entered	Yes
41	M-NA 5.2 ECRI Benchmarking results reported and submitted for publication	Yes
42	M-NA 5.3 ECRI Databases populated	Yes
43	M-NA 5.4 Special Interest Group Workshops	No
48	**WP6 ECRI and Beyond**	No
49	Task NA5.1: Strategic positioning of ECRI vis-à-vis the European CCS community	No
50	Task NA5.2: Joining efforts of integrating activities with ECCSEL	No
51	Task NA5.3: Managing innovation – creating synergy	No
52	Task NA5.4: Conducting a SWOT analysis relating to European CCS research and ECRI	No
53	M-NA 5.1 Strategic Positioning of ECRI, M24 , M48	No
56	M-NA 5.2 Interested Industrial Stackeholders Reached and Conditions for accesing ECRI agreed, M18	Yes
57	M-NA 5.2 Ex-post assesment of ECRI (M 24)	Yes
58	**WP7 Advanced measurement and monitoring techniques to improve combustion performance and validation datasets**	No
72	**WP8 Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes for CO 2 separation processes**	No
100	**WP9 Optimization and comparison of experimental methods for transport properties and surface monitoring tools in CO 2 storage**	No



Page 1

II) Joint Research Activities (JRA 1 and JRA2)

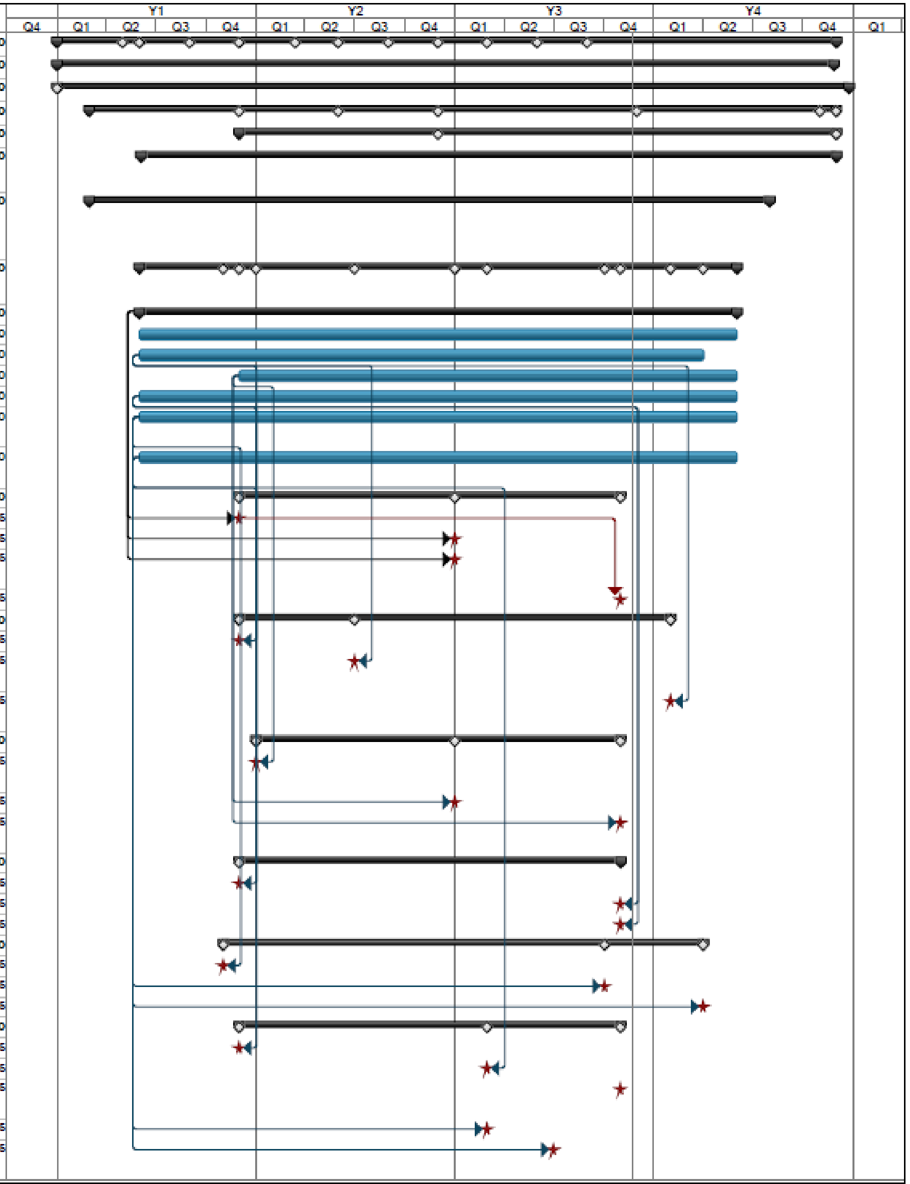
ID	Task Name	Milestone
1	**WP2 NA 1 Coordination of Transational Acces**	No
17	**WP3 ECRI Academy**	No
26	**WP4 ECRI Dissemination**	No
36	**WP5 Best Practices and Innovation along the CCS chain**	No
48	**WP6 ECRI and Beyond**	No
58	**WP7 Advanced measurement and monitoring techniques to improve combustion performance and validation datasets**	No
59	Task JRA 1.1. Development of improved measurement techniques for oxy- and gas turbine combustion systems	No
60	Task JRA 1.2 Development of an improved methodology to monitor deposition rates and investigate corrosion issues in oxy-fuel environment	No
61	Task JRA1.3 Hierarchical validation of energy conversion modelling	No
62	Task JRA 1.4 Development and evaluation of measurement techniques for dual fluidized bed systems used for advanced CCS	No
63	*M-JRA1.1.1 First measurement campaign completed at an oxy-fuel facility (Month 12)*	No
64	*M-JRA1.1.2 New probe for representative in-flame/furnace sampling developed*	Yes
65	*M-JRA1.2.1 Procedure for the characterization of metals corrosion on oxy-fuel environment by TGA*	Yes
66	*M-JRA1.2.2 First deposition tests performed*	Yes
67	*M-JRA1.2.3 Characterization of ash samples (through XRD, XRF, etc.) delivered*	Yes
68	*M-JRA1.2.4. Online monitoring system for deposition rates in oxy-fuel combustion developed*	Yes
69	*M-JRA1.3.1 Inventory of shareable validation data created*	Yes
70	*M-JRA1.4.1 RTD measurement equipment constructed*	Yes
71	*M-JRA1.4.2 Dynamic model of cold flow modelling equipment available*	Yes
72	**WP8 Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes for CO 2 separation processes**	No
73	Task 2.1. Development of methods for online process monitoring for solvent based CO2 ca	No
74	Task 2.2 Improved models for mass and heat transfer in post combustion CO 2 capture	No
75	Task 2.3. Improved spinning and characterization methods for novel hollow fiber membrane	No
76	Task 2.4 Automation of High-Throughput Experimental Systems for the Selection of Nanopo	No
77	*M-JRA2.1.1: Liquid phase FTIR tested in lab conditions for detection of degradation.*	Yes
78	*M-JRA2.1.2 Structuring of the dynamic absorber/desorber model, define interfaces and key process d*	Yes
79	*M-JRA2.1.3: Accuracy and robustness of MS for water wash liquid and analysis in lab scale has been*	Yes
80	*M-JRA2.1.4: Process control algorithms for online monitoring systems has been defined (M26, TNO)*	Yes
81	*M-JRA2.1.5: Online monitoring methods studied in the project has been tested at pilot plant scale*	Yes
82	*M-JRA2.1.6: Process control system of improved control strategy at pilot plant scale has been implem*	Yes
83	*M-JRA2.2.1 Wetted wall column modified*	Yes
84	*M-JRA2.2.2 Experimental work performed and data ready for modeling*	Yes
85	*M-JRA2.2.3 Model validated with experimental data*	Yes
86	*M-JRA2.3.1: Experiments with fibers from homogenous polymers have been performed*	Yes
87	*M-JRA2.3.2: Experiments with advanced fibers with adjusted settings done*	Yes
88	*M-JRA2.3.3: Experimental work with defect free hollow fibers performed*	Yes
89	*M-JRA2.4.1: Adsorbents needed are available*	Yes
90	*M-JRA2.4.2: ZLC automated (experiment) set-up ready for measurements at UEDIN (month 12)*	Yes
91	*M-JRA2.4.3: Experimental set-ups ready for dynamic measurements at ETHZ and SINTEF (month 12,*	Yes
92	*M-JRA2.4.4: Data analysis automated in ZLC experiments (month 24)*	Yes
93	*M-JRA2.4.5: Comparable experiments on first batch of materials have been conducted on all infrastructures and results share (month 24)*	Yes
94	*M-JRA2.4.6: Comparable experiments full range of materials have been conducted. (M33)*	Yes
95	*M-JRA2.4.2: ZLC automated (experiment) set-up ready for measurements at UEDIN (month 12)*	Yes
96	*M-JRA2.4.3: Experimental set-ups ready for dynamic measurements at ETHZ and SINTEF (month 12,*	Yes
97	*M-JRA2.4.4: Data analysis automated in ZLC experiments (month 24)*	Yes
98	*M-JRA2.4.5: Comparable experiments on first batch of materials have been conducted on all infrastructures and results shared amongst task partners (month 24)*	Yes
99	*M-JRA2.4.6: Comparable experiments full range of materials have been conducted. (M33)*	Yes
100	**WP9 Optimization and comparison of experimental methods for transport properties and surface monitoring tools in CO 2 storage**	No



Page 1

II) Joint Research Activities (JRA 3)

ID	Task Name	Milestone
1	**WP2 NA 1 Coordination of Transational Acces**	No
17	**WP3 ECRI Academy**	No
26	**WP4 ECRI Dissemination**	No
36	**WP5 Best Practices and Innovation along the CCS chain**	No
48	**WP6 ECRI and Beyond**	No
58	**WP7 Advanced measurement and monitoring techniques to improve combustion performance and validation datasets**	No
72	**WP8 Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes for CO 2 separation processes**	No
100	**WP9 Optimization and comparison of experimental methods for transport properties and surface monitoring tools in CO 2 storage**	No
101	Task JRA 3.1. Research for improving rock-fluid experimental data collection	No
102	Task JRA 3.1.1 In-situ measurements in fluid samples	No
103	Task JRA 3.1.2 In-situ CO2 saturation measurement techniques in rock samples, Month	No
104	Task JRA 3.1.3 Protocols for gas-water relative permeability measurements	No
105	Task JRA 3.1.4 Caprock characterisation, Month 6 - 42	No
106	Task 3.2 Development and testing of near-surface monitoring tools through the use of natural and man-made field laboratories, Month 6-42	No
107	Task 3.3 Development of techniques on surface bio-monitoring applied to CO 2 Storage, and measurement and modeling tools calibration	No
108	*M-JRA 3.1.1*	No
109	*a) Start of inter laboratory comparison of pH measurement*	Yes
110	*b) Evaluation of techniques for measurement of dissolved CO2*	Yes
111	*c) Start of laboratory testing of selected techniques for dissolved CO2 measurements*	Yes
112	*d) Conclusion of pH inter lab comparison*	Yes
113	*M-JRA 3.1.2*	No
114	*a) Choice of samples and flooding conditions (IFPEN, SINTEF PR, month 12)*	Yes
115	*b) Preliminary evaluation of local saturation measurements techniques for input to task 3.1.3 (IFPEN, SINTEF PR, month 18)*	Yes
116	*c) Conclusion on local saturation measurements (IFPEN, SINTEF PR, month 40)*	Yes
117	M-JRA 3.1.3	No
118	*a) Choice and characterisation of samples to be provided to partners, choice of experimental conditions (IFPEN, SINTEF PR, CIUDEN, month 12)*	Yes
119	*b) Comparison of raw data (IFPEN, SINTEF PR, CIUDEN, month 24)*	Yes
120	*c) Comparison of relative permeability (IFPEN, SINTEF PR, CIUDEN, month 32)*	Yes
121	M-JRA 3.1.4	No
122	*a) choice and availability of caprock samples*	Yes
123	*b) comparison of characterisation results (IFPEN, BGS, month 18)*	Yes
124	*c) comparison of measured transport parameters (IFPEN, BGS, month 36)*	Yes
125	M-JRA3.2-1	No
126	*a) start of joint field experiments at terrestrial sites*	Yes
127	*b) comparison of raw data*	Yes
128	*c) comparison of sensitivity, precision, accuracy, etc. of various techniques*	Yes
129	M-JRA3.2-2	No
130	*a) start of joint field experiments at marine sites*	Yes
131	*b) comparison of raw data*	Yes
132	*c) integration of various techniques to assess a marine carbon system with CO 2 bubbles*	Yes
133	*M-JRA 3.3.1 – Validation of all experimental set-ups in the selected labs*	Yes
134	*M-JRA 3.3.2– Each partner delivers a report to CIUDEN as input for the final report*	Yes



Page 1

Table 1.4 a: Work package list:

Work package No	Work package title	Type of activity	Lead participant No	Lead participant short name	Personmonths	Start month	End month	Indicative Total costs	Indicative requested EC contribution
WP1	Management	MGT	1	NTNU	28	1	48	499000	499000
WP2-N1	Coordination of Transnational Access	COORD	1	NTNU	28,5	1	48	808408	686804
WP3-N2	ECRI-Academy	COORD	18	UEDIN	16	1	48	273830	241446
WP4-N3	Dissemination	COORD	20	UNOTT	20	1	48	279809	247320
WP5-N4	Protocols , Standards and Data Sharing	COORD	12	MATGAS	45,5	1	48	590619	457214
WP6-N5	ECRI and Beyond	COORD	16	SINTEF ER	10	24	48	238256	145841
WP7-JRA1	Advanced measurement and monitoring techniques to improve combustion performance and validation datasets	RTD	23	USTUTT	175,5	1	48	1568516	1176387
WP8-JRA2	Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes for CO_2 separation processes	RTD	1	NTNU	103	1	48	1366691	1025018
WP9-JRA3	Optimization and comparison of experimental methods for transport properties and surface monitoring tools in CO_2 storage	RTD	10	IFPEN	201	1	48	2365482	1774112
WP10-TA1	Transnational access@NTNU	SUPP	1	NTNU	-	1	48	300500	300500
WP11-TA2	Transnational access@ENEA	SUPP	3	ENEA	-	1	48	190000	190000

WP12-TA4	Transnational access@BRGM	SUPP	4	BRGM	-	1	48	90000	90000
WP13-TA5	Transnational access@CERTH	SUPP	5	CERTH	-	1	48	54900	54900
WP14-TA6	Transnational access@DUT	SUPP	6	DUT	-	1	48	60000	60000
WP15-TA7	Transnational access@ETH Zurich	SUPP	7	ETH Zurich	-	1	48	80000	80000
WP16-TA8	Transnational access@IFRF	SUPP	8	IFRF	-	1	48	114000	114000
WP17-TA9	Transnational access@CIUDEN	SUPP	9	CIUDEN	-	1	48	200000	200000
WP18-TA10	Transnational access@IFPEN	SUPP	10	IFPEN	-	1	48	300000	300000
WP19-TA11	Transnational access@OGS	SUPP	11	OGS	-	1	48	230000	230000
WP20-TA12	Transnational access@MATGAS	SUPP	12	MATGAS	-	1	48	140000	140000
WP21-TA13	Transnational access@METU-PAL	SUPP	13	MET-PAL	-	1	48	51600	51600
WP22-TA14	Transnational access@BGS	SUPP	14	BGS	-	1	48	250000	250000
WP23-TA15	Transnational access@PGI-NRI	SUPP	15	PGI-NRI	-	1	48	50000	50000
WP24-TA16	Transnational access@SINTEF ER	SUPP	16	SINTEF ER	-	1	48	230000	230000
WP25-TA17	Transnational access@SINTEF PR	SUPP	17	SINTEF PR	-	1	48	101800	101800
WP26-TA18	Transnational access@SINTEF	SUPP	18	SINTEF	-	1	48	335000	335000
WP27-TA19	Transnational access@UEDIN	SUPP	19	UEDIN	-	1	48	220000	220000
WP28-TA20	Transnational access@UNOTT	SUPP	20	UNOTT	-	1	48	40000	40000
WP29-TA21	Transnational access@TUV	SUPP	21	TUV	-	1	48	154000	154000
WP30-TA22	Transnational access@UniRoma1	SUPP	22	UnitRoma1	-	1	48	62500	62500

WP31-TA23	Transnational access@USTUTT	SUPP	23	USTUTT	-	1	48	271400	271400
WP32-TA24	Transnational access@TNO	SUPP	24	TNO	-	1	48	205200	205200
				TOTAL	627,5			11721510,9	9984041,5

Table 1.4 b: Deliverable List

Del. no.	Deliverable name	WP no.	Lead Partners	Partners Involved	Nature	Dissemination level	Delivery date
D-MGT1	Project master plan including full transparency of resources, schedule and cost/performance	1	NTNU	All partners	RE	CO	M3
D-MGT1. 2	Internal Reporting to the Coordinator	1	WP leaders	All partners	RE	CO	3/year
D-MGT 1.3	ECRI Periodic Reports to the EC, M12, M24, M36, M48	1	NTNU	All partners	RE	CO	Yearly
D- MGT 1. 4	ECRI Implementation Plan (DoW	1	NTNU	All partners	RE	CO	Yearly
D-NA1.1.1	Application Procedure: Report on Implementation of Application Procedure (form, guidelines, rules, conditions and support to the users)	2	NTNU	All partners	R	CO	M5
D-NA1.1.2	Proposal Procedure: Report on Proposal Review Procedure	2	NTNU	All partners	R	CO	M6
D-NA1.1.3	TA Database: Includes an updated list of all infrastructures and installations, along with a list of accumulated TA activities (project title, abstract, user(s) names and affiliation, infrastructure/installation, duration.)	2	NTNU	All partners	O	p	M18,M36,M38
D-NA2.1	Reporting on feedback from participants to Thematic Training School 1 and 2	2	UEDIN	UEDIN, UNOTT	R	CO	M15
D-NA2.2	Reporting on feedback from participants to Thematic Training School 3 and 4	2	UEDIN	UEDIN, UNOTT, NTNU, UniRoma1, OGS	R	CO	M27
D-NA2.3	Reporting on feedback from participants to Thematic Training School 5 and overall feedback on schools	3	UEDIN	IFRF	R	CO	M33
D-NA2.1	Report on all overseas visits highlighting areas identified for possible future collaboration	3	UEDIN	Host partners	R	CO	M40
D-NA 3.1.1	ECRI Website M3	4	NTNU	NTNU	O	P& CO	M3
D-NA 3.2.2	Electronic Newsletters	4	UNOTT	UNOTT , NTNU	RE	PU	2/year
D-NA 3.3.3	Dissemination material prepared	4	UNOTT	UNOTT	O	PU	all months
D NA 3.3.4	Proceeding of Public Workhops	4	UNOTT	All partners	O	PU	1 Month after the event

D-NA4.1.1	Guidelines for implementation of protocols within ECRI energy conversion activities	5	IFRF	NA 4.1 partners	RE	CO	M10
D-NA 4.1.2	Report on implementation of the ECRI Fuels database	5	IFRF	IFRF	RE	CO	M24
D-NA4.1.3	Report on the ECRI Energy Conversion Benchmarking results	5	IFRF	NA 4.1 partners	RE	CO	M24
D-NA4.1.5	Report on test procedures	5	IFRF	NA 4.1 partners	RE	CO	M48
D-NA4.2.1	Report on benchmarking of protocols and methods for solvent, sorbent and membrane degradation studies	5	NTNU	NA 4.2 partners	RE	CO	M36
D-NA4.2.2	Best Practice Guide for testing and evaluation of new solvents, sorbents and membranes for CO_2 capture processes	5	SINTEF	NA 4.2 partnrers	RE	CO	M48
D- NA 4.3.1	A paper review on relevant petrophysical input data for reservoir modelling	5	IFPEN	NA 4.3 partnrers	RE	CO	M36
D- NA-4.3.3	Guidelines for safe operation of CO_2 transport pipelines, storage sites and related infrastructure	5	CIUDEN	CIUDEN, PGI-NRI	RE	CO	M36
D-NA5.1	Strategic plan for positioning ECRI vis-à-vis the European CCS community	6	SINTEF	All WP6 partners	RE	CO	M24
D-NA5.2	The merging of integrating activities of ECRI with ECCSEL operations	6	SINTEF	All WP6 partners	RE	CO	M36
D-NA5.3	Innovation broaching CCS technology and synergy into societal usage	6	SINTEF	All WP6 partners	RE	CO	M42
D-NA 5.4	SWOT analysis report	6	SINTEF	All WP6 partners	RE	CO	M48
D-JRA1.1.1	Report detailing the results of the measurement campaigns carried out at the different facilities and on the performance of the measurement technique(s) under experimental conditions	7	SINTEF	SINTEF ER/IFRF/ ENEA/USTU TT	RE	CO	M36
D-JRA1.1.2	Report on the effect of fine and ultrafine particle recirculation on deposition behaviour under oxy-fuel conditions based on data reported in D-JRA 1.1.1	7	USTUTT	USTUTT/IFR F/SINTEF ER	RE	CO	M40
D-JRA1.1.3	Summary report on validation data obtained during the measurement campaigns.	7	IFRF	IFRF/SINTEF ER/USTUTT/ ENEA	RE	CO	M40
D-JRA1.2.1	Report on the development of an advanced monitoring system for deposition rates in oxy-coal combustion	7	USTUTT	All task partners	RE	CO	M46
D-JRA 1.2.2	2 Report on the development of protocols for the	7	MATGAS	MATGAS,	RE	CO	M24

	characterization of metals corrosion on oxy-fuel environment by TGA			USTUTT			
D-JRA1.2.3	Guidelines for the materials selection in oxy-fuel applications	7		MATGAS	RE	CO	M36
D- JRA1.2.4	Report on the mineralogy, chemistry, and fusibility of oxy-combustion ashes. Connection of ash properties to its slagging / fouling / erosion potential	7	CERTH	USTUTT, CERTH	RE	CO	M42
D-JRA1.3.1	Report on hierarchical validation of mathematical models for oxy- and gas turbine combustion	7	IFRF	USTUTT, SINTEF, ENEA	RE	CO	M36
D-JRA1.4.1	Report on RTD measurement state of the art	7	TUV	TUV, SINTEF, BBU	RE	CO	M10
D-JRA1.4.2	Report on evaluated RTD data from cold flow models	7	TUV	BBU, TUV, SINTEF ER	RE	CO	M24
D-JRA1.4.3	Report on comparison of cold flow model to hot pilot plant	7	TUV	TUV	RE	CO	M46
D-JRA1.4.4	Report on parametric model for large scale chemical looping	7	BBU	BBU, TUV	RE	CO	M36
D-JRA2.1.1	Technical memorandum on Monitoring solvent degradation online	8	NTNU	NTNU, SINTEF, TNO	RE	CO	M12
D-JRA2.1.2	Report on dynamic models used in this study	8	TNO	NTNU, SINTEF,TNO	RE	CO	M12
D-JRA2.1.3	Technical memorandum on possibilities of using MS in emission and water wash liquid monitoring	8	SINTEF	SINTEF, NTNU, TNO	RE	CO	M15
D-JRA2.1.4	4 Pilot plant campaign report	8	NTNU	NTNU, SINTEF	RE	CO	M36
D-JRA2.1.5	Final report on the potential of using MS and FTIR for online process monitoring for solvent based CO_2 capture including process optimization and functional specification of control system.	8	TNO	TNO, SINTEF, NTNU	RE	CO	M44
D-JRA 2.2.1	Memo on the modifications done to the wetted wall column	8	SINTEF	NTNU, SINTEF, TNO	RE	CO	M10
D-JRA2.2.2	Report describing the results from the experimental work	8	NTNU	SINTEF, TNO, NTNU	RE	CO	M18
D-JRA2.2.3	Report on model validation	8	BBU	BBU, NTNU	RE	CO	M28
D-JRA2.2.3	Report on optimised, defect free hollow fibers	8	NTNU	NTNU , UEDIN	RE	CO	M20
D-JRA2.3.4	Report on coated hollow fibers – novel materials	8	UEDIN	NTNU, UEDIN	RE	CO	M24
D-JRA2.4.1	Report on the selection and characteristics of adsorbents to be	8	MATGAS	All Task 2.4	RE	CO	M10

	included			partners			
D-JRA2.4.2	Report on the experimental ZLC set-up, high-throughput set-up and set-up for dynamic measurements and related mathematical models	8	UEDIN	All Task 2.4 partners	RE	CO	M12
D-JRA2.4.3	Report on the characterization of materials under real conditions	8	ETHZ	All Task 2.4 partners	RE	CO	M12
D-JRA2.4.4	Report on the availability and limitations of the infrastructures based on the full set of experiments carried out in the task	8	UEDIN	All Task 2.4 partners	RE	CO	M36
D-JRA 3.1.1	A recommended technique(s) for determination of in-situ pH and dissolved CO_2 at under high pressure and at elevated temperature	9	BGS	BGS, SINTEF PR	RE	CO	M42
D-JRA 3.1.2	Report on in situ CO_2 saturation measurement techniques in rock samples	9	SINTEF PR	IFPEN, SINTEF PR	RE	CO	M42
D-JRA 3.1.3	Report on comparison and recommendations for best protocols for CO_2 flow parameters	9	IFPEN	IFPEN, SINTEF PR	RE	CO	M40
D-JRA 3.1.4	Report on experimental results of comparative study of flow in caprocks and recommendations for best protocols for characterising sealing potential	9	BGS	IFPEN, BGS	RE	CO	M42
D-JRA3.2-1	Integrated report comparing sensitivity, accuracy, and inter-operability of various surface / near-surface monitoring tools in terrestrial environments	9	UniRoma1	All Task 3.2 partners	RE	CO	M42
D-JRA3.2-2	Report detailing the integration of various marine monitoring tools for the characterisation of the carbon system impacted by CO_2 bubbles	9	OGS	All Task 3.2 partners	RE	CO	M42
D-JRA 3.3.1	Report on lessons learned based on the results of the different biomonitoring methodologies and techniques applied at the different sites	9	CIUDEN	All task 3.3 partners	RE	CO	M42

Table 1.4 c : Summary of transnational access provision

Part No.	Part. Short name	Co. Cod	Short name of infrastructure	Installation		Unit of access	Estimated unit cost (€)	Min. Qnty of access to be provided	Estimated number of users	Estimated number of projects
				Number	Short name					
1	NTNU	NO	Membrane Lab	TA1.1	MEM-FAB	week	4 922	9	2	2
			Membrane Lab	TA1.2	MEM-PERM	week	5 000	9	2	2
			Absorption Lab	TA1.3	ABSKIN	week	2 312	30	10	10
			Absorption Lab	TA1.4	ABSDEG	week	1 631	30	10	10
			Absorption Lab	TA1.5	ABSEQ	week	2 253	30	10	10
2	ENEA	IT	Zero Emission COal MIXed technology	TA2.1	ZECOMIX	day	1 826	60	3	3
			ENEA CCS PLATFORMS		SOTA CCS	day	2 417	33	3	3
4	BRGM	IT	Technological plateform Montmiral	TA4.1	Montmiral	day	2 038	44	4	4
5	CERTH/ ISFTA	GR	CERTH/ISFTA Storage	TA5.1	C/I Storage	day	568	70	7	7
			CERTH/ISFTA Capture	TA5.2	C/I Capture	day	415	36	4	4
6	DUT	NL	Laboratory for thermodynamic experiments	TA.6.1	ThermoLab	day	1 585	38	4	4
7	ETH Z	CH	GS Lab	TA7.1	2 PSA	day	743	54	4	4
			ADSEQ	TA7.2	AEMB	day	456	44	4	4
			Mineralization	TA7.3	FGM	day	471	43	4	4
8	IFRF	IT	L. E. A	TA8.1	IPFR	week	12 070	2	2	2
			L. E. A	TA8.2	FOSPER	day	14 913	7	3	3
9	CIUDEN	SP	es.CO2	TA9.1	Transport Rig	day	10 700	10	2	2
			es.CO2	TA9.2	CCSLab	day	2 370	20	4	4
			es.CO2	TA9.3	PISCO2	day	1 962	23	5	5
10	IFPEN	FR	TransProS	TA10.1	TransProS	day	3 448	37	6	6
			Caprock Characterization	TA10.2	CRC	day	3 204	40	8	8

			Mini-pilot absorption plant	TA10.3	U544	day	1 137	39	8	8
11	OGS	IT	Aircraft	TA11.1	Aircraft	day	7 137	8	4	2
			Geophysical imaging	TA11.2	GeoIm	day	3 590	20	4	4
			BiO marine laboratories	TA11.3	BioMarineLab	day	1 410	40	4	4
			DeepLab Sea Floor Landers	TA11.4	DeepLab	day	1 100	40	4	4
12	MATGAS	SP	GS Lab	TA12.1	Gas Separation Lab	day	635	135	27	27
			HP Lab	TA12.2	High Pressure Lab	day	398	135	27	27
13	METU-PAL	TU	PVT Lab	TA13.1	PVT Lab	day	1 291	40	4	4
14	BGS	UK	BGS NP3L	TA14.1	BGS NP3L	day	578	433	30	30
15	PGI-NRI	PL	Injection field lab	TA15.1	Pilot Injection installation	day	1 257	40	4	4
16	SINTEF ER	NO	Chemical Looping Combustion - Cold Flow Model	TA16.1	CLC-CFM	day	2 501	15	3	3
			SINTEF Combustion Lab	TA16.2	SCOM Lab	day	2 724	40	4	4
			High Pressure Oxy-Fuel Combustion Facility	TA16.3	HIPROX	day	8 850	10	2	2
17	SINTEF PR	NO	Reservoir laboratory	TA17.1	Core-SCAL	day	849	60	6	6
			Reservoir laboratory	TA17.2	Fluid-pVT	day	849	60	6	6
18	SINTEF	NO	SINTEF MC-CCS	TA18.1	SINTEF SMLab	day	2 090	58	10	10
			SINTEF MC-CCS	TA18.2	SINTEF AbsLab	day	2 249	49	8	8
19	UEDIN	UK	COFR	TA19.1	CO2 Flow Rig	day	169	90	8	8
			GREAT	TA19.2	GeoReservoir Simulator	day	292	100	10	10
			COFP	TA19.3	CO2 porescale	day	431	100	10	10
			FoAM	TA19.4	Membrane lab	week	4 415	15	5	5
			AMP	TA19.5	AdsMembLab	week	4 520	15	5	5
20	UNOTT	UK	ASGARD	TA20.1	Monitoring field	day	350	30	6	6
			Monitoring lab	TA20.2	Monitoring lab	day	300	30	6	6
			Geomechanical trapping and mineral carbonation	TA20.3	Geomechanical trapping and mineral carbonation	day	450	35	6	6
			Capture Infrastructure	TA20.4	Capture Infrastructure	day	125	30	6	6

21	TUV	AT	Technikum Vienna	TA21.1	CLPP150	week	77 024	2	2	1
22	UniRoma1	IT	Natural field laboratories	TA22.1	Natural field laboratories	day	896	70	7	7
23	USTUTT	DE	KSVA	TA23.1	500 kW Pilot scale Combustor	day	6 878	30	6	6
			BTS	TA23.2	20 kW Combustor	day	2 168	30	6	6
24	TNO	NL	TNO Pilot plant CO2 Catcher	TA24.1	TNO Pilot plant CO2 Catcher	day	3 200	20	4	4
			Micro/Mini Plant demonstrator	TA24.2	Micro/Mini Plant demonstrator	day	2 700	20	4	4
			QSCAN Solvent Test Street	TA24.3	QSCAN Solvent Test Street	day	1 400	20	4	4
			CLC Fixed Bed Facility	TA24.4	CLC Fixed Bed Facility	day	700	45	5	5
			High Pressure ABS/DES Pilot	TA24.5	High Pressure ABS/DES Pilot	day	1 400	20	4	4

Table 1.4 d: List of milestones

Milestone number	Milestone name	WP(s)	Partners Involved	Exp. date	Means of verification
M-MGT 1.1	First GA meeting/consortium workshop (kick-off meeting)	1	All	M1	MoM, Kick-off meeting
M-MGT 1.2	Project planning and reporting tools ready	1	NTNU	M3	Reporting tools
M-MGT 1.3	GA meetings/consortium workshops	1	All partners	M12, M24, M38, M48	MoMs, Proceedings
M -NA1.1.1	Report on Application Procedure submitted	2	NTNU	M5	Report
M-NA1.3	Access Calls	2	NTNU	M6, M12, M18, M24, M36	Call published
M-NA1.4	Selection Procedure Concludes	2	NTNU	M9 , M15, M21,M27, M39	Report
M-NA2.1	Thematic Training School 1	3	UNOTT, UEDIN	M6	Report
M-NA2.2	Thematic Training School 2	3	UNOTT, UDEDIN	M12	Report
M-NA2.3	Thematic Training School 3	3	NTNU	M 18	Report
M-NA2.5	Thematic Training School 4	3	UniRoma1, OGS	M 24	Report
M-NA2.5	Thematic Training School 5	3	IFRF	M30	Report
M-NA2.6	Overseas visits	3	NTNU	All months	Report
M-NA-3.1.1	Launch of the public private website	4	NTNU	M3	Website online
MNA-3.2.1	Signoff of the project 'brand' including logo	4	UNOTT	M1	logo
M-NA-3.2.2	Templates for Flyers/brochures sent for review by partners	4	UNOTT	M4	Templates
M-NA-3.2.3	Completion of the first dissemination flyers/brochures,posters	4	UNOTT	N4	Distribution
MNA3.3	Circulation of news letters	All	UNOTT	, M6,M12,M18, M24, M30, M36, M42,M48	Distribution
M-NA 5.1.1	ECRI Databases configured and first data entered	5 , 7 , 8 , 9 All TNAs	MATGAS, IFRF, IFPEN, NTNU,	M18	Database
M-NA 5.1.2	ECRI Benchmarking results reported and submitted for publication	5	All WP5 partners	M47	Reports
M-NA 5.3.1	Special Interest Group Workshops	5	All WP5 partners	M 12, M24 , M36 , M48	MoMs
M-NA 5.1	Strategic Positioning of ECRI	All	SINTEF, IFPEN, TNO, NTNU	M24, M28	Report
M- NA 5.2	Interested Industrial Stackeholders	6	SINTEF,	M18	Industrial

	Reached and Conditions for accesing ECRI agreed		IFPEN TNO, NTNU		Intesest Group
M- NA 5.2	Ex-post assesment of ECRI	All	SINTE, TNO, IFPEN, NTNU	M24	Report
M-JRA1.1.1	First measurement campaign completed at an oxy-fuel facility	7	SINTEF ER, USTUTT, IFRF and ENEA	M12	Report
M-JRA1.1.2	New probe for representative in-flame/furnace sampling developed	7	IFRF	M12	Probe
M-JRA1.2.1	Procedure for the characterization of metals corrosion on oxy-fuel environment by TGA	7	MATGA, USTUTT	M12	Report
M-JRA1.2.2	First deposition tests performed	7	USTUTT	M41	Report
M-JRA1.2.3	Characterization of ash samples	7	CERTH	M17	Report
M-JRA1.2.4.	Online monitoring system for deposition rates in oxy-fuel combustion developed	7	USTUTT	M18	Report
M-JRA1.3.1	Inventory of shareable validation data created	7	IFRF, USTUTT, ENEA	M24	Report/Database
M-JRA1.4.1	RTD measurement equipment constructed	7	TUV	M12	Equipment
M-JRA1.4.2	Dynamic model of cold flow modelling equipment available	7	BBU	M12	Software
M-JRA2.1.1	Liquid phase FTIR tested in lab conditions for detection of degradation	8	NTNU	M12	Repport
M-JRA2.1.2	Structuring of the dynamic absorber/desorber model, define interfaces and key process data is ready	8	TNO	M12	Report
M-JRA2.1.3	Accuracy and robustness of MS for water wash liquid and analysis in lab scale has been demonstrated	8	SINTEF, TNO, NTNU	M14	Report
M-JRA2.1.4	Process control algorithms for online monitoring systems has been defined	8	TNO, SINTED, NTNU,	M26	Report
M-JRA2.1.5	Online monitoring methods studied in the project has been tested at pilot plant scale	8	NTNU, SINTEF, TNI	M36	Report
M-JRA2.1.6	Process control system of improved control strategy at pilot plant scale has been implemented to the model.	8	TNO, SINTEF, NTNU	M40	Report
M-JRA2.2.1	Wetted wall column modified	8	SINTEF	M10	Report
M-JRA2.2.2	Experimental work performed and data ready for modeling	8	NTNU	M17	Report
M-JRA2.2.3	Model validated with experimental data	8	BBU	M28	Software
M-JRA2.3.1	Experiments with fibers from homogenous polymers have been	8	NTNU UEDIN	M8	Report

	performed				
M-JRA2.3.2	Experiments with advanced fibers with adjusted settings done	8	NTNU	M12	Report
M-JRA2.3.3	Experimental work with defect free hollow fibers performed.	8	UENDINNT NU	M24	Report
M-JRA2.4.1	Adsorbents needed are available	8	MATGAS	M10	Adsorbent available
M-JRA2.4.2	ZLC automated (experiment) set-up ready for measurements at UEDIN	8	UEDIN	M12	Experimen tal set-up
M-JRA2.4.3	Experimental set-ups ready for dynamic measurements at ETHZ and SINTEF	8	UEDIN, SINTEF	M12	Experimen tal set-up
M-JRA2.4.4	Data analysis automated in ZLC experiments	8	UEDIN	M24	Report
M-JRA2.4.5	Comparable experiments on first batch of materials have been conducted on all infrastructures and results shared amongst task partners	8	UEDIN, SINTEF,ET HZ	M24	Data
M-JRA2.4.6	Comparable experiments full range of materials have been conducted.	8	UEDIN, SINTEF,ET HZ	M33	Report
M-JRA3.1.1 (a)	Start of inter laboratory comparison of pH measurement	9	SINTEF PR, BGS	M12	Report
M-JRA3.1.1 (b)	Evaluation of techniques for measurement of dissolved CO_2	9	SINTEF PR, BGS	M18	Report
M-JRA 3.1.1 (b)	Start of laboratory testing of selected techniques for dissolved CO_2 measurements	9	SINTEF PR, BGS	M24	Report
M-JRA 3.1.1 (d)	Conclusion of pH inter lab comparison	9	SINTEF PR, BGS	M36	Report
M-JRA 3.1.2 (a)	Choice of samples and flooding conditions	9	IFPEN, SINTEF PR	M12	Report
M-JRA 3.1.2 (b)	Preliminary evaluation of local saturation measurements techniques for input to task 3.1.3	9	IFPEN, SINTEF PR	M18	Report
M-JRA 3.1.2 (c)	Conclusion on local saturation measurements	9	IFPEN, SINTEF PR	M40	Report
M-JRA 3.1.4 (a)	Choice and availability of caprock samples	9	IFPEN, BGS	M12	Samples available

M-JRA 3.1.4 (b)	Comparison of characterisation results	9	IFPEN, BGS	M18	Report
M-JRA 3.1.4 (c)	Comparison of measured transport parameters	9	IFPEN, BGS	M36	Report
M-JRA3.2.1 (a)	Start of joint field experiments at terrestrial sites	9	UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM	M8	Reports
M-JRA3.2.1 (b)	Comparison of raw data	9	UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM	M8	Reports
M-JRA3.2.1 (c)	Comparison of sensitivity, precision, accuracy, etc. of various techniques	9	UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM	M8	Reports
M-JRA3.2-2 (a)	Start of joint field experiments at marine sites	9	UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM	M24	Reports
M-JRA3.2-2 (b)	Comparison of raw data	9	UniRoma1, CERTH, UEDIN, OGS, UNOTT	M28	Reports
M-JRA3.2-2 (c)	integration of various techniques to assess a marine carbon system with CO_2 bubbles	9	UniRoma1, CERTH, UEDIN, OGS, UNOTT	M42	Report
M-JRA 3.3.1	Validation of all experimental set-ups in the selected labs	9	CERTH, OGS, UNOTT, BGS & CIUDEN	M12	Reports
M-JRA 3.3.2	All partners will provide interim reports on their biomonitoring site & lab results to CIUDEN for integration in the biomonitoring deliverable	9	CERTH, OGS, UNOTT, BGS & CIUDEN	M24, M36	Reports

1.4.3 Management Work Packages

WP1-MGT1: Project Management and Coordination

Work package number	WP1-MGT	start date of event:		M1		end date of event:					M48
Work package title	Project Management										
Activity Type	MGT										
Participant number	1										
Participant short name	NTNU										SUM
Person month per participant:	28										28

Objectives

The Project Coordinator shall manage the project and have operative responsibility for the organizational and technical efficiency of the project. It shall provide the sole interface with the Commission on scientific and technical matters relating to the project.

The Coordinator will be the sole ressonsible to:

- Manage the legal, financial and administrative aspects of the project, both towards the Consortium, the General Assembly and the Commission
- Administrate the financial contribution from the Commission, including distribution of share among partners, monitor all transactions and information to the Commission. Monitor the compliance by partners with their obligations under the Grant Agreement.
- Provide the Commission with periodic reports for each reporting period and a final report in order to assist the Commission in monitoring the work and results.
- Review and submit reports and other deliverables to the Commission by electronic means.
- Manage the different committees and panels
- Managing knowledge and IPR related issues
- Ensure that the generic results and results from topical activities are actively disseminated

Description of work

The Project Coordinator will be empowered by the General Assembly to manage the project in terms of its legal, financial and administrative aspects. This implies that Coordinator will have the sole authority of interacting with the General Assembly and the Scientific Officer nominated by the European Commission. Project reports will be produced in close cooperation with the WP-leaders, but resources for this work will be assigned to the various work packages. The work under this work package will include three tasks, focused on the operational management, financial matters, and the formal reporting.

Emphasis is placed on the following tasks, all led by NTNU:

- Task 1.1 Operational management
- Task 1.2 Financing
- Task 1.3 Reporting

Task MGT1 Operational management

This task covers all the work related to the practical continuous management of the project. This includes:

- Implement and monitor the fulfilment of the Consortium Agreement by all partners.
- Monitor the compliance by partners with their obligations under the Grant Agreement.
- Regular comparisons of work progress against the agreed work plan, including provision of deliverables at the agreed deadlines, attainment of milestones etc. Report any deviations to the General Assembly and take necessary actions.
- Risk assessment of the project, including contingency plans and remediation measures.

- Facilitate internal project communication, especially with the WP- and Task-leaders.
- Organize all meetings with the whole consortium, General Assembly, Executive Committee, etc)
- Establish and maintain continuous and close communication with the European Commission through the responsible Scientific Officer at the Commission.

Task MGT2 Financing

- Administrate the financial contribution from the Commission, including distribution of share among partners, and to monitor all transactions. All financial transactions to the partners will be documented and reported to the Commission as specified in the Grant Agreement.
- Establish and maintain a project master plan, follow-up of cost and work performance through cost and schedule performance indices.
- Regular control of accounts vs. project budget.
- Provide the financial report to be submitted to the Commission as agreed in the contractual rules. The financial report will be presented to the General Assembly for approval before submission to the Commission.

Task MGT.3 Internal Reporting and Periodic Reprorting to the EC

- Establish an internal reporting structure that allows for monitoring of work performance on a quarterly basis.
- Provide the Commission periodic reports for each reporting period and a final report in order to assist the Commission in monitoring the work and results. The reports will be prepared by the Coordinator based on the inputs from the WP-leaders and other management bodies (see management structure).

Deliverables

D-MGT1 Project master plan including full transparency of resources, schedule and cost/performance, M3

D-MGT2 Internal Reporting to the Coordator (every 4 months)

D-MGT3 ECRI Periodic Reports to the EC, M12, M24, M36, M48

D- MGT4 ECRI Implementation Plan (DoW), M12, M24, M36, M38

Milestones

M-MGT1 First GA meeting/consortium workshop (kick-off meeting), M1

M-MGT2 Project planning and reporting tools ready, M3

M-MGT3- GA meetings/consortium workshops M12, M24, M38, M48

1.4.4 Networking Activities Work Packages

WP2-NA1: Coordination of Transnational Access

WP3-NA2: ECRI Academy

WP4-NA3: ECRI Dissemination

WP5-NA4: Best Practices and Innovation allong the CCS chain

WP6-NA5: ECRI and beyond

Work package number	**WP2-NA1**	**start date of event:**	**M1**	**end date of event:**	**M48**
Work package title	Coordination of Transnational Access				
Activity Type	COORD				

Participant short name	**NTNU**	ENEA	BRGM	CERTH	DUT	ETH	IFRF	CIUDEN	IFPEN	OGS	MATGAS	METU-PAL	BGS
Person month per participant:	**11**	1	0.5	0.5	0.5	0.5	0.5	1	2	2	1	0.5	1
Participant short name	PGI-NRI	SINTEF ER	SINTEF PR	SINTEF	UEDIN	UNOTT	TUV	UniRoma1	USTUIT	TNO			**SUM**
Person month per participant:	0.5	0.5	0.5	1	1	0.5	0.5	0.5	1	0.5			28.5

Objectives

The objective of this work package is to establish and execute a common framework for handling transnational access with emphasis on flexibility, objectivity, transparency, and quality. Key activities include the following:

- Manage publicity campaigns to attract potential users
- Set up application procedure (e.g. Internet portal, forms and guidelines, and conditions and support offered to the users)
- Form Peer Review Board (Board) and develop evaluation criteria
- Implement review process
- Administer influx of users, in conjunction with infrastructure owners

Description of work

WP 2 is in effect the operating work package of the Transnational Access Activities and will be led by NTNU who have existing experience as coordinator of the ENGAS-RI project in FP6.

Task NA 2.1 Outreach of New Users:

This task is intended to bring awareness of 'the Transnational Access programme' that ECRI offers to all research institutions, universities and industrial CCS players in EU.

- An access web page describing 'the Transnational Access programme' will be opened immediately after project start. This will be managed by the Coordinator in collaboration with Task NA2.1. On the website, the potential user will find a description of the available infrastructures with the main characteristics of the facilities, one contact name (Local Laboratory Liaison) and address for each one, information concerning how to apply, a form to fill in order to submit a proposal and a guideline for filling the form.
- To attract potential users, a mailing will be sent to European CCS players and all the researchers, engineers involved in the project will have the opportunity to promote the project through their participation in exhibitions, conferences and visits in European Institutes

A user call for proposal will be distributed up to twice per year through the website, through advertisements in magazines and participation in conferences.

Three reports describing experience so far and completed projects under 'the Trans-national Access programme' will be released on the web page. These access reports will be generated and largely based on the EC-required database of access. The leader of this task is in charge of this work.

Task NA 2.2 Review and Selection

In order to ensure maximum benefit for the users of 'the Trans-national Access programme' being offered by ECRI, the review and selection of the proposals will be managed as follows:

Pre-screening:

The pre-screening of the proposals submitted by the applicants requires an independent technical appraisal. The purpose of the pre-screening is to analyse the type of activity the applicants will undertake, the scientific and technical merit of the research proposed, the objectives of the research to be undertaken and the ability of the facilities to meet the technical requirements as specified by the applicants. In doing so, the Transnational Access Leader (TA Leader) will undertake a quality assurance check with the Local Laboratory Liaison (LL Liaison) by independently matching the technical capabilities of the facility requested to the objectives of the work being undertaken by the applicants. During this step, the TA Leader and LL Liaison may have some exchanges with the applicants to obtain more technical information.

Selection and allocation of the facilities:

The selection of the proposal and the allocation of the facility to potential users will be managed by a **Peer Review Board** composed of:

- The Project Coordinator and TA Leader
- Internal Scientific Group from relevant partners
- External Advisors from Industry, Academia and Research Institutions

The Internal Scientific Group will consist of up to six members being partners of ECRI and representing the three areas of CCS research in the project (Energy, CO_2 capture, Storage & Transport). The membership is ratified by the General Assembly and will be valid for one year. The External Advisors will be selected from relevant academic and research organizations and industry. Each member of the Board shall have a documented reference list of expertise within the scientific topics of the project proposals. At least half of the Board members will be made up from external advisors. The external advisors are there to ensure that the research topic is within the scope of ECRI and that the process is fair and the users are treated on equal basis.

The evaluation criteria of the proposals will be:

- General eligibility criteria and priority aspects (e.g. new users, gender issues, diversity of nationalities)
- Scientific/technological quality, originality, feasibility, and relevance to ECRI
- Contribution of the project to advancing state of the art within the CCS chain
- Availability of the facilities

The Board shall have regular meetings in order to ensure reaching the goals of objectivity, transparency, and quality. We intend to hold these meetings in person a few weeks after each application deadline; the possibility of remote meetings will be explored according to the preferences of the Board members. The review process will be documented and the outcomes communicated to the applicants. In order to ensure transparency, fairness and impartiality the Board and their assessment reports will be made public via the web.

TASK NA2.3: Infrastructure Access Coordination

Immediately after a positive proposal evaluation by the Board, the LL Liaison for the installation(s) to be accessed will be notified for each approved user application. He/she will start a discussion with the USER well ahead of the access period in order to map the need for instruments, chemicals, tools, scientific and technical assistance, as well as to find a suitable period for the visit.

The LL Liaison will function as a scientific "guide" and problem solver at the host institute. This person will assist visiting researchers and will act as a helping hand with respect to administrative tasks, provide access to experimental units, laboratory space, technical assistance, and office space and make supporting staff available. Guest researchers will have access to internet and standard office amenities (telephone, printer, etc). The LL Liaison is responsible of finding local accommodation for new users, preferably in guest apartments, student houses or hotels located either within walking distance from the host institute, or a short ride by public transport.

The purpose of the coordination task is also to report the success and delivered outcomes from accessing each of

Pag. 669

the facilities. For each facility, a reporting mechanism will be introduced at the end of the testing period which will quantify the scientific and technological outcomes achieved. This will specifically address how access to the facility has aided the development of new knowledge and/or understanding of the technical challenges being investigated Users will be expected to provide feedback and experience information in the form of a report which will form the basis for the TA Database report for EC.

All Users will be invitied to participate in the ECRI Public Workshops (WP3) present their experience and research results. The outcome and papers presented at these Workshops will be disseminated via the Website and publication will be encouraged.

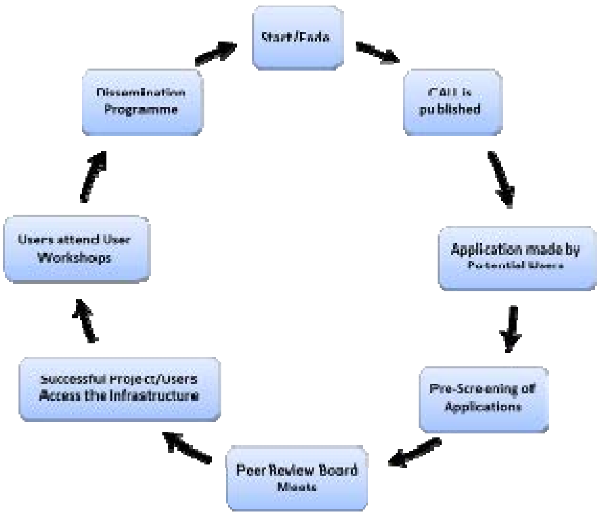


Figure 1. The Transnational Access Cycle

Deliverables

D-NA1.1.1 Application Procedure: Report on Implementation of Application Procedure (form, guidelines, rules, conditions and support to the users), M5

D-NA1.1.2 Proposal Procedure: Report on Proposal Review Procedure, M6

D-NA1.3 TA Database: Includes an updated list of all infrastructures and installations, along with a list of accumulated TA activities (project title, abstract, user(s) names and affiliation, infrastructure/installation, duration.) M18 , M36, M38

Milestones

M -NA1.1 Report on Application Procedure submitted, M5

M-NA1.2 Report on Proposal Review Procedure submitted, M6

M-NA1.3 Access Calls , M6, M12, M18, M24, M36

M-NA1.4 Selection Procedure Concludes, Access Starts,M9 , M15, M21,M27, M39

Pag. 669

Work package number	WP3-NA2	start date of event:	M1	end date of event:	M48
Work package title	ECRI -Academy				
Activity Type	COORD				

Participant short name	UEDIN	UNOTT	UniRoma1	NTNU	IFRF							SUM
Person month per participant:	**8**	2	2	2	2							16

Objectives

The objectives of the ECRI Academy is to develop a culture of co-operation between EU Research institutions and universities partners by :

i. providing technical training in key specific areas covering the whole chain of CCS through thematic lectures and practical training on research infrastructures funded by ECRI, and
ii. encouraging collaboration between ECRI institutions by providing grants for up to two months to help researchers in ECRI make study visits overseas.

Description of work

The ECRI academy will deliver a culture of co-operation between EU research institutions and universities through thematic training schools and overseas visits to ECRI institutions. When put together, the programme of the training schools will cover the whole CCS chain R&D framework.

<u>Task 2.1 ECRI CCS Thematic Training Schools (5) – Public</u>

This work package proposes to run five (5) Thematic Training Schools for a wide audience within the European CCS community. It will provide post-graduate students, post-doctoral researchers and other early career researchers from diverse academic background a broad understanding of the issues surrounding CCS and will encourage their active participation as well as networking activities.

Each Thematic Training School will be run by an ECRI partner for 3-5 days with thematic lectures and discussion groups led by EU experts in the field of CCS. Time will be allocated for networking and informal discussions with the CCS experts.

At the end of the week, attendees will leave with a network of contacts in the field of CCS and will have gained a broad overview of the issues surrounding an important area of CCS,

The summer school will be a week long exercise with presentations and discussion groups led by international experts in the field of CCS. In addition to the discussion programme, the students will be broken into teams to undertake short research activities on issues of importance within the CCS area, with a presentation to their peers at the end of the week. Time will also be allocated for networking and for informal discussions with the assembled experts. Students leaving at the end of the week will have developed a network of contacts in the field of CCS and will have gained a broad overview of the issues surrounding a particular aspect of CCS, e.g. Geological Carbon Storage. We propose a model with thematic schools attended by 15-20 attendees on average per school composed of early career and post-doctoral researchers, and Phd students. The theme of each school will be related to one research infrastructure funded by ECRI and will be run and hosted by the institution owning the shared research infrastructure.

The thematic lectures will cover the fundamentals aspects of a specific CCS topic, e.g. Energy Conversion and Combustion for CCS technologies, and will be related to the ECRI research infrastructure at the institution to allow for putting the material taught during the lectures into practice by providing practical and/or simulation training of the research infrastructure.

Partners will be submitting offers to the Executive Committee of the consortium and the choice of location and content will ratified by the General Assembly.

The funding from ECRI will cover staff time for developing/adapting material, staff time for teaching, operating costs. At least one third (1/3) of the total allocated budget for each training school will be used for the travel and subistence costs of the attendees.

Thematic Training School-1: Geological carbon storage (UNOTT)

This thematic school provides skills and training in geological carbon storage, aimed at participants with some basic geological knowledge. The focus is on the technical aspects of CO2 storage sites (site selection, storage capacity). Training includes both lectures and practical session basic calculations.

Provisional Programme

Day 1 – Edinburgh - Capacity estimates for CO_2 storage (Edinburgh)

Day 2 – Edinburg - Water-CO_2-rock interaction and tracers of CO_2 migration (Edinburgh)

Day 3 –Nottingham - Effect of impurities, Monitoring of storage sites

Day 4 – Practical training on ECRI infrastructure

Related Research Infrastruture

TA 20. 1 COFR: CO_2 Flow rig, Transport and Storage, Laboratory: Characterization and processes

TA 20.2 GREAT: GeoReservoir Experimental Analogue Technology

TA 20.3 COFP: CO_2 Flow at Pore Scale Laboratory: Characterization and processes of CO_2 flow at pore scale

Thematic Training School-2: CO_2 capture from power plants and novel separation processes (UNOTT, UEDIN)

This thematic school is aimed at engineers and focuses on the fundamental science and engineering aspects of CCS. It aims to develop advanced knowledge of capture technology, processes and, economics that underpin CCS with a particular focus on the carbon capture and transport part of the CCS chain.

Provisional Programme

Day 1: Edinburgh –Power plant engineering with carbon capture, CCS systems and economics

Day 2: Nottingham - Transport and compression of $CO_{2,}$ Capture and utilisation of CO2

Day 3: Edinburgh – Adsorption, Membranes for CO2 separation (Edinburgh)

Day 4: Practical training on UEDIN ECRI infrastructure

Related Research Infrastruture

TA 20.4 FoAM: Fundamentals of Adsorption and Membranes Laboratory

TA 20. 5 AMP: Adsorption and Membranes Processes Laboratory

Thematic Training School -3: Absorption process fundamentals (NTNU)

Provisional Programme

Day 1: NTNU Trondheim: Modelling of absorber and stripper columns, mass and heat transfer fundamentals

Day 2: NTNU Trondheim: Equilibrium and kinetic models

Day 3: NTNU Trondheim: Process energy considerations and environmental aspects

Day 4: NTNU Trondheim: Practical training, NTNU infrastructure, Mass and heat transfer, equilibrium and kinetics, pilot plant operation

Related Research Infrastruture

TA 1.3 Kinetic studies (ABSKIN) (CO_2 capture, absorption)

TA 1.4 Solvent degradation laboratory (ABSDEG) (CO_2 capture, absorption)

TA 1.5 Thermodynamic studies (ABSEQ) (CO_2 capture, absorption)

TA 18.2 : Lab scale absorption pilot plant (Capture, Absorption)

Thematic Training School-4: Learning from nature: using natural CO_2 leaking sites to understand gas migration, its potential impacts, an how to monitor it in the real world (UniRoma1, OGS**)**

This thematic school is aimed at CCS researchers who are interested in using real cases of natural CO_2 leakage to improve computer models, laboratory experiments, monitoring methods, policy decisions, etc. Frontal lessons will be given on the knowledge base of these "natural laboratories" (drawing from results and experiments from many EC-funded studies), followed by field excursions to the sites themselves for on-site explanations and demonstrations of selected monitoring tools.

Provisional Programme

Day 1: UniRoma1 - Gas migration mechanisms – geology and structural control, geochemical monitoring methods applied to the sites

Day 2: OGS -geophysical, remote sensing, and biological methods and their application to the study sites

Day 3: Field excursion to the Latera test site, one of the ECRI site infrastructures, where sites will be visited and monitoring techniques presented

Day 4: Practical training on UniRoma1 ECRI infrastructure

Related Research Infrastructure

TNA 23 Terrestrial and marine natural field laboratories

TNA 11 Data acquisition systems for terrestrial and marine natural field laboratories

Thematic Training School-5: Energy Conversion and Combustion (IFRF, This thematic school is aimed at engineers and combustion scientists and covers the three main fuel routes to CCS, pre-combustion carbon removal via gasification and associated chemical engineering processes, conventional combustion as a precursor to post combustion separation, oxy-coal combustion.

Provisional Programme

Day 1: Fuel characterisation, Combustion processes, oxy-coal with biomass co-firing in PF boilers, fluidised beds and gas turbines,

Day 2: Gasification, Ash, slogging and fouling, and corrosion in boilers,

Day 3: Emissions including heavy metal, Modelling of boiler operation/combustion processes

Day 4: Practical training on IFRF ECRI infrastructure

Related Research Infrastruture

TNA 8**.**1 IPFR (Combustion/gasification/chemical looping, solid fuel/sorbent characterisation)

TNA 8.2 FOSPER (Combustion, oxy-FGR)

Task 2.2 Researchers Exchange Programme within the ECRI Consortium (NTNU , all partners ,)

This work package is aimed at researchers from ECRI institutions only and intends to foster collaboration between ECRI institutions by providing funding for researchers for travel grants for study visits overseas in other ECRI institutions.

All ECRI partners will have the opportunity to nominate at least one researcher to participate in the ECRI Exchange Programme. The final decision will be ratified by the General Assembly and/or the Executive Committee based on the provision of a support letter outlining the benefits and the outcome of the visit. Funding will cover for hospitality and travel costs to/at the host institution.

The aim of the Exchange Programme is to promote researchers visits within the consortium to foster collaboration between research groups that were not previously collaborating and enable technology and knowledge transfer within the consortium team. The objective is to bring together scientists and engineers for mutual training and build on complementarities and synergies between ECRI institutions

The outcome will be joint-proposals and applications to EU projects from ECRI partners that do not a previous history of joint research projects.

The Exchange Programme is additional to the TNA and JRA since it will focus on fostering new collaboration activities.
Deliverables
D-NA1.1 Reporting on feedback from participants to Thematic Training School 1 and 2,M15 D-NA1.2 Reporting on feedback from participants to Thematic Training School 3 and 4, M27 D-NA1.3 Reporting on feedback from participants to Thematic Training School 5 and overall feedback on schools, M33 D-NA2.1 Report on all overseas visits highlighting areas identified for possible future collaboration, M40
Milestones
M-NA1.1Thematic Training School 1,M 6 M-NA1.2Thematic Training School 2,M 12 M-NA1.3Thematic Training School 3,M 18 M-NA1.4Thematic Training School 4,M 24 M-NA1.5Thematic Training School 5,M 30 M-NA2.1 Overseas visits (all months)

Work package number	**WP4-NA3**	**start date of event:**	**M1**	**end date of event:**	**M48**
Work package title	ECRI - Dissemination				
Activity Type	COORD				

Participant short name	**UNOTT**	NTNU	ENEA	CERTH	OGS							**SUM**
Person month per participant:	**15**	2	1	1	1							**20**

Objectives

The two objectives of this Work Package are:

1. to raise awareness of ECRI and its programme amongst all organisations and individuals affected by the requirement to reduce their greenhouse gas emissions. This group will include potential Users of ECRI Transnational Access and other potential beneficiaries of the ECRI activities.
2. to disseminate the output from the ECRI programme within the ECRI partnership and to the wider CCS community.

Description of work

Dissemination is envisaged through 5 main routes, each of which will form the basis of a distinct task:

1. Website, Databases etc.
2. Printed and Electronic Dissemination Material.
3. Electronic Newsletters.
4. Internal Technical Workshops.
5. Public Technical Workshops.

Task NA3.1 Public Website and Internal Communication (NTNU, UNOTT)

A public project web site will be created for dissemination and awareness purposes and will be on-line starting from month 3. Since the web site is a “communicative aggregator”, it will play a fundamental role in creating synergies between the different dissemination and communication channels activated by the project (press campaigns, electronic and paper mailings, organisation of workshops and seminars, etc.). The website will have two different levels of accessibility: a public level and a private level.

The public pages of the website will be accessible by month 3, but they will undergo continuous development during the project life as more content becomes available from ECRI resources. They will be directed to a technically informed audience, and will comprise of:

i. Introductory pages and Contacts.
ii. News and up-to-date information about project seminars, workshops and other relevant events.
iii. Dissemination material produced and all relevant public deliverables.
iv. Podcasts from transnational researchers and host groups.
v. ECRI CCS databases.

The private pages (restricted area) will be used as the project repository to facilitate discussion among partners. This section of the web site will provide an efficient means for ECRI partners to communicate individually, in sub-groups or as a whole partnership through the creation and maintenance of up to date mailing lists, and through on-line discussions.

Task NA3.2 Dissemination Material (UNOTT, NTNU)

To stimulate awareness on the project activities and opportunities, an extensive production and distribution of printed and electronic material is envisaged (A4 flyer, project logo, flyers, posters, CDs, etc. which can be circulated in printed form (e.g. to hand out at conferences). The electronic version (e.g. PDF file) can also be circulated electronically. UNOTT will ensure that material for each part of the CCS Value Chain is produced and vetted by partner(s) conversant with the topic featured.

Task NA3.3 Electronic Newsletter (UNOTT, all partners**)**

Starting from month 6, an electronic newsletter about the project will be produced biannually. The newsletter will include information on the progress of the project and all related information that the partners think useful to disseminate. The newsletter will be posted on the ECRI website and widely disseminated via the other CCS related networks (CO2net, CO2Geonen, ETP ZEP, TCCS7-8, ENeRG, GHGT conference series, IEGHG network EERA, etc).

Task NA3.4 Internal Technical Workshops (NTNU, all partners**)**

Annual Technical Workshops where the technical progress of ECRI will be presented and discussed will be organized by NTNU. They will be organized in conjunction with the annual meetings of the General Assembly.

Task NA3.5 Public Technical Thematic Workshops (CIUDEN, CERTH, UniRomma1, ENEA**)**

The focus of the ECRI Public Technical Thematic Workshops will be on reaching the Research, Academia, and Industry stakeholders in the complete CCS chain. In particular, it is planned to organize at least 4 thematic workshops in years 2-4. The planned duration of these workshops will be one day and will be fixed in due course after an estimation of demand in a particular theme. Special attention will be paid to promotion of results of research projects that have benefited from the access to the ECRI CCS Research Infrastructures. The aim is also to encourage a closer collaboration in developing and extending the offered services.

In addition, it is envisaged to organize special sessions at various conferences in the field whose schedule such as the Trondheim CCS and GHGT conference series, and other similar events. All participants in ECRI and the users of the ECRI RIs will be encouraged to attend and present their work.

Deliverables

D NA3.1.1 ECRI Website M3

D NA3.2.2 Electronic Newsletters (twice a year)

D NA3.3-3 Dissemination materials prepared (continues activity)

D NA 3-3-4 Proceeding of Public Workhops (1 month after actual date of the event)

Milestones

M-NA-3.1.1 Launch of the public private website, M3
M-NA-3.1.1 First Researcher Podcast, M6
MNA-3.2.1 Signoff of the project ‘brand’ including logo, M1
M-NA-3.2.2 Templates for Flyers/brochures sent for review by partners, M4
M-NA-3.2.3 Completion of the first dissemination flyers/brochures,posters Month 6
MNA3.3 Circulation of news letters, M6,M12,M18, M24, M30, M36, M42,M48
MNA3.4 Internal Technical workshop Month 12, M24, M36, M48
MNA3.5 Public Technical Thematic Workshop Events , Month 16, 26, M36, M46 (provisional)

Work package number	**WP5-NA4**	**start date of event:**	**M1**	**end date of event:**	**M48**
Work package title	**Best Practices and Innovation along the CCS chain**				
Activity Type	COORD				

Participant short name	**MATGAS**	**IFRF**	SINTEF ER	ENEA	TUV	SINTEF	UEDIN	BGS	UniRoma1	SINTEF PR	IFPEN	CIUDEN	BGRM
Person month per participant:	**7**	8	0.5	3	0.5	1.5	1.5	1	2.5	1.5	3	2	2.5
Participant short name	N|TNU	CERTH	ETH	OGS	METU-PAL	TUV	UniRoma1	USTUTT	UNOTT	TNO	PGI-NRI		**SUM**
Person month per participant:	3	0.5	1.5	2	0.5	0.5	2.5	2	0.5	0.5	1		**45.5**

Objectives

WP4 aims at defining best practices, methods, and protocols for the efficient use of the ECRI CCS research infrastructures. In will also take advantage of the large influx of data generated by the TNAs, harmonize and organise them in a way that facilitates interoperability. WP4 enhances data and knowledge exchange at a first instance between the ECRI partners and at a later with other organisations and the international scientific community through the open access ECRI CCS database.

Description of work

WP NA4 will operate through three **Special Interest Groups (SIG)** representing the three main research areas of ECRI :

- Special Interest Group-1 on Energy Conversion
- Special Interest Group-2 on CO_2 Separation
- Special Interest Group-3 on Storage & Transport

The **Special Interest Group (SIG)** will consist of one member of each participant involved in the respective JRAs. The Group members will be selected and ratified by the General Assembly during the ECRI kick-off meeting. The **Special Interest Groups** will meet annually and will be responsible to define the topics, select and assemble the necessary protocols, standards and experimental data in a harmonized and systematic way and finally deliver their input to the ECRI CCS database operated by the Coordinator (NTNU). They will also oversee the delivery of experimental data from JRA activities and TA activities to the ECRI CCS database operated by the Coordinator NTNU, as well as to other ECRI Partner databases identified as recipients by the Steering Group. The collection of data for assessment of protocols and procedures and for the benchmarking of test rigs will be done through the corresponding JRA and TNA activities. The **Special Interest Groups** will:

- define and agree protocols for collecting ECRI data in a consistent way,
- benchmark protocols and methodologies for consistency and to help identify and quantify uncertainties
- adapt or create a database(s) which will act as a depository for data collected during the ECRI project, add to it other data already available within ECRI partnership and beyond, and make the data accessible

to users in a form that makes it easy to find and easily transferable to their own applications

- integrate appropriate TA and JRA activities to ensure that opportunities to achieve the objectives of this Work Package are recognised, and that data is collected in a way that will facilitate its storage and dissemination from the outset.

Ensure compatibility between ECRI approaches and those already under development or developed within other Research Infrastructures or Organisations serving the same or related fields.

Task NA4.1: Protocols, Methodologies and Databases for the development of combustion and gasification facilities for CCS. (IFRF, SINTEF ER, USTUTT, ENEA, TUV**)**

There has been an increased effort and extensive experimental campaigns over the last year for the development of CCS energy conversion concepts such as oxy-combustion boiler and turbine applications, hydrogen enriched combustion for IGGC systems and Chemical Looping Combustion. In many of these cases, testing procedures from their conventional counterpart's e.g conventional combustion technology, were adapted resulting in low reliability and high uncertainties in the experimental results, in some other cases methods are lacking and need to be developed in parallel with the technology. In addition in all CCS research, compositional data on the fuels and process streams entering and leaving the energy conversion stages of the CCS chain are required for mass and energy balances, and for the specification and design of combustors, heat exchangers etc. The task will be closely linked with the JRA-1 and the associated TNAs and aims to define and disseminate consistent testing practices among the specialists in combustion, gasification areas for CCS. In addition , on the basis of the data acquired during the ECRI project, an ECRI fuel database will be developed based around an existing database such as the IFRF and USTUTT solid fuels database, but extending its content The activity is expected to follow the following route:

- Identification and agreement of an agenda by the Energy Conversion SIG -1.
- Initial definitions of protocols for data collection and data exchange
- Application of the protocols within the ECRI JRA1, and during relevant ECRI TA
- Review of the effectiveness of the protocols, and revision where necessary to prepare for publication
- Rationalisation of protocols and approval for publication
- Dissemination through NA3

Where appropriate, round-robin benchmarking tests on ECRI combustion and gasification rigs will be organised delivering comparable data for each process option in the CCS energy conversion process, or between successive stages where the output from one stage forms the input to the next stage. The work will be undertaken within the Joint Research Activities and during Transactional Access by Users, but the establishment of the benchmarking criteria, and pooling and analysis of the results will take place within this Task. Results of the benchmarking exercises will be disseminated using the ECRI web site.

Task NA4.2: Protocols, Methodologies and Databases used for the development of new solvent, sorbents and membranes for CO_2 capture (**NTNU**,SINTEF**,** TNO, UEDIN, MATGAS, ENEA)

Energy efficiency, economic viability and environmental performance of CO_2 separation techniques are amongst the key bottlenecks for successful implementation of CCS. In post - combustion capture via chemical absorption, new solvents with complex chemical and physical behaviour (precipitation, liquid-liquid formation) are currently being tested for their applicability and performance. Reliable kinetic, thermodynamic and thermal data are an absolute prerequisite and for this purpose improved apparatuses allowing more accurate measurements are needed. Also a standardization of interpretation methods is needed calling for development of agreed protocols. The same is true for characterization techniques of degradation products where the tools currently used do not properly represent the actual industrial situation. In pre-combustion CO_2 capture the demand for rapid screening and characterization of new sorbents and membrane materials for CO_2 separation processes necessitates further development of novel testing procedures, new laboratory equipment and instruments, and to utilize them in a systematic and integrated manner. In addition sorbents and membranes are currently the subject of many CCS related R&D collaborative efforts at European scale. Efficient combination of state of the art techniques is required to study the properties of these materials though rapid screening and advanced characterization often combined with simulation and modelling.

The Special Interest Group (SIG-2 CO_2 Separation) will be responsible for harmonizing and integrating different testing procedures used among the relevant partners. Protocols, methods and standards will be identified and evaluated for their validity through benchmarking exercises if necessary. The Group will meet annually and will be responsible for defining topics, select and assemble the necessary protocols, standards and experimental data. Assessment and benchmarking of protocols and procedures will be done through the experimental JRA and TNA activities. Best practise testing procedures disseminated among the task partners and the scientific community by issuing a Best Practice Guide.

Task NA4.3 Protocols , Methodologies and Databases in CO_2 Storage & Transport (**IFPEN**, BGS, SINTEF PR, BRGM , CIUDEN , UniRoma1, ETH, UEDIN, UNOTT, MATGAS, CERTH, OGS, PGI-NRI)

The storage of CO_2 in deep geological reservoirs requires great attention towards issues related to the feasibility of the process (e.g. injectivity, capacity, etc.) and its overall safety (e.g. monitoring from the reservoir to the ground surface, potential impacts, etc.), all issues that are addressed within JRA 3. Regarding the former, the accurate prediction of CO_2 storage capacity and transport relies on the availability of petrophysical data for the considered formation Regarding the latter, the safety of CO_2 storage has been addressed in numerous research projects, however whereas many of these techniques have undergone some level of controlled testing, there is a great lack of literature which rigorously tests them together (and under different conditions)

Regarding CO_2 transport (from CCS plants) there a few major research challenges with respect to the design of the pipeline infrastructure, selection of materials, operation , safety and environmental requirements for future large-scale CCS.

The Special Interest Group-3 Storage & Transport will address these issues, by determining the state of the art via that published in the literature combined with the work and experiments conducted within JRA 3.

Regarding processes within the reservoir, SIG-3 will gather methodologies in the literature from the petroleum industry and hydrogeology field, in order to transfer the relevant aspects to CO_2 storage. The group should be composed of reservoir modellers as well as petrophysicists working in laboratories. ¨

Regarding monitoring methods, approaches and protocols will be tabulated and compared in terms of their success rates in finding and quantifying CO_2 leaks.

CO_2 Transport task will be led by CIUDEN and will address safety and operational issues through the experience gained from the projects run at the Centre (public reports and work carried out on ECRI´s CO_2 Transport TNA) and other public results from projects regarding CO_2 transport. Also safety and operation will be addressed gathering information and methodologies from the literature review. The Group will meet annually and external technical expertise may be invited to support and share knowledge on this topics to address successfully the development of protocols, methodologies and databases in CO_2 storage and transport

Deliverables

D-NA4.1.1 Guidelines for implementation of protocols within ECRI energy conversion activities (IFRF, M10)

D-NA 4.1.2 Report on implementation of the ECRI Fuels database (IFRF , M24)

D-NA4.1.3 Report on the ECRI Energy Conversion Benchmarking results, (IFRF all task partners), M45

D-NA4.1.4 The ECRI Fuels Database in heritage ownership (IFRF, M46)

D-NA4.1.5 Report on test procedures (IFRF, all task partners M48)

D-NA4.2.1 Report on benchmarking of protocols and methods for solvent, sorbent and membrane degradation studies (NTNU, M36)

D-NA4.2.2 Best Practice Guide for testing and evaluation of new solvents, sorbents and membranes for CO_2 capture processes, M48 (SINTEF, all partners)

D- NA 4.3.1 A paper review on relevant petrophysical input data for reservoir modelling (month 36)

D-NA4.3.2 Final report and database that compares the efficiency of various surface and near-surface monitoring technolog

D- NA-4.3.3 Guidelines for safe operation of CO_2 transport pipelines, storage sites and related infrastructure. (CIUDEN, PGI-NRI)

Milestones

M-NA 5.1 ECRI Databases configured and first data entered,M18

M-NA 5.2 ECRI Benchmarking results reported and submitted for publication,M47

M-NA 5.3 ECRI Databases populated M48 M –NA 5.4 Special Interest Group Workshops , M 12, M24 , M36 , M48

Work package number	WP6-NA5	start date of event:	M1	end date of event:	M48
Work package title	ECRI and Beyond				
Activity Type	COORD				

Participant short name	SINTEF ER	NTNU	IFPEN	TNO									SUM
Person month per participant:	**5**	1	2	2									10

Objectives

- To ensure awareness of ECRI as an eminent venture by the European CCS community
- To solicit possible joint actions and contingency for pending research – under ECRI and beyond
- To identify the impact of ECRI on solving challenges addressed by European CCS road mapping
- To justify ways and actions aimed at strengthening the European technological research on CCS
- To provide synergistic knowledge products turning lessons learnt into best practices
- To bring science and CCS innovation closer to markets

Description of work

This work package shall address the inherent status and standard for ECRI – particularly in terms of reputation and perfection. This will affect the planning and positioning of ECRI outwith its normal, daily operations within and beyond the project period. To be specifically addressed are: 1) joint actions and survival of integrating research activities with ECCSEL, 2) adjusting research direction to meet a high practical impact on deployment of CCS, 3) justifying plausible improvements of European CCS research (strengthening approach), 4) providing synergistic knowledge products, and 5) bringing innovation closer to the market place.

Emphasis will placed on the following tasks:

- Task NA5.1: Strategic positioning of ECRI vis-à-vis the European CCS community
- Task NA5.2: Joining efforts of integrating activities with ECCSEL
- Task NA5.3: Managing innovation – creating synergy
- Task NA5.4: Conducting a (strength-weakness/limitations-opportunity-and-threat) SWOT analysis relating to European CCS research and ECRI

Task NA5.1: Strategic positioning of ECRI vis-à-vis the European CCS community

This task will emphasise needs and challenges as faced by the European CCS community. In particular this applies to challenges that require research to be resolved. Analyses of these needs will require a structured process (e.g. collective intelligence) aimed at bringing about ideas on how challenges can be addressed, communicated and eventually resolved.

The structured process will be formed preferably as a Delphi using expertise from the consortium in the expert panel. The process will be well planned and structured by task leader and the outcome will be assessed by the team behind the task.

Task NA5.2: Joining efforts of integrating activities with ECCSEL

It is anticipated that ECRI and ECCSEL may create synergy; First, ECRI may help kick-starting ECCSEL in 2015 by joining efforts of conducting commonly transnational access (2015-2016). Second, by terminating ECRI by end of 2016, projects and ideas that have been initiated in ECRI – but not closed – may then become part of the project portfolio of ECCSEL – provided, however, that the topical approach and the relevance of the ECRI project comply with the criteria of ECCSEL. To sort out these opportunities, networking will be required.

Efforts will be made to identify and plan joint actions with ECCSEL, such as exchanging ideas and experience. This also includes identification of topical anchorage of projects within ECRI, assessing how these may be structured as a joint undertaking with ECCSEL from 2015.

The plan must also include transnational projects and/or joint research that are brought to completion during the project period. This will include ideas about how actions – still open in the end of the project – may survive under the hallmark of ECCSEL. The realism of this approach owes to the consortium, because most partners of ECCSEL are also partners of ECRI.

ECRI may also integrate specific activities with the large European CCS demonstration projects – possibly via the new CCS-PNS project (2012-2015), although on a marginal basis.

Task NA5.3: Managing Innovation & Outreach to Industrial Stakeholders

Innovation is an important component in bringing about new CCS technology. As the purpose of ECRI is to move the frontier within science and technological development, efforts are needed to make sure that innovative technology does not remain in the laboratory. As time is often necessary to broach innovation throughout the incubator phase, actions beyond the project period must be planned in some manner.

This task will be directed towards integrating activities carried with industrial stakeholders. Such integrating activities are expected to have a strong and direct impact on the innovation by confronting ideas relating to science and technology among partners and industry. Strategic advantage becomes obvious, in some manner, such as the ability of:

- Offering services that no one else can
- Shifting competence – especially the competitive edge within CCS research
- Handling complexity, as investment keeps development barriers high
- Incremental innovation – via continuous improvements, especially the frontiers of cost, performance and lead time (in the laboratory and for reaching the market place).

As such, ECRI will take into account in its planning and execution, the development of innovative knowledge products – for instance by adding value to data, knowledge and experience arising from actions carried out under ECRI to report on how lessons learnt are turned into best practices.

Task NA5.4: Conducting a (strength-weakness/limitations-opportunity-and-threat) SWOT analysis relating to European CCS research and ECRI

Under this task a SWOT analysis shall be conducted as a component of the overall strategic planning of ECRI. The analysis shall specifically address the objective and targets of the project and identify the internal and external factors that are favourable and unfavourable to meet the objective and achieve the stated targets.

Subsequent to the SWOT analysis, recommendations for adjusting the direction towards the new achievable objectives and targets should be provided.

Deliverables

D-NA5.1 Strategic plan for positioning ECRI vis-à-vis the European CCS community, M24

D-NA5.2 The merging of integrating activities of ECRI with ECCSEL operations, M36

D-NA5.3 Innovation broaching CCS technology and synergy into societal usage, M42

N-DA5.4 SWOT analysis report, (interim M22, final M48)

Milestones

M-NA 5.1 Strategic Positioning of ECRI, M24 , M48
M-NA 5.2 Interested Industrial Stackeholders Reached and Conditions for accesing ECRI agreed, M18
M-NA 5.2 Ex-post assesment of ECRI (M 24)

1.4.5 Joint Research Activities Work Packages

WP7-JRA1:

WP8-JRA2:

WP9-JRA3:

Work package number	WP7-JRA1	start date:	M1	end date :	M48
Work package title	Advanced measurement and monitoring techniques to improve combustion performance and validation datasets				
Activity Type	RTD				

Participant short name	USTUTT	IFRF	ENEA	TUV	BBU	MATGAS	CERTH	SINTEF ER	SINTEF							SUM
Person month per participant:	36	18	18	32	36	8	8.5	11.5	7.5							175.5

Objectives

The overall objective of this work package is to improve the services provided by existing fossil fuel energy conversion experimental facilities by developing advanced measurement/monitoring techniques and supporting modelling and validation data gathering activities. This will involve the following sub-objectives:

- To develop improved measuring and monitoring techniques for oxy-combustion and gas turbine systems
- To improve accuracy of instruments and validate sampling techniques through interlaboratory testing
- To evaluate the performance of these measurement techniques at different scales, when firing different fuels (solids/gases) and at different pressures in an oxy-fuel environment.
- To develop an advanced monitoring system for deposition rates in oxy-coal combustion facilities
- To develop protocols for validation data needed for CFD models/submodels for oxy-combustion.
- To develop improved measuring techniques for dual fluidized bed systems used for advanced CCS

Description of work

This work package has been broken down into a number of tasks each of which will focus on at least one individual sub-objective, with a number of complementary partners collaborating to address the problems. These tasks are:

Task JRA 1.1. Development of improved measurement techniques for oxy- and gas turbine combustion systems. (IFRF, SINTEF ER, ENEA,USTUTT**)**

Experimental campaigns will be undertaken in order to initiate the development of new instruments for industrial flame investigations and at the same time, to fulfil the needs of new experimental data and quantify the uncertainties in in-flame/furnace measurements as a first step to providing validation data for CFD codes and sub-models (supporting in this way the development of **Task JRA 1.3**). The performance of different measurement techniques under a range of experimental conditions (different pressures, fuels, scales) will be assessed at pilot and semi-industrial scale facilities at **SINTEF ER**, **USTUTT**, **IFRF** and **ENEA**.

IFRF, with the access to combustion facilities at Livorno (semi-industrial 3MW Furnace, Fo.Sper.) and other facilities in the ECRI network, will develop and test a new sampling probe that can guarantee that the gas brought to the analyzer is representative of the gas inside the system under study. To achieve such result the probe should be designed with specific materials and quenching characteristics.

SINTEF ER and **SINTEF** will develop optical instrumentation for measurement and monitoring based on the characteristics of the spontaneous emission spectrum typical for oxy-fuel combustion. The development will be done in view of large scale test units where optical access is difficult. The methods and probes will also be tested and improved on the different scales available (SCOM Lab, HIPROX, IFRF (Fo.Sper), KSVA).

The new measurement techniques developed by partners contributing in this task would also be tested at **USTUTT**´s pilot scale 0.5 MWth pulverized coal combustion facility (KSVA) and compared with results obtained using existing tools for such measurements. In addition, SO_3 and particle measurements would allow assessing the role of recycled ash, especially of the fine and ultrafine fraction, on deposition behavior under oxy-fuel conditions.

Experimental tests using of the optical technique named ODC (Optical Diagnostic of Combustion) will be conducted at **ENEA**'s and **IFRF**´s combustion facilities and, if required, at other facilities in the ECRI network. The technique is able to monitor the state (stable or not) of the combustor and hence, to identify instability precursors in real time by developing a suitable strategy for radiant energy signal interpretation. The sensor would be eventually able to activate control and Large Eddy Simulation could help to assess the identification strategy of precursor events. **ENEA** together with **SINTEF ER** and **SINTEF** will plan common tests to in order to compare their methodologies.

In general, the probes and instrumentation have to be developed for transportable test facilities for capture techniques for open access (field testing). Test campaigns on different semi-industrial facilities in the network can be planned and executed through Transnational Accesses. This task contributes in further developing and improving and upgrading the main components of existing facilities

<u>Task JRA 1.2 Development of an improved methodology to monitor deposition rates and investigate corrosion issues in oxy-fuel environment.</u> (USTUTT,IFRF, CERTH, MATGAS)

During the combustion tests at **USTUTT** (0.5 MW_{th} test rig -KSVA), fly ashes and depositions will be sampled in order to determine their slagging and fouling propensity. **CERTH** will comparatively assess the slagging, fouling, and corrosion potential of the various oxy-combustion ashes, including samples collected during the experimental campaigns at **USTUTT**, by determining the ash mineralogy (XRD), the ash chemistry (oxides composition, by XRF or ICP-AES) and the ash fusion temperatures, i.e. I.D, S.T., H.T., and F.T. Furthermore, **CERTH** will perform studies for the direct linking of ash fusibility to ash mineralogy and the optimum temperature and stoichiometry conditions, in terms of slagging / corrosion / erosion phenomena mitigation will be proposed.

Parallel and related to these activities, an online system to monitor deposition rates at facilities operating under oxy-coal conditions will be developed and tested at **USTUTT** and also at **IFRF** (at FoSper during the planned TA tests).

Several materials used on heat exchangers and boilers will be exposed to synthetic oxycombustion flue gases and their behaviour will be characterized by microscopy and the evolution of their weight on a thermobalance at **MATGAS**. Different operating conditions will be simulated on the microbalance by changing gas composition and temperature; allowing to determine the most suitable materials in function of operating conditions. Based on this, protocols and procedures for material compatibility will be developed and improved by **MATGAS**. This will allow a better selection of materials for engineering equipment used on oxycombustion.

<u>Task JRA1.3 Hierarchical validation of energy conversion modelling</u>. (IFRF, USTUTT, ENEA)

IFRF will investigate both numerically and experimentally (through TAs) oxy-combustion flames in semi-industrial systems following the Verification & Validation approach. The concept is based on the proper Design of Experiment (DoE), that is necessary for developing a joint experimental and modeling activity. The construction of hierarchies will be used in designing validation experiments (through the facilities available in ECRI), so that, with input from partners working in **Task JRA1.1** (**USTUTT, ENEA), IFRF** will develop and agree criteria for validating mathematical models for oxy- and gas turbine combustion. These criteria will then be applied across a range of models, CCS processes and fuels. As by-products for other JRAs and NAs activities, protocols for qualifying and sharing experimental data for model validation will be defined. Linked to activities in **WP NA.1**, **IFRF** will create and coordinate the implementation of an inventory of 'shareable' validation data (on-line database available to ECRI Members, Users) based primarily on experimental results obtained in **Task JRA1.1** and **Task JRA1.2**.

<u>Task JRA 1.4 Development and evaluation of measurement techniques for dual fluidized bed systems used for advanced CCS</u> (TUV, BBU, SINTEF ER)

Cold flow model experimental data will be used by **TUV** as input to detailed reactor models in order to assess the expected performance improvement due to specific design optimizations. In particular, fluidized bed systems featuring the highly promising dispersed counter-current movement of gas phase and solids in the fuel reactor or in the carbonator, respectively, will be analysed.

A residence time distribution measurement system (RTD-MS) will be developed, constructed and applied to existing cold flow models at **TUV** in order to determine particle mean RTD within a fluidized bed cold flow model. Two levels of mathematical modelling will be covered by work at **BBU**. The first stage is a dynamic model of the cold flow model for effective evaluation of tracer measurement data. Using the developed model, the experimental data will be jointly evaluated by **BBU**, **TUV** and **SINTEF ER** and cold flow model results will be compared with results obtained from hot CLC unit. The second stage is semi-empirical parametric models of large scale units for chemical looping combustion and calcium looping, respectively. The methods developed within this JRA will be a significant contribution to formalizing dual fluidized bed reactor design, which at the moment seems to be based mostly on trial-and-error.

Deliverables

D-JRA1.1.1 Report detailing the results of the measurement campaigns carried out at the different facilities and on the performance of the measurement technique(s) under experimental conditions (SINTEF ER/IFRF/ ENEA/USTUTT, Month 36)

D-JRA1.1.2 Report on the effect of fine and ultrafine particle recirculation on deposition behaviour under oxy-fuel conditions based on data reported in D-JRA 1.1.1. (USTUTT/IFRF/SINTEF ER, Month 40)

D-JRA1.1.3 Summary report on validation data obtained during the measurement campaigns. (IFRF/SINTEF ER/USTUTT/ENEA, Month 44)

D-JRA1.2.1 Report on the development of an advanced monitoring system for deposition rates in oxy-coal combustion (USTUTT, Month 46)

D-JRA 1.2.2 Report on the development of protocols for the characterization of metals corrosion on oxy-fuel environment by TGA (MATGAS, Month 24)

D-JRA1.2.3 Guidelines for the materials selection in oxy-fuel applications (MATGAS, Month 36)

D- JRA1.2.4 Report on the mineralogy, chemistry, and fusibility of oxy-combustion ashes. Connection of ash properties to its slagging / fouling / erosion potential (CERTH, Month 42)

D-JRA1.3.1 Report on hierarchical validation of mathematical models for oxy- and gas turbine combustion (IFRF, Month 36)

D-JRA1.4.1 Report on RTD measurement state of the art (TUV, Month 10)

D-JRA1.4.2 Report on evaluated RTD data from cold flow models (BBU, TUV, SINTEF ER, Month 36)

D-JRA1.4.3 Report on comparison of cold flow model to hot pilot plant (TUV, Month 46)

D-JRA1.4.4 Report on parametric model for large scale chemical looping Units (BBU, Month 46)

Milestones

M-JRA1.1.1 First measurement campaign completed at an oxy-fuel facility (Month 12)

M-JRA1.1.2 New probe for representative in-flame/furnace sampling developed (Month 12)

M-JRA1.2.1 Procedure for the characterization of metals corrosion on oxy-fuel environment by TGA (Month 10)

M-JRA1.2.2 First deposition tests performed (Month 14)

M-JRA1.2.3 Characterization of ash samples (through XRD, XRF, etc.) delivered (Month 17)

M-JRA1.2.4. Online monitoring system for deposition rates in oxy-fuel combustion developed (Month 18)

M-JRA1.3.1 Inventory of shareable validation data created (Month 24)

M-JRA1.4.1 RTD measurement equipment constructed (Month 12)

M-JRA1.4.2 Dynamic model of cold flow modelling equipment available (Month 12)

Work package no	WP8-JRA2	start date :	M1	end date :	M48
Work package title	Improved Methodologies, Protocols and Instrumentation for the development of solvents, sorbents, and membranes for CO_2 separation processes.				
Activity Type	RTD				

Participant short name	NTNU	SINTEF	TNO	UEDIN	ETHZ	MATGAS	BBU									SUM
Person month per participant:	**16**	12	9	22	14	18	12									103

Objectives

- Improve the services of lab- infrastructure used for the development of solvents, materials for separation process in CCS
- Expand the understanding of kinetics and mass transfer phenomena related CO_2 capture by improved lab-infrastructure
- Evaluate the robustness of FTIR based liquid online monitoring methods suitable for solvent monitoring
- Evaluate the robustness of MS based online liquid and gas sampling methods for monitoring of water wash section and emissions for solvent based CO_2 capture
- Develop functional specification of process controls algorithms for online monitoring systems to optimize water wash and gas emissions
- Build an experimental set-up suitable for combined mass and heat transfer studies
- Develop and validate combined mass and heat transfer model for chemical absorption
- Perform detailed validation of dynamical absorber and desorber models
- Improve spinning and characterization methods for novel hollow fiber membrane materials
- Develop automation of high-throughput experimental systems for rapid ranking nanoporous materials for carbon capture applications.

Description of work

Task 2.1. Development of methods for online process monitoring for solvent based CO_2 capture (**SINTEF**,NTNU, TNO)

Understanding the dynamic behavior of CO_2 capture plants requires both accurate dynamic models as well as reliable experimental data. Online measurements of the composition of gas and liquids in the process provide valuable information for studies of transient conditions and provide input data for real-time process control and optimization. Online monitoring is beneficial both in pilot plant operation and lab scale experiments. In this task, new methods for online process monitoring will be tested and further developed. The experimental data produced will provide valuable input to dynamic models for absorber/desorber operation and for effects of water wash operation on gas emissions.

- *Solvent process monitoring and dynamic model validation*

Previous work shown that liquid Fourier Transform Infrared Spectroscopy (FTIR) by attenuated total reflectance (ATR) combined with multivariate methods such as partial least squares analysis (PLS) is well suited for analysis of amine solvents, both in the lab and for online process monitoring. Results indicate both amine concentration and CO_2 loading can be measured simultaneously by online FTIR-ATR. In addition, continuous information regarding the solvent degradation level and/or impurities can be obtained by implementing algorithms for outlier detection and analysis of spectral residuals in the multivariate calibration. For monitoring of specific compounds, often present in low concentration, online MS analysis can also be an option, especially when monitoring solvent degradation and nitrosamine formation.

- *Online gas emission measurements and water wash operation*

Emission monitoring in amine absorbers is a challenging task, due to the high water content of the gas combined with the very low concentrations of components of interest. No present commercial online instrumentation meets the demand for quantitative online analysis of sub-ppm concentrations of amines, degradation products or nitrosamines. Dedicated methods for analysis of sub-ppm components are only found in relation with ambient air analysis and monitoring. However, these designs are to date only suitable for non-condensing gases. Heated sampling lines in order to ensure complete evaporation represent a potential problem in relation to induced artifact formation in the gas due to the increased temperature.

Mass spectrometry (MS) has been heralded as a "golden standard" for identification of chemical substances. MS is widely used for manual analysis of solvents, water wash liquid, and emission measurements in pilot plants for amine based CO_2 capture. Recently developed online MS liquid analysis by automated extractive sampling can be applied for online analysis of solvent and water wash, but also for gas emission measurements. This requires instrumentation for online emission monitoring by MS that handles the high water content without the use of heated sampling lines making it possible to get online analysis that until now have required manual sampling and analysis.

In this task 2.1 the feasibility and robustness of FTIR and MS is demonstrated for solvent process monitoring and water wash liquid monitoring as well as for emission measurements. A model of the absorber and desorber will be built and structured such that the online monitoring system can be interfaced with the dynamic simulation model and the model will be tested and calibrated with process data. Additionally based on online monitoring approaches the process control algorithms will be adjusted accordingly and validated via dynamic system studies with the objective to optimized process performance, minimize emission to air and solvent degradation.

SINTEF will develop online monitoring methods based on MS suitable for both water wash liquid and emission monitoring and test them in the laboratory. NTNU will be responsible for the solvent monitoring methods and the accuracy of the method in laboratory scale will be tested. Furthermore the developed methods will be further tested in a pilot plant campaign jointly performed by SINTEF and NTNU, in realistic process conditions.

TNO will be responsible for the dynamic system modeling of the absorber/desorber system and calibration against online/experimental process data. Dynamic systems studies will be performed by implementing experimental data from measurement techniques (FTIR, MS) into the models. As a result improved operational control strategies that optimize the operation and minimize gas emissions in chemical absorption plant will be indentified.

Task 2.2 Improved models for mass and heat transfer in post combustion CO_2 capture.(**NTNU**, SINTEF, BBU)

The models predicting heat transfer during chemical absorption provided in commercial process simulators are normally very simple. The mass transfer models are better as they take into account the interaction between reaction and mass transfer. However, the combination of convective and diffusive mechanisms is not implemented in any commercial simulator yet and neither is the combined heat and mass transfer, with their very strong interactions. Reactive absorbers and desorbers are characterized by large fluxes of for example acid gases, as CO_2, and water across phase boundaries. These fluxes may be counter or co-current to each other depending on position in the process and are associated with simultaneous latent and sensible heat flows. Good models for this do not exist today and to improve the accuracy of process simulations and modelling better models are needed.

The objective of this work package is to modify a wetted wall column (part of the ABSKIN installation presented in TA1.3), currently used for pure mass transfer studies to carry out experiments for combined mass and heat transfer. The column itself will be modified to enable full temperature control, and monitoring of the surface temperature. Thereby local driving forces can be accurately controlled and the combined meat and mass transfer can be studied under very accurately defined conditions. The results from the experiments will be used to validate new combined mass and heat transfer models. The task will include apparatus modification, model development, experimental test programme and model validation. **SINTEF** will plan the modifications for the wetted wall column and **NTNU** will run the experiments. **BBU** will improve the state of art combined heat and mass transfer model together with NTNU, and will validate the model with the data produced by NTNU.

Task 2.3. Improved spinning and characterization methods for novel hollow fiber membrane materials

(**NTNU**-UEDIN)

Beside high selectivity, membranes for low temperature CO_2 separation have to show very high fluxes to cope economically with the large volume of gas that is emitted from industrial sources or power plants. To achieve high fluxes, thin selective layers have to be formed, either as selective thin films with a porous support or asymmetric membranes. The influence of thickness on the permeability of the membranes needs to be investigated and the presence of defects in the selective layer become critical. Furthermore the properties of the microporous support layer can be crucial and may limit the mass transport in the membrane, and have to be studied on both sides in order to fully characterise the limiting resistance.

Membranes produced as hollow fiber modules are the optimum solution for separation of large gas volumes as these modules have very high packing densities (m^2/m^3). In this task the spinning itself of novel polymeric materials with optimum separation properties,such, as nanocomposites will be investigated by studying the influence of thickness and formation condition of the selective layer on the permeability of the membrane. In addition the presence of defects and the porosity of the support material. This will lead to improved spinning operation and characterization methods. Additionally this will give further insight on the mass transport mechanism in asymmetric and supported membranes and thereby valuable information for the design of membrane and the formation process.

NTNU has extensive experience in the spinning of asymmetric hollow fibers from polymers such as cellulose acetate and polysulfone. In the proposed task, nanocomposites will also be investigated and coating of fibers by dip-coating or in a continuous operation tested. The spinning rig at NTNU will be used to make hollow fiber membranes under different conditions; both as asymmetric hollow fibers and coated hollow fibers (composites).

UEDIN has extensive experience in carbon capture with nanoporous and polymeric materials for adsorption and membrane processes. In the proposed task UEDIN use Porometer to measure porosity, permeability and sorption capacity for the fibers prepared by NTNU. The continuous collaboration with the company that developed the Porometer will allow for the development and modification of the system to suit better the need for reliable test of the integrity of new membranes.

Task 2.4 Automation of High-Throughput Experimental Systems for the Selection of Nanoporous Materials for Carbon Capture Adsorption Applications (**UEDIN**- MATGAS-SINTEF-ETZH)

Several research projects are currently underway at both European and member states level aimed at the development of novel nanoporous materials for carbon capture applications. One of the key aspects that slows innovation is the lack of equipment designed for fast and high-throughput ranking of materials for carbon capture applications. In this task we propose to develop improved systems that deliver automation in both the running of the experiments and the analysis of the results. UEDIN, MATGAS, ETZH and SINTEF have combined extensive experience in the development and evaluation of adsorbents for CO_2 capture, and in the simulation of both equilibrium and dynamic adsorption experiments, which can be used to carry out non-linear parameter regression using a wide range of experiments and operating conditions. An additional key advancement that ECRI will allow is the development of the techniques to determine the mass transfer coefficients (LDF and diffusional time constants) and reaction kinetics, for example in amine supported materials, which show significant differences when measured by different research groups. The combined experimental-simulation approach allows us to improve the current infrastructure (infrastructure IDs) through collaboration between laboratories that have the pool of equipment necessary to obtain a full characterization and testing of a sorbent under realistic CO_2 capture conditions. For this project, MATGAS and SINTEF will provide a range of complementary low-temperature materials needed to develop and validate the methodologies for high throughput screening of adsorbents taking place in UEDIN (ZLC) and in SINTEF (microcolumn) and compare them to tests performed by MATGAS and ETZH, including the effect of water and other impurities on the stability of the materials. To do this, different materials (zeolites, Metal Organic Frameworks, carbons, silicas and amine supported materials) having a broad range of properties is needed to assure a rigorous test for the fully automated systems developed.

UEDIN will further automate and develop the Zero Length Column system for high throughput screening of different adsorbents. The analysis of the data will be automated to include simultaneous regression of multiple experiments to derive both equilibrium isotherms and kinetic parameters for physisorption (zeolites, MOFs, carbons, silicas) and chemisorption (amine supported materials) and integrated with the experiments. The results will be compared with data obtained by the other partners in this task assessing the advantages and the possible limitation of the new setup.

MATGAS will provide the organic-inorganic and some other functionalized materials needed for the experimental work to validate the methods and models used within the task. It will also use its gas reactivity laboratory (magnetic microbalance) to first test the materials under real conditions and the simulation lab for understanding the interaction of the CO_2 and impurities with the materials.

SINTEF will further test and develop their in-house 8 bank micro-column high throughput unit constructed for high pressure usage. The experimental output will be compared with data obtained and derived from the ZLC with the same materials. From the study the availability, limitation and possible drawbacks of the setup can be concluded. In addition to this, SINEF will also provide adsorbent materials for testing in this task, ensuring a broad range of characteristics.

ETHZ will test the new materials developed in the task. Static measurements (single component and multi-component adsorption isotherms) will be performed, together with dynamic measurements in a single column set-up. This set-up will be expanded in such a way to allow for measurements in the presence of controlled concentrations of water vapor and under conditions reproducing not only the PSA but also the TSA operation, as it is likely that a combination of the two will be the technology of choice for CO2 capture by adsorption. The set-up will be fully-automated and fully-monitored.

Deliverables

D-JRA2.1.1 Technical memorandum on Monitoring solvent degradation online (M12, **NTNU**)

D-JRA2.1.2 Report on dynamic models used in this study (M12,**TNO**)

D-JRA2.1.3 Technical memorandum on possibilities of using MS in emission and water wash liquid monitoring (M15, **SINTEF**)

D-JRA2.1.4 Pilot plant campaign report (M36**, NTNU**)

D-JRA2.1.5 Final report on the potential of using MS and FTIR for online process monitoring for solvent based CO_2 capture including process optimization and functional specification of control system. (M44, **TNO)**

D-JRA 2.2.1 Memo on the modifications done to the wetted wall column (**SINTEF** M10)

D-JRA2.2.2 Report describing the results from the experimental work (**NTNU** , M18)

D-JRA2.2.3 Report on model validation (BBU) M28

D-JRA2.3.1 Report on improved spinning operation and characterization methods (M14**, NTNU**)

D-JRA2.3.3 Report on optimised, defect free hollow fibers (M20, **NTNU**)

D-JRA2.3.4 Report on coated hollow fibers – novel materials (M24, **UEDIN**)

D-JRA2.4.1: Report on the selection and characteristics of adsorbents to be included (**MATGAS** month 10)

D-JRA2.4.2 Report on the experimental ZLC set-up, high-throughput set-up and set-up for dynamic measurements and related mathematical models (**UEDIN**, M12)

D-JRA2.4.3: Report on the characterization of materials under real conditions (**ETHZ** month 24)

D-JRA2.4.4: Report on the availability and limitations of the infrastructures based on the full set of experiments carried out in the task (**UEDIN**, month 36)

Milestones:

M-JRA2.1.1: Liquid phase FTIR tested in lab conditions for detection of degradation. (M12, NTNU)

M-JRA2.1.2 Structuring of the dynamic absorber/desorber model, define interfaces and key process data is ready. (M12, TNO)

M-JRA2.1.3: Accuracy and robustness of MS for water wash liquid and analysis in lab scale has been demonstrated. (M14, SINTEF)

M-JRA2.1.4: process control algorithms for online monitoring systems has been defined (M26, TNO)

M-JRA2.1.5: Online monitoring methods studied in the project has been tested at pilot plant scale. (M36, NTNU)

M-JRA2.1.6: Process control system of improved control strategy at pilot plant scale has been implemented to the model. (M40, TNO)

M-JRA2.2.1 Wetted wall column modified. (SINTEF, M10)

M-JRA2.2.2 Experimental work performed and data ready for modeling. (NTNU, M17)

M-JRA2.2.3 Model validated with experimental data. (M28, BBU)

M-JRA2.3.1: Experiments with fibers from homogenous polymers have been performed (M8, NTNU, UEDIN)

M-JRA2.3.2: Experiments with advanced fibers with adjusted settings done (M12, NTNU)

M-JRA2.3.3: Experimental work with defect free hollow fibers performed. (M24, UENDIN, NTNU)

M-JRA2.4.1: Adsorbents needed are available (month 10)

M-JRA2.4.2: ZLC automated (experiment) set-up ready for measurements at UEDIN (month 12)

M-JRA2.4.3: Experimental set-ups ready for dynamic measurements at ETHZ and SINTEF (month 12)

M-JRA2.4.4: Data analysis automated in ZLC experiments (month 24)

M-JRA2.4.5: Comparable experiments on first batch of materials have been conducted on all infrastructures and results shared amongst task partners (month 24)

M-JRA2.4.6: Comparable experiments full range of materials have been conducted. (M33)

Work package number	WP9-JRA3	start date:	M6	end date:	M48
Work package title	Optimization and comparison of experimental methods for transport properties and surface monitoring tools in CO_2 storage				
Activity Type	RTD				

Participant short name	**IFPEN**	BGS	BRGM	CERTH	CIUDEN	OGS	UoRomma1	UEDIN	UNOTT	SINTEF PR						SUM
Person month per participant:	**15**	30	6	22	33	33	18	12.5	19.5	12						201

Objectives

Compare and optimize experimental methods

- **for flow property determination in reservoir and caprock formations (task 3.1).**
- **for surface monitoring tools using geochemical and biological methods (tasks 3.2 and 3.3).**

Detailed objectives of task 3.1:

- Evaluate relevant in-situ pH and CO2 dissolution measurements under pressure and elevated temperature (task 3.1.1).
- Compare two local saturation measurement techniques in core flood experiments (task 3.1.2)
- Compare 4 methods for determining relative permeability curves (task 3.1.3)
- Compare experimental methods for caprock characterization (liquid/gas permeability, entry pressure, task 3.1.4)

Detailed objectives of task 3.2:

RIGOROUS INSTRUMENT AND NOVEL PROTOTYPES INTER-COMPARISON AT THE FIELD SCALE

STRENGTHEN PROTOCOL AND METHOD DEVELOPMENT

Detailed objectives of task 3.3:

- Evaluate the biological and geochemical response of increasing CO_2 concentration in terrestrial and marine environments.
- Once assessed, search of bioindicators for early CO_2 detection
- Perform comparatives studies between the 5 different sites and lab activities to provide a lesson learned protocol.

Description of work

Task JRA 3.1. Research for improving rock-fluid experimental data collection (SINTEF PR, BGS, IFPEN, CIUDEN**)**

<u>Task JRA 3.1.1 In-situ measurements in fluid samples, Month 6-42 (BGS</u>, *<u>SINTEF PR)</u>*

Objective of this sub-task: recommended techniques for in-situ pH and dissolved CO_2 measurements under high pressure and elevated temperature.

When conducting experiments to assess the impact of CO_2-rock-water interactions, fluid chemical changes are normally determined on depressurised samples at lab temperature. However, some key parameters needed for constraining inputs to geochemical models are sensitive to changes in pressure and temperature (i.e. pH, CO_2 - solubility and speciation). This proposal seeks to develop, evaluate, compare and improve the range of currently available in-situ measurement techniques.

BGS has developed a small flow cell, with fibre optic connection to a UV-Vis instrument to determine pH at temperature and pressure by colourimetric means. In addition BGS has a 'commercially supplied' high-pressure pH probe that is currently being evaluated for laboratory use. SINTEF PR also has a commercially supplied pH-probe. These techniques will be compared with respect to accuracy and repeatability as well suitability for lab use (and perhaps eventually also as monitoring tools). BGS and SINTEF PR will conduct common experiments and compare the measured values of pH using the above mentioned pH probes, under a range of pressure/temperature conditions using both batch and flow reactors;

The measurement of dissolved CO_2 is also a key parameter both in terms of concentration and speciation. This is perhaps less advanced than determination of in-situ pH. Various methodologies have been trialled with varying success e.g. FT-IR and Raman Spectroscopy, and optic fibre tools. (BGS). It is proposed that techniques able to determine CO_2 are further evaluated and developed (BGS, SINTEF PR) prior to undertaking common lab experiments.

Task JRA 3.1.2 <u>In-situ CO2 saturation measurement techniques in rock samples, Month 6-40 (SINTEF PR, IFPEN)</u>

Objective of this sub-task: Give recommendations of in-situ saturation techniques for CO_2 flow experiments in rock samples, compare protocols and instruments.

In-situ techniques which are currently been used in laboratories, are mainly applied in core analysis related to oil reservoirs for estimation oil, gas and water saturations during core floods. Usually, X-ray or γ-ray are being used, although other methods like NMR, resistivity, acoustic methods, exist. We will focus here on X-ray and γ-ray techniques. For these techniques, due to strong attenuation of radiation in the solid rocks, the contrast between the individual fluids saturating the rock may be low giving a poor signal for estimating fluid saturations. Adding dopant chemicals to the various fluids may improve contrast and increase accuracy of saturation estimation. For CO_2 applications, detection may differ significantly from hydrocarbon-water systems due to the large compressibility of CO_2 which gives large density variation with pressure as well as the important solubility of CO_2 in water at elevated pressures. There is therefore a clear need to improve the in-situ measurement techniques and adapt and optimize these for CO_2 saturation applications.

IFPEN and SPR will compare full porosity and saturation profiles for well defined flooding conditions on the same samples (or samples taken from the same block), for sandstones and carbonates. The flooding conditions will be chosen in relation to the one used in task 3.1.3 focusing on relative permeability. A particular attention will be put on the effect of evaporation on saturation evaluation.

<u>Task JRA 3.1.3 Protocols for gas-water relative permeability measurements, Month 12-42 (IFPEN, SINTEF PR,CIUDEN)</u>

Objective of this sub-task: Recommended protocols for determination of CO_2 flow parameters.

For gas-water experiments, there exists a fundamental difficulty related to the high mobility of the gas phase compared to water. As a consequence, the CO_2-water front may not be driven by capillary forces but by digitations linked to small scale local heterogeneities of the porous media. It has been shown (Chalbaud et al. SPE 111420) that even for samples that can be considered as homogeneous, experimental data must be interpreted with techniques designed for heterogeneous samples. Hence, different techniques may not give the same results; for example, the centrifuge experiment, which is in essence a gravity drainage experiment with gravity forces increased progressively, is not subjected to front instabilities. At the opposite, a high flow rate gas injection may be severely dominated by heterogeneities and hence different results can be predicted. The use of 3D imaging techniques can be of great help for describing unstable front.

The following issues will be addressed:

- Perform state-of-the-art gas-water displacement experiments including local saturation measurements,
- Perform state-of-the-art numerical interpretation,
- Perform different experimental protocols from different laboratories on the same or similar samples to

obtain relative permeability curves,

- Compare the results and separate interpretation issues from petrophysical issues

On a set of sandstone and carbonate plugs (same plugs or plugs extracted from the same block), the different laboratories will perform the following experiments:

IFPEN: gas-water Pc and Kr first drainage centrifuge experiments, N_2-water Pc and Kr semi-dynamic experiments with X-ray local saturation. This work will be closely linked to Task JRA 3.1.2

CIUDEN: standard USS and SS CO_2 flooding experiments without local saturation measurements, and numerical/analytical uncertainty analysis

SINTEF PR: CO_2 flooding (SS or USS) with in-situ saturations (γ-ray) and data interpretation. This work will be closely linked to Task JRA 3.1.2

Task JRA 3.1.4 Caprock characterisation, Month 6 - 42 (IFPEN, BGS)

Objective of this sub-task: A comparative study to optimize protocols for liquid and gas permeability measurements, including entry pressure, transient and steady-state permeability, and to examine the linkage and merits between short and longer term characterisation methods.

Different laboratories employ different protocols when measuring gas transport properties. It is common for tests to be conducted on small plugs of material in a relatively short period of time (e.g. hours/days). BGS has expertise in conducting long term (6 months and longer) detailed flow tests in order to accurately define steady state flow conditions in low permeability shales. This approach can be used to reduce uncertainty associated with key processes which underpin the long-term storage of CO_2. The aim of the proposed comparative study is to determine the merits and pitfalls of using either short- or long-duration testing procedures, and define best protocols. The proposed experimental program is the following:

Starting core material will be prepared by one organisation for use by all participating laboratories in order to eliminate issues of sample preparation from the proposed comparative study. All samples will be measured using NMR techniques by IFPEN in order to determine physical property heterogeneity and to ensure that all participating laboratories are using similar test materials.

Experimental work at IFPEN will focus on measuring water permeability and entry pressure using a combination of methodologies including pressure decay techniques. Values from these tests can be compared with those obtained from more dedicated experiments; such as step by step approach for P_E, gas entry and permeability obtained from steady state experiments. Tests will also be performed on partially saturated caprocks controlled using relative humidity controlled chambers. Classical gas permeability tests will be conducted using a DarcyGas experimental rig on 40mm and 15mm diameter plugs.

Experimental work at BGS will focus on longer term high precision flow testing of caprock material using super-critical CO_2 to determine entry pressure, flow parameters and underlying flow physics, and to determine the sensitivity of flow to changes in boundary conditions. Care will be taken to ensure that steady-state flow conditions have been achieved. Experience has shown that this can take upwards of 30 days following any change in boundary condition.

The results from the two different approaches will be critically compared and carefully analysed.

Task 3.2 Development and testing of near-surface monitoring tools through the use of natural and man-made field laboratories, Month 6-42 (UniRoma1, BGS, CERTH, UEDIN, OGS, CIUDEN, BRGM, UNOTT**)**

The present JRA will address issues such as risk assessment , health and safety , CO_2 leakage detection, remediation monitoring etc. by exploiting the unique instrument and site infrastructure within the ECRI consortium. In particular, a wide range of monitoring instruments (from well assessed techniques to cutting-edge prototypes) will be compared and tested at natural sites where is CO_2-leaking ("natural field laboratories") and man-made controlled CO_2–leakage sites. **This rigorous instrument and novel prototypes inter-comparison at the field scale will help to understand the capabilities and shortcomings of each and will strengthen protocol and method development. In turn, continued characterisation of the test site infrastructure will bring added value to external researchers accessing this TA site infrastructure.**

A key aspect of this work will be the use of the large number of naturally leaking field laboratories within the ECRI partnership, located primarily within geologically active areas of Italy (see TA@UniRoma1) Greece (see

TA@CERTH), and Spain (see TA@ CIUDEN). Each of these sites is unique, thus providing a wide range of test conditions. Collaborative research has already been conducted at these locations in various EU-funded, CCS-related projects (e.g. NASCENT, CO2GeoNet, RISCS) by various ECRI consortium partners (UniRoma1, BGS, OGS, BRGM, CERTH, UNOTT). This work has defined leakage locations, pathways, and rates (thus allowing controlled but realistic instrument testing), preliminary instrument testing has been performed (thus facilitating and accelerating ECRI experimentation), and local contacts have been established (guaranteeing access). In addition, the consortium also has access to a man-made marine test site infrastructure where CO_2 can be injected below the sea floor into 15m of unconsolidated sediments off the coast of Scotland in waters about 20m deep (see TA@UEDIN). This site has excellent local support from a national marine laboratory (complete with survey equipment and small boats), the ecological and sedimentary setting is very well known with a history of prior work, and the borehole is on land for ease of experiment injection. The proposed Joint Research Activities at these sites can be subdivided into terrestrial and marine work.

For terrestrial work, the natural field laboratories will be used for testing, inter-comparison, and further development of a series of near-surface monitoring tools. Field labs will include Latera (Italy), Florina (Greece), and Campo de Calatrava (Spain), where isolated and well-defined gas leakage points will be chosen for experimentation, with priority given to locations with low leakage rates to focus on method sensitivity and reliability. Experiments will include blind tests to examine leakage detection capabilities and non-blind tests to examine leakage quantification capabilities. This work will be integrated with remote sensing measurements (whereby the geochemical measurements will be used to validate Lidar, hyperspectral, and thermal camera surveys used to define leakage areas) and geophysical surveys (to couple an assessment of the gas migration pathways characteristics and gas flux rates). Research will also focus on the accumulation of leaked CO2 in shallow aquifers to test monitoring sensitivity and impact. The ECRI instrument infrastructure to be tested (see appropriate TA descriptions for each partner) will include, but not be restricted to, that provided by UniRoma1 (continuous CO_2-concentration monitoring stations, ground surface leakage mapper, new generation flux meters, soil gas), BGS (eddy covariance, continuous CO_2-flux monitoring stations, mobile open-path lasers for CO_2 and CH4, soil gas), OGS (aeroplane with remote sensing tools, various geophysical instruments), CIUDEN (Magnetotellurics, membranes for passive monitoring): CERTH (groundwater monitoring instruments); BRGM (continuous CO2 soil gas probes, continuous CO2 isotope analyser, soil gas).

For marine work, the natural field laboratories at Panarea (Italy) and Santorini (Greece) Islands, and the man-made test site off the coast of Scotland (UK) will be used to test and improve marine monitoring tools (autonomous monitoring systems, visualisation methods, active/passive acoustic systems, etc.), with validation and calibration being performed by discontinuous measurements of the main parameters necessary to describe the whole carbonate system (pH, Dissolved Inorganic Carbon and alkalinity). These analyses will result in standard operative procedures (SOP) to characterize the naturally leaking CO2 sites. Laboratory work will be conducted to test geochemical and visual detection and monitoring techniques in a rig specifically designed for the simulation of CO2 seepage in sediments and water. ECRI instrument infrastructure to be tested (see appropriate TA descriptions for each partner) will include, but not be restricted to, that provided by UniRoma1 (continuous CO_2 monitoring probes, which are undergoing testing with acoustic modems for data transfer), OGS (DeepLab Landers, biological laboratories), and UNOTT (Particle Imaging Velocimetry, acoustic systems at Panarea).

Task 3.3 Development of techniques on surface bio-monitoring applied to CO_2 Storage, and measurement and modeling tools calibration (CIUDEN, UNOTT, OGS, BGS, CERTH**)**

Background

One of the activities deployed by **CIUDEN**, through its PISCO2 platform (see TA 9.3) is testing the influence of different CO_2 concentrations in the soil on microorganisms, lichens, and plants. The objective of the biomonitoring surveys is the search of bio-indicators for its use on wide areas at effective cost. These activities will be reinforced by the development of further activities by **CERTH** on natural CO_2 sites (see TA.5), where they will perform a division into zones and thus correlating the biological response under high, mid and low CO2 concentrations. In parallel, there are marine examples, both in terms of natural CO_2 Leakage (Panarea, **UNOTT**) as for the study on the relationship between calcareous macroalgae behaviour and natural pCO_2 gradients, focusing in the suppression of calcification, the carbonate dissolution or both in calcareous macroalgae (Panarea, **OGS**). The tool developed by **OGS**, after opportune field and laboratory testing will serve to evaluate the effect of different leakage scenarios (i.e. short intense events *vs* prolonged low-intensity events). It consists in a tool able to collect calcareous macroalgae in different marine environments. In consequence, these sites will help to provide an approach for the understanding of different environments with a series of flux ranges and settings.

In connection with the above activities, several laboratory experiments will be deployed, in terms of biological response through tools as the microtox acute toxicity bioassay coupled to standard epifluorescence microscopy for microbial counts **BGS** will produce results from the samples of subsurface biota, and these results will be compared with data from field sites such as ASGARD, Latera and Florina. The kinetics of biota response will also be studied in samples exposed at different CO_2 concentrations in from the mentioned sites, the results will be tested by comparing them with field observations.

Further approaches will be deployed in lab scale mainly focused on the geochemical response with different CO_2 regimes, in this case **UNOTT** will utilise three experimental rigs, two for terrestrial purposes and another one for marine environments. Furthermore, the results of these studies will be compared with the results of the field data from ASGARD (**UNOTT**). Other geochemical analyses will be deployed in samples from ASGARD, Latera and Florina, they will measure pH, major anions-cations and selected redox coupled (**BGS**). There are several geochemical surveys, mainly focused on the determination of pH and moisture parameters in soil samples, which will be acquired by **CIUDEN, UNOTT, CERTH** and **BGS**.

The testing and calibration of measurement instruments (such as accumulation chamber with controlled subsoil CO_2 injection) will be done along at **CIUDEN** site (see TA 9.3), it will help to perform an approach to the best suitability of a given instrument under each condition, this work will also be deployed at further sites (ASGARD, FLORINA).

Finally, **CIUDEN** will develop and calibrate numerical models of multiphase transport of CO_2 in the vadose zone of soils, whereas **CERTH** will develop further modelling for their natural Florina site. The aim of these activities is to improve the knowledge of the behaviour of CO_2 fluxes in the vadose zone of soils helping to predict processes involved of any future leakages.

The results are focussed on obtaining biomonitoring tools that will give an early indication of leakage in terms of allowing time for remedial action to be initiated and having the knowledge of the impacts over the different ecosystems (marine and terrestrial).

Deliverables (partner in bold is responsible of the report using all the partner's contribution)

D-JRA 3.1.1 A recommended technique(s) for determination of in-situ pH and dissolved CO_2 at under high pressure and at elevated temperature **(BGS, Month 42)**

D-JRA 3.1.2 Report on in situ CO_2 saturation measurement techniques in rock samples **(SINTEF PR, Month 40)**

D-JRA 3.1.3 Report on comparison and recommendations for best protocols for CO_2 flow parameters **(IFPEN, Month 42)**

D-JRA 3.1.4 Report on experimental results of comparative study of flow in caprocks and recommendations for best protocols for characterising sealing potential (**BGS, Month 42**)

D-JRA3.2-1 – Integrated report comparing sensitivity, accuracy, and inter-operability of various surface / near-surface monitoring tools in terrestrial environments (**UniRoma1**, Month 42)

D-JRA3.2-2 –Report detailing the integration of various marine monitoring tools for the characterisation of the carbon system impacted by CO_2 bubbles (**OGS**, Month 42)

D-JRA 3.3.1– Report on lessons learned based on the results of the different biomonitoring methodologies and techniques applied at the different sites (**CIUDEN**, Month 42)

Milestones

M-JRA 3.1.1

a) Start of inter laboratory comparison of pH measurement (SINTEF PR, BGS, month 12)

b) Evaluation of techniques for measurement of dissolved CO2 (SINTEF PR, BGS, month 18).

c) Start of laboratory testing of selected techniques for dissolved CO2 measurements (SINTEF PR, BGS, month 24)

d) Conclusion of pH inter lab comparison (SINTEF PR, BGS, month 36)

M-JRA 3.1.2

a) Choice of samples and flooding conditions (IFPEN, SINTEF PR, month 12)

b) Preliminary evaluation of local saturation measurements techniques for input to task 3.1.3 (IFPEN, SINTEF PR, month 18)

c) Conclusion on local saturation measurements (IFPEN, SINTEF PR, month 40)

M-JRA 3.1.3

a) Choice and characterisation of samples to be provided to partners, choice of experimental conditions (IFPEN, SINTEF PR, CIUDEN, month 12)

b) Comparison of raw data (IFPEN, SINTEF PR, CIUDEN, month 24)

c) Comparison of relative permeability (IFPEN, SINTEF PR, CIUDEN, month 32)

M-JRA 3.1.4

a) choice and availability of caprock samples (IFPEN, BGS, month 12)

b) comparison of characterisation results (IFPEN, BGS, month 18)

c) comparison of measured transport parameters (IFPEN, BGS, month 36)

M-JRA3.2-1

a) start of joint field experiments at terrestrial sites (UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM) (Month 8)

b) comparison of raw data (UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM) (Month 24)

c) comparison of sensitivity, precision, accuracy, etc. of various techniques (UniRoma1, BGS, CERTH, OGS, CIUDEN, BRGM) (Month 38)

M-JRA3.2-2

a) start of joint field experiments at marine sites (UniRoma1, CERTH, UEDIN, OGS, UNOTT) (Month 12)

b) comparison of raw data (UniRoma1, CERTH, UEDIN, OGS, UNOTT) (Month 28)

c) integration of various techniques to assess a marine carbon system with CO_2 bubbles (UniRoma1, CERTH, UEDIN, OGS, UNOTT) (Month 42)

M-JRA 3.3.1 Validation of all experimental set-ups in the selected labs (Month 12)

M-JRA 3.3.2 All partners (CERTH, OGS, UNOTT, BGS & CIUDEN) will provide interim reports on their biomonitoring site & lab results to CIUDEN for integration in the biomonitoring deliverable. (CERTH, OGS, UNOTT, BGS & CIUDEN ,Month 36)

1.4.6 Transnational Access Work Packages

WP10-TA1	Transnational access@NTNU
WP11-TA2	Transnational access@ENEA
WP12-TA4	Transnational access@BRGM
WP13-TA5	Transnational access@CERTH
WP14-TA6	Transnational access@DUT
WP15-TA7	Transnational access@ETH Zurich (Missing TA Access Costs)
WP16-TA8	Transnational access@IFRF
WP17-TA9	Transnational access@CIUDEN
WP18-TA10	Transnational access@IFPEN
WP19-TA11	Transnational access@OGS
WP20-TA12	Transnational access@MATGAS
WP21-TA13	Transnational access@METU-PAL
WP22-TA14	Transnational access@BGS
WP23-TA15	Transnational access@PGI-NRI
WP24-TA16	Transnational access@SINTEF ER
WP25-TA17	Transnational access@SINTEF PR
WP26-TA18	Transnational access@SINTEF
WP27-TA19	Transnational access@UEDIN
WP28-TA20	Transnational access@UNOTT
WP29-TA21	Transnational access@TUV
WP30-TA22	Transnational access@UniRoma1
WP31-TA23	Transnational access@USTUTT
WP32-TA24	Transnational access@TNO

Work package number	**WP10-TA1**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@NTNU**				
Activity Type	**SUPP**				

Participant number	1															
Participant short name	NTNU															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**NTNU MEMB-FAB , NTNU MEMB-PERM, ABSKIN,ABSDEG, ABSEQ**
Location (town, country):	NORWAY
Web site address:	www.ntnu.no
Legal name of organisation operating the infrastructure:	Norwegian University of Science and technology
Location of organisation (town, country):	Trondheim. Norway
Annual operating costs (excl. investment costs) of the infrastructure (€):	800 000

TA1.1 NTNU MEMB-FAB (Capture, Membranes)

Description of the facilities

This infrastructure provides facilities and methods to fabricate polymer-based membranes in lab scale and pilot scale, including the spinning of hollow fiber membranes, carbonization to prepare carbon membranes and coating of thin composite membranes on flat sheet or hollow fiber supports. The facilities are listed below with pictures in Figure 1:

1. Spinning machine for hollow fiber fabrication and coating
2. Carbonization rig
3. Pilot scale flat sheet coating device

Figure 1. Pictures of the spinning machine (left), carbonization rig(middle) and the pilot scale flat sheet coating device(right)

The replacement costs for the Infrastructure (€): 500,000

TA1.2 NTNU MEMB-PERM(Capture, Membranes)

This infrastructure provides facilities and methods to test membrane gas permeation performance in lab scale and pilot scale in different conditions, including single gas, mixed gas, gas separation in humidified conditions and at high pressures, with either flat sheet or hollow fiber membrane modules. The facilities are listed below with pictures in Figure 2:

1. Membrane gas permeation test rig for single gas and mixed gas (GC for gas composition analysis)
2. Membrane gas permeation test rig for mixed gases at humidified conditions (GC for gas analysis)
3. Membrane gas permeation test rig for mixed gases at high pressures (MS for gas composition analysis)

Figure 2. Pictures of membrane gas permeation test rig for single/mixed gas(left), membrane permeation test rig for humidified conditions(middle) and membrane permeation test rig for mixed gas at high pressures (right)

The replacement costs for the Infrastructure (€): 800,000

State of the art for TA1.1 and TA1.2

- In the TA1.1 NTNU MEMB-FAB infrastructure, the well-equipped facilities support broad techniques for the fabrication of polymer-based membranes, providing researchers the opportunity for 'one-stop' works in developing novel membranes of various materials or unique morphology that enhance the CO_2 separation performance. The facilities are updated and easy to operate, which enables users to conduct high quality researches.
- In the TA1.2 NTNU MEMB-PERM infrastructure, the facilities provided are advance and updated, equipped with automatic controlling and indication system as well as devices for auto-sampling and auto data-recording, providing researchers the opportunity to test membrane gas permeation performances in different conditions with reliable and high quality data.

Services currently offered by the infrastructures TA1.1 and TA 1.2 and achievements

- There is a widespread interest from users in other countries to conduct research in developing new and more efficient membranes for CO_2 separation, and in testing gas permeation of membranes in different conditions. During recent years, researchers from our international partners from Italy, France, USA and China have also used the facilities.
- The current users at NTNU have obtained many scientific achievements based on the services offered by the infrastructures, including EU projects, industrial and NFR projects, 5 patents and more than 30 papers:

<u>EU funded projects</u>: NaturalHy, Ulcos, Engas, NanoGlowa, etc.

<u>Other large initiatives</u>: SINTEF- NCSU (2 projects), NFR, Statoil, Alstom project, RECCO2 (NFR, Statoil for KMB and BIP projects)

<u>Selected patents</u>:

1. M. Sandru, T-J Kim, M.-B. Hagg, Gas separation membrane, WO2010086630A1, 2010.
2. Liyuan Deng, May-Britt Hägg, Taek-Joong Kim, CO2 capture membrane, European patent EP1897607, EP1900419 and US Patent US2008078290
3. Hägg MB, Lie, JA; Carbon Membranes, WO2007017650A

<u>Selected publications</u>:

1. Shao, L, Samseth, J, Hagg MB; Crosslinking and stabilization of nanoparticle filled PMP nanocomposite

membranes for gas separations; J.Membr.Sci., 326 (2) 285-292 (2009)
2. M.Sandru, S.H. Haukebø, M-B Hägg, Composite hollow fiber membranes for CO2 capture, J.Membr.Sci., 346 (2010) 172-186
3. He, Xuezhong, Hägg MB, Structural, Kinetic and Performance Characterization of Hollow Fiber Carbon Membranes, submitted to J.Membr.Sci, April 2011

TA 1.3 Kinetic studies (ABSKIN) (CO_2 capture, absorption)

The package offers a possibility to measure absorption kinetics with string of discs apparatus and with wetted wall column. Both apparatuses are suitable for loaded and unloaded solutions. The String of discs can be used up to 70^{o}C and the wetted wall column can be used up to 80^{o}C. Additionally measurement of viscosity, density and physical solubility of CO_2 using N_2O analogy measurement can be measured.

TA1.4 Solvent degradation laboratory (ABSDEG) (CO_2 capture, absorption)

Solvent degradation laboratory makes it possible to study fundamental solvent degradation. This installation includes 3 apparatuses. The oxidative degradation in closed-batch reactor is suitable for degradation studies at absorber temperatures (45-60^{o}C) whereas the thermal degradation tests can be done up to 135^{o}C. Additionally with a new screening apparatus for oxidative degradation, it is easy to test inhibitors and effect of metal. The degradation laboratory has a closed co-operation with analytical

Figure 3 Oxidative degradation apparatus (left) and string of discs apparatus (right).

TA1.5 Thermodynamic studies (ABSEQ) (CO_2 capture, absorption)

The installation includes 5 different apparatuses. The low temperature VLE apparatus can be used to measure vapor-liquid equilibrium of loaded absorption liquids up to 80^{o}C and up to 35 vol% CO_2. In high temperature VLE, the VLE up to 120 ^{o}C can be measured. And an apparatus for liquid-solid equilibrium studies is available. The high pressure VLE apparatus is able to provide VLE information up to 20MPa. The reactor calorimeter is suitable for heat of reaction measurements under pressures from -1 to 100 bar gauge and temperatures of from -20 to 200 ^{o}C.

Figure 1. Pictures of low pressure VLE apparatus (left), reactor calorimeter (middle) and high pressure VLE apparatus (right).

State of art for TA1.3, TA1.4 and TA1.5

thermodynamic and kinetic models can be used to model the experimental results. The laboratory has a close co-operation with analytical laboratory (SITNEF Biotechnology), which makes it possible to analyze liquid samples for degradation products and amines. Additionally NMR can be used to find the speciation in the liquid.

***Services currently offered by the infrastructure and achievements for* TA1.3, TA1.4 and TA1.5**

Measurement of thermodynamic data, like VLE and heat of absorption, needed for example in process modelling can be performed. Absorption kinetics including measurement of physical properties is needed for sizing of absorber. Degradation studies will give fundamental understanding of the solvent as well as indicate the solvent make-up costs.

Part of experimental apparatuses have been / are used in CASTOR, CESAR, DeCarbit, ENGAS and iCAP EU-funded projects. There is a close co-operation with SINTEF Materials and Chemistry and a long history of collaboration with the Department of Thermal Engineering, Tsingua University, Beijing and the Department of Chemical Engineering, University of Austin, Texas through exchange of PhD students and research personnel. In the last 5 years, more than 30 peer reviewed journal publications has been published presenting data from these installations.

Selected publications related to TA1.1

Sholeh Ma'mun et al. Kinetics of the Reaction of Carbon Dioxide with Aqueous Solution of 2-((2Amino(ethylamino) ethanol", Ind. Eng. Chem. Res., (2007), 46, 385-394

Hartono A. et al. Solubility of N2O in aqueous solution of Diethylenetriamine, J.Chem Eng. Data 2008, 53, 2696-2700

Knuutila, H et al. Kinetics of the reaction of carbon dioxide with aqueous sodium and potassium carbonate solutions. Chemical Engineering Science, Volume 65, Issue 23, 1 December 2010, Pages 6077-6088.

Hartono A et al. Kinetics of carbon dioxide absorption in aqueous solution of diethylenetriamine(DETA), Chem. Eng. Science, 2009, 64, pp 3205-3213

Selected publications related to TA1.2

Kim I. et al. Enthalpy of absorption of CO2 with alkanolamine solutions predicted from reaction equilibrium constants, Chem. Eng. Science, 2009, 64, pp2027-2038

Qin F. et al. Study of the Heat of Absorption of CO2 in Aqueous Ammonia: Comparison between Experimental Data and Model Predictions, Ind. Eng. Chem. Res., 2010, 49(8), pp3776- 3784

Knuutila, H. et al. Vapor-liquid equilibrium in the sodium carbonate-sodium bicarbonate-water-CO2-system, Chemical Engineering Science, Volume 65, Issue 6, 15 March 2010, Pages 2218-2226.

Aronu U.E., et al. Vapor-liquid equilibrium in amino acid salt systems: Experiments and modeling. Chem. Eng. Sci. 2011, 66, 2191-2198

Ma'mun, S. et al. Experimental and Modeling Study of the Solubility of Carbon Dioxide in Aqueous 30 Mass % 2-((2-Aminoethyl)amino)ethanol Solution. Ind. Eng. Chem. Res. 2006, 45 (8), 2505 – 2512.

Selected publications related to TA1.3

Lepaumier, H., et al. Energy Procedia. Comparison of MEA degradation in pilot-scale with lab-scale experiments. **2011**, 4, 1652.

Lepaumier, H., et al. Chemical Engineering Science. Degradation of MMEA at absorber and stripper conditions. **2011**, 66, 3491.

Eide-Haugmo, I. et al. Chemical stability and biodegradability of new solvents for CO2 capture. Energy Proceedia 4 (2011) pp. 1631-1636.

The replacement costs for the installation of the Infrastructure (€):

Pag. 702

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
MEM-FAB	week	4 922	9	2	43	2
MEM-PERM	week	5 000	9	2	43	2
ABSKIN	week	2 312	30	10	150	10
ABSDEG	week	1 631	30	10	150	10
ABSEQ	week	2 253	30	10	150	10

Pag. 702

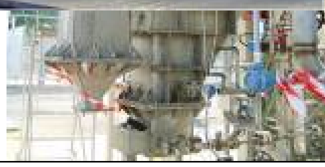
Work package number	**WP11-TA2**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@ENEA**				
Activity Type	**SUPP**				
Participant number	2				
Participant short name	ENEA				

Description of the infrastructure	
Name(s) of the infrastructure	Infrastructure: **ENEA CCS PLATFORMS**
Location (town, country):	ENEA Casaccia Research Center, Rome
Web site address:	www.enea.it
Legal name of organisation operating the infrastructure:	Italian National Agency for new technologies, Energy and sustainable economic development
Location of organisation (town, country):	Rome. Italy
Annual operating costs (excl. investment costs) of the infrastructure (€):	200000

TA2.1 ZECOMIX platform

Zecomix platform is aimed at studying H2 and electrical energy production with advanced coal gasification and CO2 capture processes, as well as post combustion technologies.

In pre-combustion case, the hydrogen and steam syngas produced can be feed a 100 kWe microturbine for electrical energy production. It is possible to test the gasifier with different O2/steam temperature (until 600 °C. The fluid bed is olivine based with dolomite adding for tars and H2S removal. The fluid bed gasifier of 50 kg/h of coal works at atmospheric pressure whereas the decarbonation section is based on a fluid bed reactor working at high temperature with solid sorbents alternatively in absorption and sorbent regeneration phase; the power production section, based on a microturbine, derived from a Turbec 100 kW model in which the combustor chamber has been modified to work with H2 and steam. The plant has been designed to test both the whole process from gasification to power generation and the single sub-systems (gasification test, carbonator test, micro-turbine test).



TA 2.1.1 Gasification island (Energy conversion, gasification)

Description of the facilities

The coal gasifier is a fluidized bubbling bed reactor having a nominal load of 50 kg/h of coal. Steam and oxygen are fed on different points of the reactor, in order to control the solids hydrodynamics, and the reaction rate all over the reactor. Dolomite is added to the coal helping tar removal and capturing the H2S formed during coal gasification. The syngas, at 800°C, is is sent to a regenerative heat exchanger to pre-heat inlet O2/steam mixture, reducing its temperature around 600°C. Then the syngas can be introduced into the carbonation reactor, or can be clean-up in a scrubber, after a second cooling step to 350°C.

State of the art

Coal/biomass gasification in fluid bed reactor can be performed, changing oxygen/steam feed composition and flow rate in more inlet points. More types of additives can be added in fluid bed, also during operations, for "in situ" H2S and tars removing. The experimental activities in the infrastructure are supported by laboratory tests; the laboratory is equipped by several instruments for solid sorbents and coal analysis and characterization

Services currently offered by the infrastructure and achievements

By using the gasifier one can evaluate the purity of produced syngas against existing gas cleaning and conditioning systems, by means of fluidized bed reactor at pilot scale to provide sufficient and dependable information for industrial applications. Furthermore, by using a catalytically active agent such as dolomite and olivine, indeed primary tar reforming reaction could happen with a simultaneous sulphur compound removal. Particularly the effect of pre-treatment of olivine as catalyst agent for tar removal will be investigated.

References

A. Calabro`, P. Deiana, P. Fiorini, G. Girardi, S. Stendardo. Possible optimal configurations for the ZECOMIX high efficiency zero emission hydrogen and power plant . Energy 33 (2008) 952–962

S. Attanasi, A. Calabrò, S. Cassani, A. Dedola, C. Herce, S. Stendardo, L. Pagliari. Commissioning of the Zecomix Pilot Plant. Clean Coal Technologies CCT 2011 Zaragoza 8-12 May 2011.

P.Fiorini, E. Sciubba, A. Calabrò, P. Deiana, G. Girardi, S. Stendardo. Thermo-economic analysis of an innovative CO2 zero emission process for the co-production of fhydrogen and power. Clean Coal Technologies CCT 2011 Italy 15-17 May 2007.

TA 2.1.2 Carbon capture and mineral carbonation (Capture, adsorption)

Description of the facilities

Decarbonising reactor is a cylinder 1m diameter and 4.5m height cylindrical chamber. At the bottom of the reactor there are two burners in order to increase temperature up to 900 °C for regenerating the sorbent. The incoming syngas can be added with methane and steam, to improve steam methane reforming and CO-shift reactions. The fluidized bed reactor is loaded with a mixture of Ni-based catalyst, necessary for the steam methane reforming, and Ca-based sorbent in order to capture CO2. Once the solid sorbent reaches at its ultimate conversion (after around one hour of operation which decarbonises approximately 120 Nm3/h of methane enriched syngas), it is sent back to the regeneration step activating the burners.

State of the art

The infrastructure permits to perform several tests on: a) advanced reforming of natural gas, with simultaneous CO2 capture and H2 production; b) CO-shift and CO2 capture of syngas with variable composition; c) post-combustion CO2 capture of NGCC or USC plants flue gas; all these tests are performed in a significant scale reactor in adiabatic conditions.

Services currently offered by the infrastructure and achievements

Particularly multi-cycling CO2 capture could be performed coupled with water gas shift and steam methane reforming reactions. This reactor could be used in a pre-combustion CO2 capture mode by reforming the fuel gas or in a post-combustion CO_2 capture mode when flue gases are passed through the solid bed of CO_2 acceptor. Finally in such a reactor different types of CO_2 acceptor agent could be tested ranging from naturally occurring sorbents to synthetic ones. The experimental campaign will end up with a collection of data for model validation, developing or improving existing models. Particularly the hydrodynamics and kinetics interacting in the investigated fluidised bed reactor has been considered.

References

S. Stendardo, L. Di Felice, K. Gallucci, P. U. Foscolo. CO2 capture with calcined dolomite: the effect of sorbent particle size. Biomass Conv. Bioref. 1 (2011) 149–161;

K. Gallucci, S. Stendardo, P. U. Foscolo. CO2 capture by means of dolomite in hydrogen production from syn gas. Int. J. of hydrogen energy 33 (2008) 3049 – 3055;

S. Stendardo, P. U. Foscolo. Carbon dioxide capture with dolomite: A model for gas–solid reaction within the grains of a particulate sorbent. Chemical Engineering Science 64 (2009) 2343 – 2352;

S. Stendardo, L. K. Andersen, C. Herce, A. Calabrò. Experimental investigation of synthetic solid sorbents for multi-cycling carbon dioxide uptake. Clean Coal Technologies CCT 2011 Zaragoza 8-12 May 2011;

TA 2.1.3 Power generation section (Energy conversion, combustion)

Description of the facilities

The power generation is produced by means a micro-turbine, modifying the Turbec T100, with 100 kWe of power output, by bretrofitting with a hydrogen burner developed by Ansaldo Energy. The high H_2 content syngas, at the outlet of the scrubber is compressed until 6 bar, by means a three stage intercooled compressor and then re-heated until 250 °C before mixing of a fixed amount of steam.

State of the art

The combustion chamber, designed for burning H_2 and enriched air, is of lean pre-mix emission type achieving flue gases with low content of CO and NOx and unburned hydrocarbons. In order to prevent high temperature in the combustion chamber a certain quantity of water steam is injected.

Services currently offered by the infrastructure and achievements

The activities will test the hydrogen combustion technology at different scale levels and grades of integration with the whole experimental platform. In particular a dynamic model of the microturbine has been developed and integrated in a commercial power plant simulator. Such a model is a valuable tool for the simulation of a the microturbine in a number of operative conditions.

TA2.2 COHYGEN PILOT + SOTALABS

TA 2.2.1 COHYGEN PILOT (Energy Conversion Systems, Gasification) PLANT

Description of the facilities

The plant has been developed in order to study and optimize the gasification process and to produce a syngas flow to feed the experimental syngas treatment process for combined production of hydrogen and electrical energy. It can be described into five sections:

Section 1 - Gasification process

The Pilot unit is based on a 50 kg/h of coal gasifier, where temperature profile is determined through a series of 11 thermocouples disposed over a metallic probe (which can operate up to 1200 °C) insert through the top of the gasifier and located near the reactor vertical axis. A series of three ceramic lamps allows the heat of the reactor, initially feed with wood pellets and subsequently charged with coke.

Section 2 - Dust and tar removal system

The raw syngas from the gasification process is sent to an integrated component which includes a wet scrubber, a first cold gas desulphurization stage and an electrostatic precipitator (ESP). Finally, the need to use coal with a very high sulphur content and to protect the electrostatic precipitator by the effects of acid atmosphere, suggested to insert, between wet scrubber and ESP, a first cold gas desulphurization stage, which generally uses sodium hydroxide (40% in volume, diluted in water), as solvent for H2S removal. Downstream the ESP, syngas can be sent to the power generation line or to the hydrogen production line.

Section 3 - Power generation line

Power generation line is constituted by the second cold gas desulphurization stage directly followed by an internal combustion engine (ICE), fed with clean syngas, eventually enriched in hydrogen. In particular, the second cold gas desulphurization stage is a packed column, made of polypropylene, in which hydrogen sulphide is chemically absorbed through a proper solvent.

Section 4 – CO_2 capture and Hydrogen production line

Hydrogen production line includes a compressor followed by an electric heater, a dry hot gas desulphurization process, an integrated water-gas shift (WGS) and CO2 absorption system and a hydrogen purification section. In particular, hot gas desulphurization process operates at about 300-500 °C and includes three main components: a catalytic filter for COS conversion and two H2S adsorbers.

In the catalytic filter, the small amount of carbonyl sulphide contained in syngas reacts with hydrogen to be converted in H2S, according with the hydrogenation reaction. The integrated water-gas shift and CO2 separation system includes both high and low temperature shift reactors with an intermediate and a final CO2 absorbers. In particular, WGS process takes place into two reactors (operating at 300-450 °C and about 250 °C, respectively) which have been installed in order to test different catalysts, including conventional Fe3O4/Cr2O3/CuO based catalysts for high temperature (HT) stage and CuO/ZnO/Al2O3 based catalysts for low temperature (LT) stage; to this goal, the reactors have been designed with a maximum bed volume of 9.6 and 17.5 dm3, respectively. Carbon dioxide absorption takes place into two identical bubbling reactors, in which syngas is injected through 40 diffusers based on ceramic membranes and reacts, at about 30 °C and atmospheric pressure, with amine-based solvents. In particular, different solvents, such as monoethanolamine (MEA) in different concentrations and a solution of methyldiethanolamine (MDEA) and piperazine (PZ), have been used in this process in some experimental tests. Finally, the hydrogen purification section is based on the pressure swing adsorption (PSA) technology, which is widely common in the industrial applications due to its low costs. In particular, PSA is composed by a simple double-stage process based on carbon molecular sieves.

Section 5 - Regeneration plant

The amine regeneration unit is able to regenerate continuously and batch amine solutions from sections of CO2 adsorption. In general, this system is very flexible and easy to use and does not require long time of switch on and switch off. The regeneration plant mainly consists of a stripping column and ancillaries components like heat exchanger, back wash tank; recirculation pump of the solution regenerated; column stripping back wash pump, Feed pump to the column of the solution to be regenerated, reboiler of the stripping column, Piping and control instrumentation.

State of the art

The plant has been widely tested, and now it's - together with ZECOMIX - one of the most important infrastructures involved in CCS national programme, mainly for studying capture technologies – both pre and post combustion – in power plants fed with low rank coal.

Services currently offered by the infrastructure and achievements

- Availability of basic services as air, steam, gas, electricity supply
- Availability of extended online monitoring and data acquisition of all operative plant parameters

Pag. 707

- Availability of gas analysis equipment that will enable users to conduct high quality research
- Availability of laboratories for off line analysis of solid and liquid materials

References

A. Pettinau, F. Ferrara, C. Amorino, "An overview about current and future experimental activities in a flexible gasification pilot plant". Accepted for publication in: "Gasification: Chemistry, Processes and Applications" Nova Publishers, New York (USA), 2011, ISBN: 978-1-61209-681-0;

A. Pettinau, C. Frau, F. Ferrara, "Performance assessment of a fixed-bed gasification pilot plant for combined power generation and hydrogen production", Fuel Processing Technology, vol. 92, 2011, pp. 1946-1953.

TA 2.2.2 SOTALABS – (Energy Conversion and Capture Systems, Gasification /Absorption)

Description of the facilities

The laboratories were built in the framework of the activities funded by the Italian Ministry of Industry in the field of CCS R&D. The main laboratories are:

1. Sample preparation e granulometric analisys
2. Elementary analisys (CHN + TGA)
3. Thermal analisys (CAL)
4. Chemical analisys
5. Porosimetry
6. Gas analisys (mGC)
7. Bench scale plant for hot desulphurization system by using oxide metallic sorbents

The main equipments are: Thermogravimeter Analyzer (TGA), CHN/S analyzer, Porosimeter, Jaw crusher, Cross Beater Mill and Sieve Shaker, Calorimeter, Gas chromatography.



State of the art

The main use of laboratories is in characterization of substancies and materials related to the activities carried in gasification and CO2 capture sperimentation. The areas of research normally supported by this installation is related to activities funded by the Italian Ministry of Industry in the framework of Carbon Capture and Storage R&D.

Services currently offered by the infrastructure and achievements

- Availability of basic services as air, steam, gas, electricity supply
- Availability of gas, liquids, solid analysis equipment that enable users to conduct high quality research
- Off line analysis of solid and liquid materials.

Pag. 707

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
ZECOMIX	day	1 826	60	3	60	3
SOTA CCS	day	2 417	33	3	33	3

Work package number	WP12-TA4	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@BRGM				
Activity Type	SUPP				

Participant number	4															
Participant short name	BRGM															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**Technology platform Montmiral**
Location (town, country):	Montmiral France
Web site address:	Not yet
Legal name of organisation operating the infrastructure:	BRGM
Location of organisation (town, country):	Orléans France
Annual operating costs (excl. investment costs) of the infrastructure (€):	

TA 4.1 Technology platform Montmiral (Storage, Site characterization and monitoring/CO2 impacts)
Montmiral is a natural gaz field with 97-to 99% CO_2, in Triassic sandstones and Rhaetian to Hettangian carbonates at more than 2400 m depth. CO_2 has been exploited from 1990 to 2010 for an industrial use.

The infrastructure comprises:

- the Montmiral CO_2 well (V.Mo.2) – total depth 2480 m, currently immobilzed by brine
- two nearby wells Saint-Lattier SL1 (2790 m deep) and SL2 (2425 m deep) at distances 8 to 10 km from Montmiral. SL2 well cross-cut CO_2 reservoirs in triassic to hettangian levels.
- two other CO_2 well exist in the Valence Basin: at Montoison (B.Mt1 – 50 km in the south of V.Mo.2, 3976 m depth) and at Brézin (Br.1- 25 km in the north of V.Mo.2, 1833 m depth)
- thirty springs (depth zero) and groundwater wells (up to depths 250 m) which exploit pliocene and miocene aquifers, within a radius distance of 15 km around Montmiral
- the knowledge acquired on the site through research projects

It is envisaged to upgrade the facility with:

- Reopening of the well to produce CO2
- Surface installations to test impact of CO_2 on materials or CO_2 reuse technics
- On site small laboratory

Projects to fund these upgrades have been submitted

Unique infrastructure
Throughout the world there are many occurrences where natural CO_2 has been trapped in geological reservoirs. These reservoirs, called natural analogues, offer a unique opportunity to study the long-term behaviour of CO_2 underground, the chemical reactivity of the reservoir and caprock due to CO_2 interactions with rock minerals and fluids, the trapping mechanisms, and the nature of leakage if it occurs. Therefore, the studies of natural CO_2-rich reservoirs, which act as long-term laboratories and give specific examples in various settings of long term CO_2 behaviour and impact, raise lot of interest in the international scientific community. Long term observations at

Pag. 710

these sites usefully complement the investigations carried out at CO_2 storage pilots and demonstrators that have been operating at most 15 years and for which only short-term lab or field observations can be made, while long term behaviour can only be predicted. They also enable to integrate better the long term perspective for site selection, characterisation and risk management of future CO_2 storage sites.

The Montmiral research infrastructure is unique in Europe and even in the world due to the rare combination of the following characteristics:

- fluid samples from the CO_2 reservoir can be collected at the well-head of V.Mo.2, and along the CO_2 purification process chain;
- rock samples (cores) at various depths from the basement, the reservoir, the caprock and the overlying formations are available (TOTAL corestore at Boussens)
- cuttings samples from the base to the top of the well (TOTAL corestore at Boussens);
- comparison possible between the CO_2 field and adjacent zones with no CO2 in order to discriminate the effects due to CO_2
- Overlying fresh-groundwaters in the surrounding area can be sampled
- extensive set of data and knowledge being acquired on this site from 2001, plus historical data acquired in the 1960s during oil&gas exploration (geochemistry, seismic, petrography, well test, diagraphies, ...) .

Fig1. Motniral CO_2 field and technology plattform

State of the art

The areas of research supported at the Montmiral research infrastructure are:

- long–term behaviour of the reservoir and the caprock: CO_2-rock-fluid geochemical interactions, impact on the CO_2 trapping mechanisms, on reservoir physical properties (porosity, permeability, …), on geomechanical stability
- relationship between diagenetic history, tectonic events of the basin, and CO2 migration along faults and fractures
- identification of leakage pathways, if any, through the caprock, the overlying formations and up to the surface; characterisation of mineral infills ; description of processes using logging tools and geophysical methods (active seismic, magnetotelluric (MT), Electrical resistivity imaging (ERT) and EM soundings).
- co-mobilisation of other substances than CO_2 (hydrocarbons, heavy metals, H2S, Rn, etc.)
- assessment of impacts on associated and overlying groundwaters and on ecosystems at depth or at ground surface, or demonstration that no impact is observed.
- Monitoring techniques at surface or at depth to track the CO2 or any indirect impact.
- Well behaviour after 20 years of CO2 production.

Services currently offered by the infrastructure:

- Acces to rock samples from the Paleozoic and the sedimentary column until the Oligocene.
- Access to fluid samples from the deep CO_2 reservoir at the well head of exploitation borehole and from overlying groundwaters (springs and irrigation wells)

Pag. 710

- Possibility of field monitoring at various depths and at surface using geophysical, geochemical, biological, remote-sensing techniques
- Access to specific equipment for field measurements, services for fluid and rock field and lab analyses
- Access to the knowledge already gathered around the site

The planned upgrades will allow:
- to study the impact of CO_2 on materials for surface storage and transport
- To test CO_2 reuse technology
- To simulate CO_2 leakage to study the dispersion of CO_2 in the atmosphere

The most interesting scientific achievements already obtained by users are the following:
- Mantle origin of the CO_2;
- The CO_2 induced in Triassic sandstones, the dissolution of K-feldspar and precipitation of kaolinite and carbonates; 3% increase of porosity
- CO_2 migration along faults was detected into Rhaetian and Hettangian formations by fluid inclusions studies CO_2 fluid inclusions are locally linked to hydrocarbon;
- This CO_2 migration is estimated to be of post-Pyrenean age during an extensive phase (35-23 My);
- Along the overall well, petrographical and geochemical data demonstrate a possible connection between Palaeozoic substratum and Triassic Liassic levels and a disconnection between the base and the top of the well created by the Jurassic marly level (575 m thickness);
- Concerning soil gas analyses, two field trips were done in 2006 and 2007. In the vicinity of the exploited CO_2 well, no evidence of leakage of deep origin is found, CO_2 concentrations and Rn activities suggesting a sub-surface or biologic-related origin. Nevertheless, at some distance (10 km to the NW), CO_2 concentrations can rise up to 8%, but with isotopic ratios apparently due to biologic soil activity. This discrepancy between high CO_2 content and depleted ratio is not well understood up to now, and need further studies (campaigns in winter during low biological activity, sampling at depth greater than 1 m).

This site has become a European research infrastructure from 2001 at the start of the FP5 NASCENT project entitled “Natural Analogues for CO2 Storage in the Geological Environment” (2001-2004). The has been used for further research activities within the **CO2GeoNet** European Network of Excellence (from 2004), a French research project (**ANR-Monitoring** 2006-2008) and a PhD thesis (2005-2008). The site is also part of the current FP7 project **CO2care** site abandonment and **RISCS** on impacts and safety of CO2 storage.

The following publications quoting scientific results acquired at the Montmiral infrastructure demonstrate that there is a widespread interest worldwide:

1. **Czernichowski-Lauriol I., Rochelle C., Gaus I. *et al.*** (2006) - Geochemical interactions between CO_2, pore-waters and reservoir rocks: lessons learned from laboratory experiments, field studies and computer simulations. In : Advances in the Geological Storage of Carbon Dioxide, p.157-174. Ed. by Lombardi, S. et al. Netherlands : Springer
2. CZERNICHOWSKI.LAURIOL.I., Persoglia.S., Riley.N. (2006) **On-going joint research activities within the CO2GeoNet European Network of Excellence on CO2 geological storage**, in *Proceedings* of the *GHGT-8* International Conference on Greenhouse Gas Control Technologies - Trondheim - Norway - 18-22/06/2006, 6 p.
3. **Gaus I., Le Guern C., Pearce J. *et al.*** (2004) - Comparison of long-term geochemical interactions at two natural CO_2-analogues: Montmiral (Southeast basin, France) and Messokampos (Florina basin, Greece) case studies. 5-9 sept. 2004, GHGT7 - Vancouver, Canada.
4. **NASCENT project, Final report** (2005) - Natural analogues for the geological storage of CO_2. 92 p. IEA-GHG Report Number 2005/6.
5. **Pauwels H., Gaus I., Le Nindre Y. M. *et al.*** (2007) - Chemistry of fluids from a natural analogue for a geological CO_2 storage site (Montmiral, France): Lessons for CO_2-water-rock interaction assessment and monitoring. *Applied Geochemistry*, 22, p. 2817-2833.
6. **Pearce J. M., Shepherd T. J., Kemp S. J. *et al.*** (2003b) - A petrographic, fluid inclusion and mineralogical study of Jurassic limestones and Triassic sandstones from the Montmiral area of the Southeast Basin of France, *British Geological Survey External Report*. 76 p. (CR/03/144).
7. **Rubert Y** (2009) - Petrographic indicators of CO_2 migration in the Montmiral natural analogue. Phd

The replacement costs for the installation of the Infrastructure (€):

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Montmiral	day	2 038	44	4	44	4

Work package number	**WP13-TA5**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@CERTH/ISFTA**				
Activity Type	**SUPP**				
Participant number	5				
Participant short name	CERTH/ ISFTA				

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**CERTH/ISFTA Storage, CERTH/ISFTA Capture**
Location (town, country):	ATHENS, PTOLEMAIS, GREECE
Web site address:	www.lignite.gr
Legal name of organisation operating the infrastructure:	
Location of organisation (town, country):	Athens, Ptolemais, Greece
Annual operating costs (excl. investment costs) of the infrastructure (€):	100,000

TA5.1 CERTH/ISFTA Storage

Description of the facilities

The CERTH/ISFTA Storage infrastructure provides facilities for the characterisation of a storage site. That includes an X-Ray Diffractometer for the mineralogical characterisation of the reservoir and cap rock, a spectrophotometer for the chemical analysis of the water samples, a CHNS analyser for the determination of the carbon, hydrogen, nitrogen and sulphur. The facilities can be seen in the pictures below:

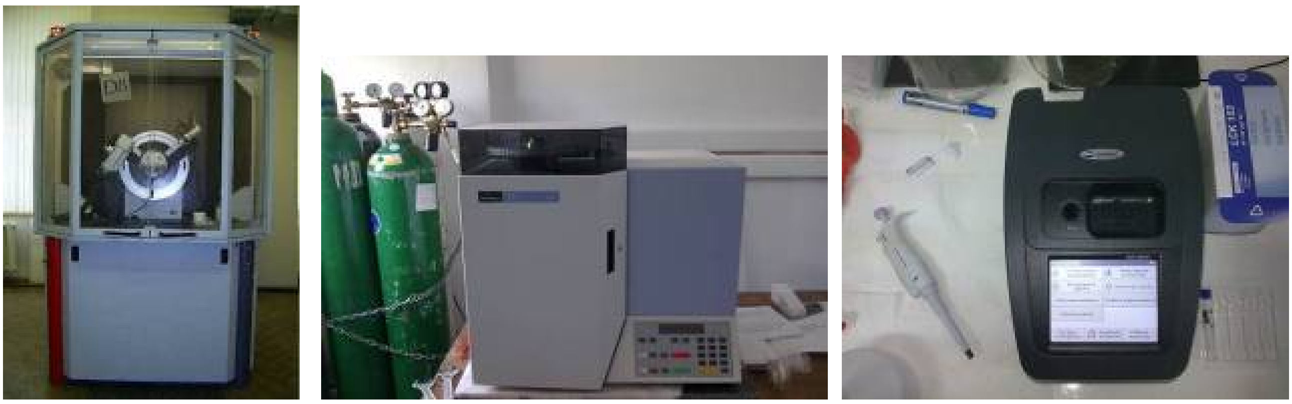


Figure 1. X-Ray Diffractometer (left), CHNS analyser (middle), specrophotometer (right).

The laboratory is under ISO17025 certification for the determination of: moisture, ash, volatiles, total moisture, chlorine, CHNS, heating value, ash metals, as well as the biogenic fraction of SRF fuels. The process will be completed within next few months which lay the uniqueness of CERTH/ISFTA facilities in Greece.

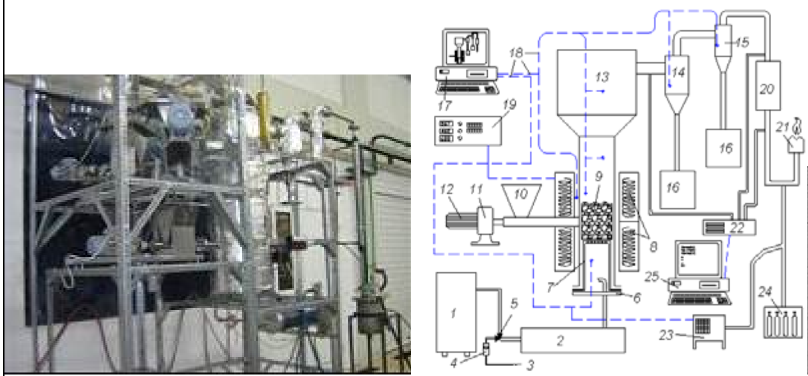
Figure 2. Pictures of the Atomic Adsorption spectrometer (left) and the calorimeter (right)

Moreover, the CERTH/ISFTA Storage is equipped with an Atomic Adsorption Spectrometer (AAS) for the determination of chemical elements and a calorimeter (figure 2) for the measuring of the high heating value of coal and lignite samples.

The replacement costs for the Infrastructure (€): 300,000

TA5.2 CERTH/ISFTA Capture

Furthermore, CERTH/ISFTA has a 5kWth high temperature bubbling fluidized bed flexible in operation either for gasification or combustion experiments of coal/lignite that can be performed in the presense of Ca sorbents. The infastructure can be seen in the figure below. Additionally, the CERTH/ISFTA Capture infrastructure can support activities relative to combustion and gasification technologies.



1	Electric steam boiler	13	Feedboard
2	Steam superheater/air heater	14/15	primary/secondary cyclone
3	Pressurized air flow	16	Ash collection bin
4	Air mass flow meter	17	PC/data collection system
5	Steam – air valve	18	Measuring system
6	Distributor flange	19	PID controllers
7	Distributor	20	Gas cleaning
8	Electric resistance	21	Product gas destruction system
9	Fluidized bed	22	Tar measurement
10	Fuel silo	23	Gas analyser Multor
11/12	Inverter/electric motor	24	Sampling line for GC

Figure 3. Picture of the Bubbling fluidized bed gasifier (left) and its diagram along with an explanatory table (middle and right, respectively)

The replacement costs for the Infrastructure (€): 100,000

State of the art for TA5.1 and TA5.2

Over the last years, both CERTH/ISFTA's facilities are becoming more and more attractive for carrying out scientific research due to uniqueness of the services that it can provide. The equipment and the highly qualified personnel have drawn, also, the attention of the industrial sector. That led to a large private contract with Public Power Corporation (PPC). Also, one of the key assets of the infrastructure is the fluidised bed installation. One of the most important advantages of this is the in situ capture of CO_2 and SO_2 by calcined additives.

The areas of research that are normally supported by the infrastructure are outlined below:

- Promotion, implementation and improvement of "cleaner" coal combustion technologies (CCTs).
- Minimization of pollutants including fly ash, other by-products utilization and CCS technologies.
- Optimization of coal deposits exploration techniques and development of innovative environmental

management methods.

- Biomass and/or waste co-combustion with lignite in existing combustion/ gasification systems.
- Promotion and enhancement of gasification and hydrogen production technologies.
- Technology transfer from and to market operators and decision makers.

The CERTH/ISFTA's infrastructures are part of a larger ensemble and the scientific personnel of the Institute and the visiting scientists can be benefit from that by having access to other laboratories that will help achieve the expected, each time, results. Moreover, CERTH/ISFTA is the main Greek organization for the promotion of research and technological development aiming at the improved and integrated exploitation of solid fuels and their by-products. It develops a number of activities aiming to enhance the exploitation of the indigenous solid fuel supplies, such as lignite and solid biomass. The experience gained throughout the years and the collection of know – how, by undertaking large – scale R&D and demonstration projects, may classify CERTH/ISFTA among the Centres of Excellence and of equal importance to other European and non-European centres involved in solid fuels technologies. Furthermore, CERTH/ISFTA represents Greece in the Carbon Sequestration Leadership Forum (CSLF), the Euracoal and the Technology Platform for Zero Emission Power Plants. CERTH/ISFTA is involved in various European Commission's Research Projects related to CCS.

Services currently offered by the infrastructure and achievements

The services that are offered by CERTH/ISFTA Lab are achieved through the use of its equipment infrastructure and involve proof of concept experiments, heat balance studies, combustion and gasification studies, mineralogical and petrographical examination, cores/samples studies etc.

High-quality research can be performed in CERTH/ISFTA's infrastructure. Both visiting and CERTH/ISFTA's scientists can conduct experiments that will add value to the state-of-the-art energy research, by utilizing CERTH/ISFTA laboratory equipment, which consists of state-of-the-art instruments, of the latest technology. The constant use of this equipment within cutting-edge EU energy research projects, has resulted in a number of journal publications of significant importance by CERTH/ISFTA's scientists, with a clear increasing trend over the last 5 five years. Thanks to the possession and the continuous upgrade of such equipment, as well as by steadily training its scientists on the latest advances in energy research, CERTH/ISFTA has managed to build an important expertise in the field of conventional and alternative fuels. It is noted that such expertise is widely recognized and has led to the attraction of both major research and industrial projects. It is noted that CERTH/ISFTA has been recently officially evaluated as a Centre of Excellence in Greece; CERTH/ISFTA's infrastructures are currently under ISO17025 certification, which will led to its expansion both inside and outside the country's borders.

After 2000, CERTH/ISFTA has been awarded with over 90 EU- and national-research and industrial projects. Some of them are mentioned further below. Thanks to its overall research activity, CERTH/ISFTA has published over 500 papers at international scientific journals and conferences. Some of the most important research and industrial projects, CERTH/ISFTA has been awarded with, are:

Finally, in the last five years, a large number of scientists from Europe have chosen CERTH/ISFTA in order to perform their research in CERTH/ISFTA facilities. Amongst them, scientists from renown Institutes from Germany, Spain, and the UK have spent a sufficient time in CERTH/ISFTA's facilities conducting experiments for the successful advance of theirs projects. An overwhelming interest from scientists from China and India has been also expressed; the Institute is currently in the phase of considering such applications for short-term research visits.

List CCS related EU funded projects where the infrastructure was used, or other large initiatives

EC DG Research / RFCS: UCG-CO_2, CAL-MOD, ASSOCOGS

EC DG Research / FP6, 7: RISCS, ENCAP

Other EC DG Research: FENCO.ERANET

GSRT / Bilateral Cooperations – national projects: CO_2 mineralization

Other large initiatives: Solid and fossil fuels analyses according to ISO 17025

Achievements (include also 5 recent relevant scientific publications)

- N. Koukouzas, F. Ziogou, V. Gemeni (2011), *Cost of pipeline-based CO_2 transport and geological storage in saline aquifers in Greece*, Energy Procedia, 4, p. 2978-2983
- Pietzner, K., Schumann, D., Tvedt, S.D., Torvatn, H.Y., Naess, R., Reiner, D. M., Anghel, S., Cismaru, D., Constantin, C., Daamen, D.D.L., Dudu, A., Esken, A., Gemeni, V., Koukouzas, N., Ziogou, F. *Public Awareness and Perceptions of Carbon Dioxide Capture and Storage (CCS): Insights from Surveys Administered to Representative Samples in Six European Countries*, Energy Procedia, 4, p. 6300-6306
- Koukouzas, Gemeni, V., Ziock, H. (2009) *”Sequestration of CO_2 in magnesium silicates, in Western Macedonia, Greece”*, Int. Journal of Mineral Processing, 93 (2), p. 179-186
- N. Koukouzas, F. Ziogou, V. Gemeni (2009) *Preliminary assessment of CO_2 geological storage opportunities in Greece*, International Journal of Greenhouse Gas Control, 3 (4), p. 502-513.
- Koukouzas, N., Typou, I. (2009) *An assessment of CO_2 transportation cost from the power plants to geological formations suitable for storage in North Greece.* GHGT-9, Energy Procedia, 1, p. 1657–1663
- Kakaras E., Koumanakos A., Doukelis A., Giannakopoulos D., Vorrias I. (2007) *”Oxyfuel boiler design in a lignite-fired power plant”* Fuel, 86 (14), p 2144-2150

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
C/I Storage	day	568	70	7	70	7
C/I Capture	day	415	36	4	36	4

Work package number	WP14-TA6	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@DUT				
Activity Type	SUPP				

Participant number	6															
Participant short name	DUT															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**Thermolab**
Location (town, country):	The Netherlands
Web site address:	www.pe.tudelft.nl
Legal name of organisation operating the infrastructure:	Delft University of Technology
Location of organisation (town, country):	Delft, The Netherlands
Annual operating costs (excl. investment costs) of the infrastructure (€):	220,000

TA6.1 Laboratory for thermodynamic experiments (Thermolab)

The laboratory for thermodynamic experiments in Delft is well known for its unique high-pressure facilities. The equipment used the synthetic-static method. The cell is filled with a sample of known composition. Phase boundaries are determined by visual observation by variation of temperature at constant pressure or of pressure at constant temperature . The pressure ranges are 0.2-15MPa (for Cailletet setups, 8 in total) and 0.5-4000MPa (for high-pressure autoclave setups). The temperature range is in all cases 240-473K.

Figure 2. High pressure autoclave setup (left) and Cailletet setup (right).

Typical thermodynamic properties that can be measured are: dew points, bubble points, gas solubilities. Since the 70s, the laboratory has been involved in many industrial projects involving the measurement of thermodynamic properties. In cooperation with companies like Shell, DOW and DSM, phase equilibria were determined with are relevant for transport of oil and gas, enhanced oil recovery, preventing wax and gashydrate precipitation in pipelines and high pressure polymer producing processes. Another line of research was the application of ionic liquids and supercritical carbon dioxide as green process solvents in various applications. Recent projects include for example: the application of hyperbranched polymers as process solvents for CO2 removal and the properties of acid gasses in mixtures with natural gas and water (both sponsored by Shell). Current research is focused on the application of liquid crystals to act as solubility switch for CO2 adsorption. For this, accurate phase diagrams of liquid crystals+CO2 are being measured, thereby identifying the different phases. The lab is currently also participating in the Cato2 project by the Dutch government aiming at application of CCS in the Netherlands, as well as the ADEM innovation lab by the Dutch ministry of economic affairs. In the latter project, ionic liquids are screened in the lab for their potential use as absorbent for CO2. In some of these projects, molecular simulations are developed to complement the experimental measurements.

Replacement costs for all equipment is approximately 1.5Meuro. As the Cailletet setup require the use of Mercury, many safety features are currently installed to ensure a safe operation. Due to these large investment costs, our facilities are quire unique.

Recent publications:

- **Phase behavior of Hyperbranched Polymer systems: Experiments and Application of the Perturbed-Chain Polar SAFT Equation of State**
  M.K. Kozlowska, B. Jürgens, C.S. Schacht, J. Gross and T.W. de Loos
  J. Phys. Chem. B 113 (2009) 1022-1029.
- **Using Infinite Dilution Activity Coefficients for Determining Binary Equation of State Parameters**
  C.S. Schacht, L. Zubeir, T.W. de Loos, J. Gross.
  Ind. Eng. Chem. Res. 49 (2010) 7646-7653.
- **Phase behavior of the system hyperbranched polyglycerol + methanol + carbon dioxide.**
  C.S. Schacht, S. Bahramali, D. Wilms, H. Frey, J. Gross, T.W. de Loos.
  Fluid Phase Equilibr. 299 (2010) 252-258.
- **Using an analytic equation of state to obtain quantitative solubilities of CO_2 by molecular simulation**
  C.S. Schacht, T.J.H. Vlugt, J. Gross
  J. Phys. Chem. Lett., 2011, 2, 393-396.
- **Calculating Thermodynamic Properties from Fluctuations at Small Scales**
  S.K. Schnell, X. Liu, J-M Simon, A. Bardow, D. Bedeaux, T.J.H. Vlugt, S. Kjelstrup
  J. Phys. Chem. B, 2011, 115, 10911-10918.

The replacement costs for the Infrastructure (€): 1.500.000

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
ThermoLab	day	1 585	38	4	38	4

Work package number	**WP15-TA7**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@ETHZ**				
Activity Type	**SUPP**				

Participant number	7															
Participant short name	ETHZ															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**Two columns PSA setup (2-PSA); Adsorption Equilibrium Measurement Balance (ADS_EQ); Flue Gas Mineralization Unit (FGM)**
Location (town, country):	Institute for Process Engineering, Sonnegstrasse 3, ETH Zurich, Switzerland
Web site address:	www.ethz.ch/laboratories/spl
Legal name of organisation operating the infrastructure:	ETH Zurich
Location of organisation (town, country):	Zurich, Switzerland
Annual operating costs (excl. investment costs) of the infrastructure (€):	?????

TA 7.1 Two-columns PSA setup

Description of the facilities

The two-columns lab PSA is a set up can be used to investigate the dynamic behavior of commercial or newly developed adsorbents performing breakthrough experiments with different feed mixtures resembling either to flue gas (post –combustion) or syngas (pre-combustion). Furthermore it allows performing full PSA cycles with interconnected columns. Besides the hardware a detailed model in Fortran taking into account mass, energy and momentum balances as well as different constitutive equations is used to describe the breakthrough experiments, as well as the full PSA cycles.

State of the art

Breakthrough experiments as well as full PSA cycles can be performed in the proposed experimental unit. The columns (height: 1.2 m; inner diameter: 0.25 m) are manufactured in-house from a stainless steel pipe and are equipped with an electrical heater. Five thermocouples are placed regularly inside each column. Two mass flow controllers are used to control the feed flow rates, while the system pressures are controlled by two back pressure regulators mounted downstream of each column; additionally, the pressure drop across the beds is measured using four pressure transducers installed at the inlet and at the outlet of the columns, respectively. A combination of automatically and manually activated valves allows for a flexible choice of a PSA cycle. Online monitoring of the outlet gas composition is achieved by a mass spectrometer. The operating conditions are: Pprocess = 0.01 - 50 bar; Tprocess = 20 - 150°C; Tregeneration < 500°C; vfeed = 2-100 ln/min; xfeed --> any gas (as it is placed in a hood).

The PSA lab pilot plant was built in house and is therefore very flexible. Adaptation and small changes can be easily implemented. The mass spectrometer has a very high resolution (0.1 s), which allows to monitor also fast processes.

We consider inviting parties who have suitable alternative materials and are able to produce sufficient quantities of that material for the lab-scale pilot. This would broaden the chance of success for application of the process with new materials.

Services currently offered by the infrastructure and achievements

The research staff of the Separation Processes Laboratory at the ETH Swiss Federal Institute of Technology Zurich is constituted of 15 Ph.D. students and 3 post-doc research associates, from 8 different countries. The two column PSA setup is used in EU/FP7 DECARBit ("Decarbonise it", 2008-2011). Joss L. , (2011): „Characterization of novel adsorbent materials for a CO2 capture pressure swing adsorption process" (small column). Master thesis

Casas N., Johanna S., Pini R., Mazzotti M. "Dynamic adsorption of different CO2/H2 mixtures on activated carbon" (big column / PSA) submitted to

TA7.2 Adsorption equilibrium measurement balance - AEMB (Capture, Absorption)

Description of the facilities

The adsorption equilibrium installation's central piece is a magnetic suspension balance (MSB, Rubotherm, Germany), used to measure excess adsorption isotherms. This balance maintains a sample of adsorbent attached to a permanent magnet suspended in a closed chamber by an electromagnet on the outside of the chamber. This allows for precise measurement of any changes in weight of the sample under conditions of temperatures up to 250°C and pressures up to 400 bar. In addition, the MSB has the capacity to measure the density of the gas phase in situ. The MSB was integrated into a circuit that connects it with a secondary, larger, adsorption chanber, a circulation pump, and a sampling loop for a gas chromatograph. This circuit can be used to measure multicomponent adsorption isotherms. The secondary adsorption chamber provides volume for a larger amount of sorbent, which ensures that the adsorption is sufficient to alter the composition of the gas phase. Once the gas mixture has been circulated long enough to be in equilibrium with the sorbent, a gas sample is taken from the gas phase and analyzed using the gas chromatograph.

State of the art

The main advantages of the ADS_EQ installation are the ability to measure the density of the gas phase in situ, the measurement of multicomponent isotherms, and the conditions under which these measurements can be performed. In particular the ability to measure multicomponent isotherms makes this installation attractive, as that portion of the installation was designed and built in-house. The results obtained with this installation have been invaluable in the research are of carbon dioxide capture as well as storage. For capture processes, adsorption isotherms have been used to design pressure swing adsorption as well as temperature swing adsorption processes. Quantifying competitive adsorption helps in the validation of the models used to describe the behavior of adsorption columns. For cabon dioxide storage, the obtained results were used in the research area of enhanced coalbed methane recovery (ECBM). Adsorbed amounts of methane under various conditions are used to estimate the gas in place in coal seams considered for ECBM, while carbon dioxide isotherms are used to estimate the capacity for sequestration. Among other projects, the results obtained have been used in the EU project DeCarbIt, which aims to enable zero-emission power plants in Europe by 2020 through the use of pre-combustion capture in an integrated gasification combined cycle (IGCC) power plant.

Services currently offered by the infrastructure and achievements

1. The research staff of the Separation Processes Laboratory at the ETH Swiss Federal Institute of Technology Zurich is constituted of 15 Ph.D. students and 3 post-doc research associates, from 8 different countries.Adsorption equilibrium measurement balance is used in EU/FP7 DECARBit ("Decarbonise it", 2008-2011) and in numerous projects funded by the Swiss National Science Foundation (SNF).
2. S. Ottiger, R. Pini, G. Storti, and M. Mazzotti, "Competitive adsorption equilibria of CO_2 and CH4 on a dry coal," Adsorption - Journal of the International Adsorption Society, vol. 14, no. 4-5, pp. 539-556, 2008.
3. R. Pini, S. Ottiger, L. Burlini, G. Storti, and M. Mazzotti, "Sorption of carbon dioxide , methane and nitrogen in dry coals at high pressure and moderate temperature," International Journal of Greenhouse Gas Control, vol. 4, pp. 90-101, 2010.

The replacement costs for the Infrastructure (€):

TA7.3 Flue Gas Mineralization unit - FGM (Capture, mineral carbonation)

Description of the facilities

Fixation of CO2 by mineralization Mineral carbonation means dissolving alkaline solid materials to leach out magnesium and calcium that reacts with the CO2 to form stable and environmentally benign solids. Our unit allows for parametric kinetic studies of mineral and alkaline solid waste dissolution and carbonates precipitation reactions. It is a temperature and presure. controlled autoclave (CSTR reactor) with the feature of gas flow through at elevated pressure and at different gas and reactor solution composition (liquid: salinity, acidity, alkalinity, gas: N2/CO2 mixtures). Liquid and gas residence time can be varied independently. Solutes and solids are monitored in-situ, online, and offline (e.g. Raman, IC, MS). Several natural minerals and industrial waste materials contain alkalinity, and mineral carbonation provides the technic to 1) store CO2 permanently away from the atmosphere and 2) turn meritless materials such as natural silicates or industrial wastes into profitable goods such as PCC, inert waste, aggregates, fillers.

Potential partners can provide and study alkalinity containing materials from their processes/industry, thus extending the capability of the unit to operate at conditions closer to the realistic cases.

State of the art

The installation is a temperature and pressure controlled CSTR with the feature of gas flow through at elevated pressure and any composition (e.g. synthetic flue gas). Residence times for reactor solution and gas phase can be independently adjusted. The unit allows for parametric kinetic studies of mineral dissolution and precipitation reactions. Analytical tools included are in-situ Raman spectroscopy for solids and molecules in solution, and online ion chromatography for cations in solution, pH meter, and mass spectroscopy for gas composition.

The unicity of the installation is represented by the direct CO_2 removal from flue gas by various natural silicate carbonation.

Services currently offered by the infrastructure and achievements

The research staff of the Separation Processes Laboratory at the ETH Swiss Federal Institute of Technology Zurich is constituted of 15 Ph.D. students and 3 post-doc research associates, from 8 different countries.*The Flue Gas Mineralization unit is used in projects with Shell (2010) , in numerous projects funded by the Swiss National Science Foundation (SNF), and in CARMA, a Swiss research project that aims to explore the potential and feasibility of Carbon dioxide Capture and Storage (CCS) systems deployment in Switzerland (www.carma.ethz.ch).*

1. Werner M., Hariharan S., Hänchen M., Zingaretti D., Prigiobbe V., Baciocchi R., Mazzotti M., "Activated Serpentine Carbonation for CO2 Capture and Storage", poster presentation at ISIC18, 18th International Symposium on Industrial Crystallization, Sep 13-16, 2011, Zurich, Switzerland.
2. Werner M., Gasser L., Zingaretti D., Hariharan S., Mazzotti M., "Dissolution and Carbonation of Activated Serpentine for Combined Capture and Storage", oral presentation at TCCS-6, 6th Trondheim CCS Conference, June 14-16, 2011, Trondheim, Norway.
3. Werner M., Verduyn M., van Mossel G., Mazzotti M., "Direct flue gas CO2 mineralization using activated serpentine: Exploring the reaction kinetics by experiments and population balance modelling", Energy Procedia 2011, 4: 2043-2049.
4. Werner M., Mazzotti M., "Direct Flue Gas CO2 Mineralization using Activated Serpentine: Exploring the Reaction Kinetics by Experiments and Population Balance Modeling", oral presentation at ACEME10, 3rd International Conference on Accelerated Carbonation for Environmental and Materials Engineering, Nov 29 - Dec 1, 2010, Turku, Finland.

The replacement costs for the Infrastructure (€):

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
2 PSA	day	743	54	4	54	4
AEMB	day	456	44	4	44	4
FGM	day	471	43	4	43	4

Work package number	WP16-TA8	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@IFRF				
Activity Type	SUPP				

Participant number	8															
Participant short name	IFRF															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**Livorno Experimental Area (L.E.A.)**
Location (town, country):	ITALY
Web site address:	www.ifrf.net
Legal name of organisation operating the infrastructure:	International Flame Research Foundation
Location of organisation (town, country):	Livorno , Italy
Annual operating costs (excl. investment costs) of the infrastructure (€):	400000 €

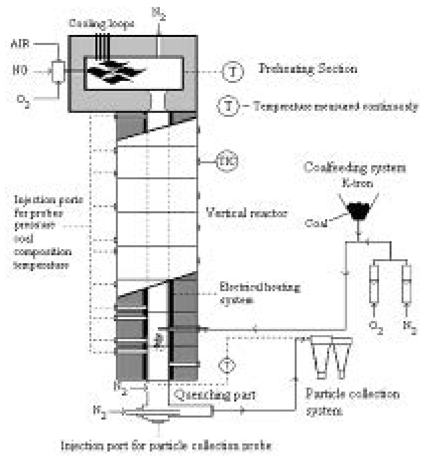
IFRF has access to ENEL I&I Experimental Area located in Livorno. The area has been developed to answer to the research needs coming from different aspects of power generation sector (fuel characterisation, combustion, heat transfer, emission treatment, industrial measurement, etc.) and includes several facilities of different scales.

The infrastructure is part of a network of research structures including the University of Pisa Engineering Departments (Energy, Processes and Systems Engineering) and ENEL I&I Research Centre, Pisa. Visiting scientists and industrial users would benefit of the opportunity to interact with Pisa research and academic environment.

In the frame of ECRI , IFRF is in the position to offer two installations (***TA 8.1 Isothermal Plug Flow Reactor (IPFR), TA 8.2 Experimental Furnace with flue gas recirculation (FOSPER)*** *that fit into combustion/gasification topic for CCS. .The two installations are unique, and are thought to be complementary among them, and between other facilities in ECRI project, since they range from 50kW to 3 MW and allow to perform tests in different controlled atmospheres of O2/CO2/H2O/N2/ and other gases (SO2, NO,etc.). Details are reported in the following.*

TA 8.1 IPFR (Combustion/gasification/chemical looping, solid fuel/sorbent characterisation)

IFRF has developed a drop tube reactor – the Isothermal Plug Flow Reactor (IPFR) - to characterize the combustion/gasification properties of pulverized coal, substitute fuels and blends in various atmosphere compositions (oxy-fuel combustion/gasification) and solid sorbent performances. This facility allows running tests under conditions similar to industrial applications, since pulverized solid fuel particles are injected into a high temperature reactor (1400ºC max) wherein they increase temperature rapidly due to the heat transmitted by the pre-heated gases flowing in the reactor and the hot tube walls. The particle heating rate is evaluated within the range of 10^4 – 10^5 K/s. The gases flowing into the reactor are preheated by an air - natural gas burner (max thermal input 60 kW) in the range of temperature of 900 – 1400ºC; Secondary gases (O_2, CO_2, N_2, SO2, etc) can be injected to obtain the desired composition in the reactor (that can be checked *in situ* by a gas analyzer). The reactor tube consists of eight modules that can be independently heated with 32 (4 each module) electrical Silicon Carbide (SiC) elements (max electrical input 32 kW) controlled by 24 thermocouples. In this way it is possible to adjust isothermal conditions within 10ºC over the whole reactor length. The tube has an operating length of 4.5 m and an internal diameter of 150 mm. It is built of Morganite Triangled 90V Alumina that allows the performing of test with very high concentration of O_2. Laminar or transient flow can be chosen by changing the flow of inlet gases. The pulverized solid fuel (minimum flow: 100 g/h) is injected in the drop tube reactor with a water-cooled probe that can be inserted at various heights in the reactor (there are 19 ports along the reactor) to simulate various residence times. The particles are quenched to 100ºC at the exit of the reactor by a cold nitrogen flow. For devolatilisation tests the particles are quenched inside a water-cooled sampling probe that can be inserted from the bottom of the reactor. Residence times obtainable are in the range of 5 to 1500 ms. The particles, after being quenched, are collected by a set of high-efficiency cyclones.



State of the art

The qualification activities (upgrading of specific components and diagnostic tests) and the experimental procedures developed for IPFR –make it a unique facility for providing data and parameters for advanced models of pulverized fuel combustors as well as innovative plants (e.g., oxyfiring and gasification, chemical looping). Users will be enable to conduct high quality research thanks to the qualification of the IPFR, that is a continuous in-progress activity consisting in improving the reactor characteristics, verifying the performance and validating the reliability of data obtained. The isothermal conditions of the reactor are a crucial issue to provide reliable data for combustion related investigation. The interpretation of the raw results requires further efforts, in particular on the balance of macro-products, that hardly closes, and the effective thermal history of solid particles, that may differ significantly from the nominal conditions of the reactor

The IPFR is used to study char burnout and devolatilisation properties of coals, secondary fuels and blends in a very large range of temperature (900 - 1400ºC), residence times (5 – 1500 ms) and atmosphere composition conditions, including oxygen-free and oxy-fuel combustion atmosphere. Combustion characteristics such as pyrolysis and combustion/gasification behavior of pulverized fuels can be determined by analyzing gaseous and solid combustion products thanks to the University of Pisa fuel characterisation lab (Elemental, Proximate, chemical analysis of samples, FTIR gas analyser for gas species O_2, CO, NO, SO_2, Scanning Electron Microscope (SEM) for sample) and ENEL research area, with additional pilot and semi-industrial facilities The slagging and fouling tendencies of ashes can be analyzed by using specific probes for ash collection (slagging) and with a section of controlled gas cooling and ELPI diagnostics for inorganic aerosols (fouling).

-

Services currently offered by the infrastructure and achievements

The IPFR is currently used in several projects (EU, National projects, Private companies) for solid fuel characterisation and sub-model development for combustion/gasification-related heterogenous phenomena.

The following projects will be running for the next four years: FP7-ENERGY-2010-2: RELCOM—*Reliable and Efficient Combustion of Oxygen/Coal/Recycled Flue Gas Mixtures*, FP7 GA 284498: BRISK- *The European*

Pag. 725

Research Infrastructure for Thermochemical Biomass Conversion

Recent pubblications

Simone M. Biagini E., Galletti C., Tognotti L. *Evaluation of global biomass devolatilization kinetics in a drop tube reactor with CFD aided experiments*, FUEL,vol. 88,pp 1818,tot.pag 10, **2009**

Karlstrom O., Brink A., Hupa M., Tognotti L., *Multivariable optimization of reaction order and kinetic parameters for high temperature oxidation of 10 bituminous coal chars*,Combustion and Flame,vol. 10.1016/j.combustflame.2011.03.003, pag 15,**2011**

Hercog J., Oskar K., Brink A., Hupa M., Tognotti L., *Kinetic combustion parameters for chars using the IFRF solid fuel data base*, 16th IFRF Members' Conference, pp O1-O12, Boston, MA,**2009**

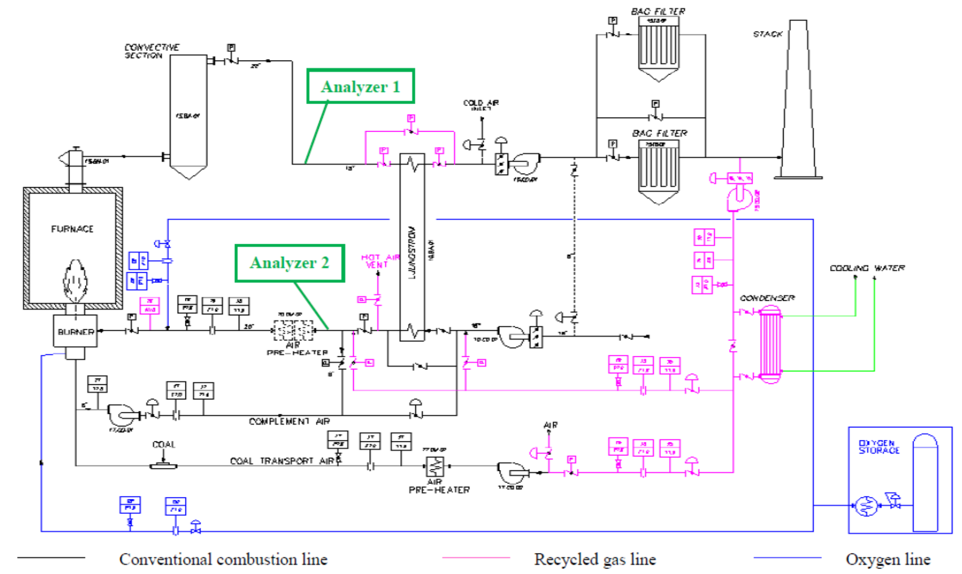
The replacement costs for the installation of the Infrastructure (€):500000 €

TA 8.2 FOSPER (Combustion, oxy-FGR)

The furnace FOSPER is a replica of the IFRF Furnace N.1, a well-known and extensively tested 3 MW furnace which was specially designed for characterizing innovative burners fired with a wide range of fuels (gas, heavy fuel oil and coal but also coal-water slurries, petcoke, wood residues, sewage sludge…) in conditions similar to those encountered in boilers and other industrial combustion equipment (e.g. glass furnaces, petrochemical furnaces, iron and steel heat treatment furnaces). Recently the furnace and its ancillary equipment has been modified to allow the execution of oxy-fuel combustion tests. This special capability makes FOSPER one of the few in the world where new burners and combustion techniques for CO_2 capture can be studied

The FOSPER furnace is a single burner facility with maximum furnace wall temperature of 1600 °C and air preheating temperature up to 350 °C. The length of the test furnace can be varied between 2 and 5 m. If the total length of the furnace is used, burners designed for a total maximum heat input of up to 3 MW_{th} can be tested.

The furnace has several accesses for different measurement techniques. On the right side there are five viewports (∅ 50 mm) for flame visualization and in-flame measurements (a range of conventional and new designed IFRF probes is available for this scope, see JRA1.1s and figure 2). In order to characterize oxy-flames which can reach temperatures up to 2300 °C, a special pyrometer has been developed together with an innovative calibration system. In addition to conventional techniques for the on-line analysis of major pollutants (NO_X, CO, CO_2) both in flame and at the stack, special probes and in-lab techniques are available for measuring micropollutants both organic and inorganic. The FOSPER furnace is also equipped with a patented on-line carbon-in-ash analyzer (MITER), which is particularly useful to check the steady operation of the furnace and the repeatability of tests when coal is used.



The full plant is shown in the Figure 1. The flue gas coming out the combustion chamber is sucked by a fan for flue gas extraction, set upstream the bag filters. This fan is used also to control the pressure inside the combustion chamber. The flue gases go in the first convective section where they are cooled down to about 400°C. This convective section is a flue/water heat exchanger that uses closed-circuit water. After the convective section the gas stream crosses the Ljungström exchanger that further reduces its temperature up to about 150°C, and increases the temperature of the comburent stream. The cooled flue gas then crosses through two bag filters, which remove the solid particulate, and afterwards it is divided in two streams, one is sent to the stack, the other is recycled. Another fan is set upstream the furnace and the Ljungström exchanger; it provides the secondary and tertiary RFG streams. RFG pass through two electrical pre-heaters; the secondary/tertiary RFG crosses first the Ljungström and then the electrical pre-heaters reaching a temperature about 300°C. All the pipelines are equipped with the instrumentation for measuring flowrates, temperature and pressure.

The plant allows a number of experimental configurations available:

Wet/Dry recycle – a condenser is installed in the flue gas recycle line, in order to enable both dry recycle and wet recycle. In this unit there is a system to neutralize the pH of the condensate, which is expected to be very low due to the solubilisation of the SO_x present in the flue gas. The neutralisation system uses a solution of NaOH and it is regulated by measuring the pH of the condensate.The dry recycled flue gas is used as secondary/tertiary comburent and also as primary transport gas for coal;

Ljungström mode – the Ljungström can be by-passed, both in comburent and in the flue gas sides, in order to study the influence of this equipment in the air-in leakage into the system. Hence it can be set in three modes: completely by – passed, completely in service, with flue gas in both the hot and the cold side; partially by-passed with air in the cold side and the flue gases in the hot side;

Oxygen injection – there is the possibility of feeding oxygen in the primary gas, injecting it in primary duct of the burner. As far as the secondary and tertiary gas are concerned , the oxygen is mixed with the flue gas prior to the burner. When coal is fired, is also the possibility of injecting part of oxygen directly in flame through lances located inside the burner (see later on burner description). The flexibility in the injection mode of the oxygen is crucial to study the influence of this parameter on flame stability and NO_X emissions, which is one of the issues about the design of oxy-burners, and one of the scopes of the research going on.

Service currently offered by the installation

- Study the feasibility of the conversion of power plant components from conventional combustion to oxy-combustion with recycled flue gas. In particular tests are carried out for evaluating the maximum CO2 level achievable in the system, and thus assess the air in-leakage amounts and their causes.
- Study the influence of the burner type and settings and of the recycle ratio on flame stability, heat transfer and pollutant emissions.
- Perform in-flame measurements both in conventional air combustion, to be used as baseline, and in oxy-combustion with recycled flue gas, to assess and compare flame structure and properties.

IFRF probes for in-flame measurements in FO.SPER

Test rig FOSPER provides unique opportunity in Europe regarding combustion testing of industrial scale burners with a wide range of gaseous, liquid and solid fuels in oxy-combustion conditions or in conditions similar to those encountered in the power, steel and glass industries.

CCS related EU funded projects where the infrastructure was used, or other large initiatives

Contract n° RFCR-CT-2006-00007 *Cost Effective and Environmental friendly Oxyfuel Combustion of Hard Coals*

Contract RFCR-CT-2009-00005: *Boiler Corrosion under oxyfuel conditions*

FP7-ENERGY-2010-2: RELCOM—*Reliable and Efficient Combustion of Oxygen/Coal/Recycled Flue Gas Mixtures*

Achievements

Pag. 727

Coraggio G., Laiola M., Cumbo D., Rossi N., Tognotti L.,*Oxy-combustion tests on low nox burners at fo.sper. furnace,* 16th IFRF Members' Conference, pp 1-10, Boston,**2009**

Brunetti I., Rossi N., Galletti C., Sorrentino L., Tognotti L.*Numerical model of oxy-fuel experiments in a semi industrial furnace*, 10th Conference on Energy for a Clean Environment, pp CD Rom-, Lisbon,**2009**

Coraggio G., Cumbo D., Brunetti I., Tognotti L., *Retrofitting oxy-fuel technology in a semi-industrial plant: Flame characteristics and NOx production from a low NOx burner fed with natural gas*, PROCEEDINGS OF THE COMBUSTION INSTITUTE,vol. 33,pp 3423,tot.pag 3430,**2011**

The replacement costs for the installation of the Infrastructure (€):2,500,000 €

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
IPFR	week	12 070	2	10	2	2
FOSPER	day	14 913	7	3	7	3

Work package number	**WP17-TA9**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	Transnational access@CIUDEN				
Activity Type	SUPP				

Participant number	9															
Participant short name	CIUDEN															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	***es.CO₂* CCS Technology Development Centre**
Location (town, country):	Cubillos del Sil, Spain
Web site address:	www.ciuden.es
Legal name of organisation operating the infrastructure:	Fundación Ciudad de la Energía
Location of organisation (town, country):	Ponferrada, Spain
Annual operating costs (excl. investment costs) of the infrastructure (€):	2.300.000

TA 9.1 Transport Rig (Transport: Thermo physical properties, Safety and Training)

Description of the facilities

CIUDEN´s CO_2 Transport Test Rig, currently under construction (commissioning on January 2012), is a semi-industrial size CO_2 transport installation integrated on the CCS capture plant at the *es.*CO_2 centre. The CO_2 Transport Facility at the *es.*CO_2 Centre includes the following main units, as it is shown in Figure 2:

(a) Pumping system to transport CO_2 either from storage vessels (commercial quality) or the CPU (Compression and Purification Unit) of the Centre

(b) High pressure vessel to avoid fluctuations in the flow

(c) Recirculation pump and heat exchanger systems so as to set operation pressures and temperatures within the range of 80 - 110 barg and 10 - 31 ºC respectively. In order to operate the test rig in thermal conditions similar to those expected in CO_2 transport pipelines (mainly buried), the facility is located inside a thermal isolated building with temperature control.

(d) Dimensions of the industrial building are 23x18x9 m^3. Isothermal conditions in the interval of 15 to 28 ºC, The building is concrete pre-fabricated with an effective ventilation system to avoid sub-oxygenated atmospheres.

(e) Dosing equipment to add impurities and contaminants to simulate different CO_2 streams compositions expected in industry applications: H_2O, NO_x, SO_x, N_2, O_2, Ar, CO, H_2, H_2S, CH_4. It is important to point out that in addition to the oxycombustion technology, the CT experimental facility is designed to test CO_2 streams including typical contaminants from other CCS options such as pre-combustion technology (CO, H_2, H_2S and CH_4).

(f) Tube coils with variable length and materials: each coil has an equivalent length of approximately 300m and a 2" nominal diameter. Considering the number of tube coils, the length of the whole test rig is around 3,000 meters. It is also possible to by-pass one or several tube coils in order to be adapted to specific conditions.

(g) Test zones with pipes of different diameters in order to install new equipment or instrumentation to be tested in real conditions of CO_2 transport. The number of test zones is designed considering the different tests that will be carried out.

State of the art

The CIUDEN´s CO_2 Transport Test Rig that is installed in the CIUDEN´s Technology Development Centre for CO_2 Capture will provide real basis for the design, maintenance and operation of industrial CO_2 pipelines. The designed test campaigns will generate valuable information for material selection, impure CO_2 behavior, depressurization and CO_2 safety operation; besides this and considering that the installation is located inside a building, it will be possible to test CO_2 small releases in order to study or validate dispersion models.

All wrap up with the lab facilities at the Centre, the offices infrastructures and the research environment should add an outstanding service to conduct high quality research.

A set of specific testing campaigns has been designed focused on the data acquisition for scaling-up the system, operator training and CO_2 safety operation. Table 1 shows the type of tests and the independent variables that will be modified during the tests performance.

Table 1. Summary of the test campaign

ID	Type of test	Independent variable
1	Corrosion rates in different materials.	Pressure, Temperature. CO_2 quality. CO_2 velocity.
2	Flow assurance (depressurization in the line).	Pressure, Temperature. CO_2 quality. CO_2 velocity.
3	Installation of industrial instrumentation or equipment.	Diameter. Pressure, Temperature. CO_2 quality.
4	Release studies.	TBD.

As mentioned before CIUDEN´s CO_2 Transport Test Rig is integrated at the *es.CO₂* Centre CCS capture industrial experimental plant. The CCS capture plant includes a full fuel preparation area (coal and biomass), two boilers (PC and CFB), gasifier, depuration train, CPU and transport rig. Outside the CCS installation facilities there are also technical buildings, laboratories and an interpretation building where the conferences and projects work meetings are hold. Although the CCS installations facilities mentioned before (with the exception of the transport rig) will not be accessible for the project during its time period due to Intellectual Property Rights of the technologist, scientists and researchers will benefit of an international environment, where many European funded projects are taking place and different companies, researcher institutions and technologist will be involved, being able to share work space and different know-how at their stay.

Services currently offered by the infrastructure and achievements

es.CO_2 Centre offers the following services: fully equipped laboratories and specialized operating staff. Offices and laboratories (3500m^2) and contractors offices and workshop (1300m^2), Personal Protective Equipment, Warehousing for tested equipment and Maintenance Shops (mechanical, electrical and Inspection and Control), IT support, offices and testing space.

List CCS related EU funded projects where the infrastructure was used, or other large initiatives

-The Compostilla OXYXFB300 Project co-financed by the European Union's European Energy Programme for Recovery. It's a 300 MWth Carbon Capture and Storage (CCS) integral commercial demonstration project including CO_2 capture transport and storage. www.compostillaproject.es

-ECCSEL, active partner and part of the Steering Board, currently at preparatory phase, the aim is to develop a European distributed, integrated research infrastructure on CCS, involving the construction and updating of research facilities.

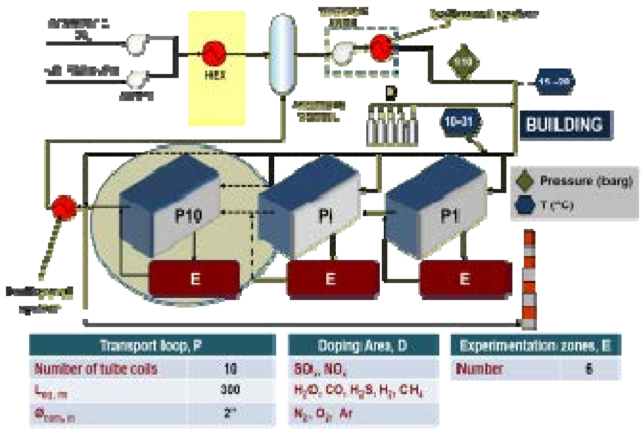
-Brisk FP7 project integrates leading European research infrastructures for advancing fundamental and applied research in thermo-chemical biomass conversion.

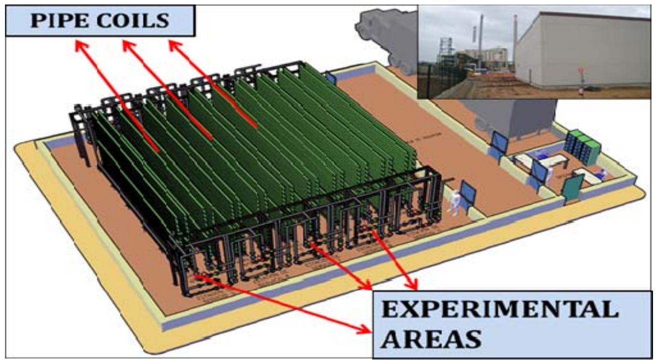
Relevant Scientific publications:

M. Lupión, R. Diego, L. Loubeau, B. Navarrete. CIUDEN CCS Project: Status of the CO2 Capture Development Plant in Power Generation. Energy Procedia 4 (2011) 5639-5646.

B. Navarrete, M. Lupion, I. Llavona, M.A. Delgado; An installation to study the uncertainties in CO2 transport: description of CIUDEN´s test rig. Elsevier. Under evaluation.

The replacement costs for the Infrastructure (€): 3.800.000€





Block diagram of CO_2 Transport experimental facility & 3D Simulation of the facility with actual building

TA 9.2 CIUDEN CCSLab (Transport and storage of CO_2, Laboratory: Characterisation & processes).

Description: The aim of this fully equipped laboratory is to become a high class service facility for scientific research in all the fields of the CCS chain. It provides service to CIUDEN´s two Technological Development Plants (one on CO2 Capture and the other one on Geological Storage) while carrying out independent investigation in the framework of national and international projects. The labs are divided in 15 rooms of a total area of approximately 700m^2 (additional facilities, such as sample preparation units and storage rooms, included).

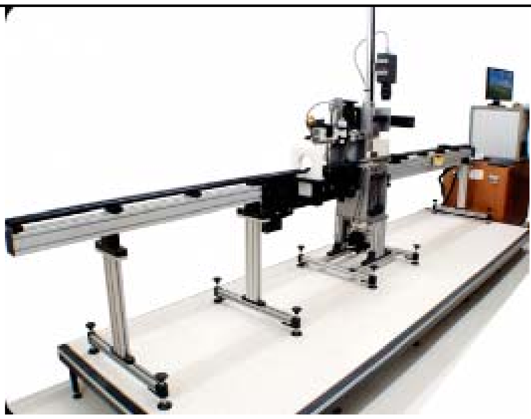
a) The **Control Laboratory of the CO2 Capture** unit is fully dedicated to the operation of the Plant of the ES.CO2 Centre, by the quality control of fuels, working fluids and combustion gases. The main equipment available includes: Thermo-gravimetric Analyzer (TGA); Elemental Analyzer, CHN, S; ICP-OES; Hg analyzer; Carbon Analyzers (TOC); Laser Granulometer; Ion Chromatography; Calorimeter; Thermo-mechanical Analyzer (TMA).

b) The main objectives of the **Geology Laboratory** are (i) petrological and petrophysical characterization of storage and seal formations; (ii) analysis of water and gas samples during the monitoring; and (ii) the investigation of durability and reactivity of natural and engineering materials when in contact with $CO_{2\ (sc)}$ and under real storage conditions.

The main uniqueness of this lab is related to three equipments, two for the investigation of chemical and physical reactions in the CO2 – brine – rock system under real storage conditions (i.e. high temperature and pressure): (i) the CO2 permeability system will allow absolute and relative permeability measurements in steady and un-steady state applying CO2, brine and/or gas; while (ii) the so-called High Pressure System will allow the monitoring of possible chemical reactions under storage conditions. In addition, the Multi Sensor Core Logger system is a non-destructive technique for the logging of various physical parameters of borehole cores, thus allowing the correlation of the in-situ borehole log measurements with laboratory data. The system will be equipped with the following sensors: electric resistivity, magnetic susceptibility, P-wave velocity, gamma density, and natural gamma.

Finally, the possibility of arranging short-courses for acquiring the basis on "Lab techniques for CCS Characterization" is also offered.

The replacement costs for the Infrastructure (€):2.000.000€



View of the two equipments within the CCSLAB: The MSCL-S system for laboratory core logging & Benchtop liquid permeability system to be upgraded for $CO_{2\,(sc)}$ studies

TA 9.3 CIUDEN PISCO2 (Transport and storage of CO2, Site characterisation & monitoring).

Description: The aim of this facility is to develop low cost sustainable biomonitoring tools for their application in the CO_2 storage programme. The main objective is to simulate diffuse leakage at the soil interface in order to identify efficient bioindicators of anomalous CO_2 concentrations. Ciuden is at the start-up of the PISCO2 facility.

The facility consists of 18 cells isolated by concrete. Each cell has an area of 16 square meters and a depth of 2.5 meters; and is equipped with (i) systems for controlled CO_2 injection at different depths (12 of the cells are instrumented with the injectors while the remaining 6 will be used as control ones) (ii) systems for sampling groundwater and gases and (iii) for monitoring different parameters, such as water content, pH, CO_2 flux, microbiological, botanical, and geochemical alterations and the chemical composition of water.

Services currently offered by the Infrastructure:

a) The platform will serve to test how small CO_2 diffusive leakages can influence, microorganisms, lichens and soils in general and it aims to find low cost sustainable bio-indicators of CO_2 concentrations in wide areas. It will also serve as a laboratory for agricultural tests of the beneficial effects of low CO_2 emissions.

b) The installation will be a tool to test and calibrate measurement instruments such as accumulation chambers.

All the monitoring systems will be designed for remote online use. The design of the cells is flexible and it can be customized to the requirements of future investigations. Finally, the possibility of arranging short-courses for acquiring expertise on biomonitoring techniques and its associated role on safety of CO2 Storage is also offered.

The replacement costs for the Infrastructure (€):1.000.000 €

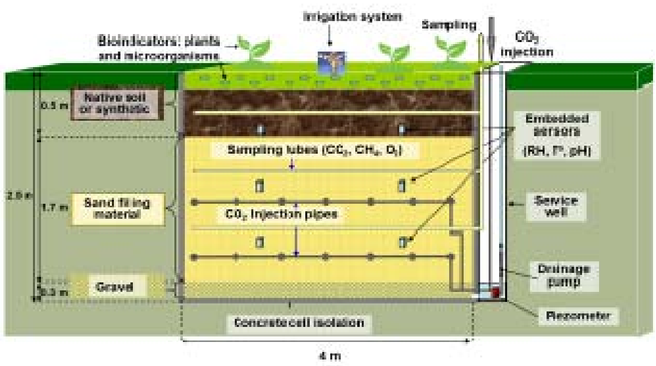


Diagram of the experimental cells of the PISCO2 Project & General View of the Infrastructure

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Transport Rig	day	10 700	10	2	10	2
CCSLab	day	2 370	20	4	20	4
PISCO2	day	1 962	23	5	23	5

Pag. 733

Work package number	**WP18-TA10**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@IFPEN**				
Activity Type	**SUPP**				

Participant number	10															
Participant short name	IFPEN															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**TransProS (Transport Properties for CO_2 Storage)** **CRC (Caprock Characterization)** **U544 (CO_2 post combustion capture mini-pilot)**
Location (town, country):	Rueil-Malmaison and Solaize (Lyon), France
Web site address:	www.ifpen.fr
Legal name of organisation operating the infrastructure(s):	IFP Energies nouvelles
Location of organisation (town, country):	Rueil-Malmaison, France
Annual operating costs (excl. investment costs) of the infrastructure(s) (€):	1 351 998 €

TA10.1 TransProS (Transport Properties for CO_2 Storage)

This research infrastructure provides advanced techniques for measuring capillary pressure (Pc) and relative permeability (Kr), needed for proper simulations of CO_2 behaviour. Due to the high mobility of gas, the measurement of Kr curves is not trivial and needs advanced techniques such as local saturation measurements during displacement experiments in a core sample. Furthermore, Pc should be measured on the same sample in order to perform the numerical interpretation of the collected data. We propose here two experimental installations to measure Pc and Kr curves: i) a CT scanner equipped with a flooding cell providing 3D saturation maps and ii) an automated centrifuge providing simultaneously Pc and Kr curves. The associated numerical tools for data interpretation are also included.

TA 10.1.1 Centrifuge laboratory (Storage, Laboratory: Characterization and processes)

Description of the facilities

The centrifuge laboratory comprises two large size centrifuges with rotating speed up to 4000 rpm. One centrifuge has the capability of measuring the produced fluids continuously using an accurate capacitance based technique. Custom-build core holders can accommodate samples of diameter 40 to 50 mm, and length up to 60 mm, at a mean radius of rotation of 170 mm. Six samples can be analyzed in a single experiment. The range of capillary pressure for the air-water fluid system is 50 mB – 15000mB.

Figure 1 Automated centrifuge at IFPEN

The second centrifuge can accommodate longer samples, up to 120 mm, without fluid measurement capabilities. It is mostly used to desaturate samples at irreducible saturation.

State of the art

The centrifuge experiment when performed with continuous recording of saturation, is well adapted for the

Pag. 733

simultaneous determination of air-brine Pc and Kr curves, in the entire saturation range. IFPEN's unique system overcomes frequently encountered technical difficulties of measuring precisely water saturation while rotating and is complemented by a dedicated numerical interpretation procedure. Centrifuge air-brine Kr experiments are largely superior to standard gas injection subject to fingering unstabilities caused by local heterogeneities. At the end of drainage, samples can be immersed in water in order to obtain the residual gas saturation, another useful quantity for reservoir simulations.

Services currently offered by the infrastructure and achievements

Air-water capillary pressure curves in drainage, and water relative permeability curve; Oil-water capillary pressure curves in drainage and forced imbibition; Oil-water relative permeability curves in drainage and forced imbibition; USBM wettability tests

Relevant scientific publications

Fleury M., P. Poulain and G. Ringot, ‘A capacitance technique for measuring production while centrifuging’, Proceedings of the International Symposium of the Society of Core Analysts, La Haye, September 14-16, 1998.

Fleury M., P. Egermann, E. Goglin, A model of capillary equilibrium for the centrifuge technique, International Symposium of the Society of Core Analysts, 18-22 October 2000, Abu Dhabi, United Arab Emirates

Fleury M., S. Gautier, N. Gland, P. Boulin, B. Norden, C. Schmidt-Hattenberger, Petrophysical measurements for CO_2 storage: Application to the Ketzin site. International Symposium of the Society of Core Analysts, Calgary, Canada, 10-13 September, 2010.

The replacement costs for the installation of the installation (€): 200 000

TA 10.1.2 X-RayComputed tomography (CT)

Description of the facilities

IFPEN's CT scanner is a commercial medical scanner GE Fxi. This equipment, combined with an appropriate flow cell, has the capability of measuring the fluids saturations in a core while flooding, from which the Kr curves can be deduced. If used with our semi dynamic approach both of Pc and Kr curves can be obtained. The measured local saturation profiles bring a significant improvement in the interpretation of coreflood experiments by a better accounting of the capillary pressure effects during the relative permeabilities determination.

Figure 2 CT Scan

State of the art

Relative permeabilities are usually determined from flow experiments performed on core samples using either the Unsteady Steady State (USS) or the Steady State (SS) method. The main advantage of the semi dynamic approach is to establish several equilibrium states between the viscous and the capillary forces within the sample by injecting one fluid while the other circulates at the outlet face. These equilibrium states enable the analysis of both the kr of the injected phase and the Pc curve. The kr of the displaced phase can also be obtained by history matching of the transient evolution of the pressure drop.

The in-situ saturation monitoring brings a significant added value to the interpretation process because it enables the direct identification of the influence of the capillary effects on the experimental data. Several ways exist to use this information in the inversion procedure of the kr data. To date, the local saturation profiles are either included in a global objective function (in addition to the production and the pressure drop data) that is minimized during the inversion process, or smoothed and used as input data in the simulation, which leads to non-smoothed simulated pressure drop.

Services currently offered by the infrastructure and achievements

Capillary pressure curves and both fluids relative permeability curves can be measured. In a standard experiment, Swi is first established. If the wettability has to be restored, the wettability is restored by aging at reservoir conditions with live oil. Then, the live oil is replaced by dodecane using several successive miscible displacements prior to injection of nitrogen at ambient conditions.

The gas injection experiment is conducted under the medical CT-scanner (voxel 0.12×0.12×1 mm3) to follow the evolution of the saturation profiles as a function of time (1 acquisition every 2 seconds). The oil and gas productions are recorded and CT-profiles are measured regularly during the experiment. Different differential pressure are successively applied. Further details on the experiment can be found in a previous paper dedicated to gas injection processes**.**

Achievements (include the most relevant scientific publications, up to 5)

Lombard J.-M., Egermann P., and Lenormand R., "Measurement of Capillary Pressure Curves at Reservoir Conditions", SCA n° 2002-09, Society of Core Analysts, Monterey, California, 2002

Egermann P., Robin M., Lombard J.-M., Modavi A., and Kalam M. Z., "Gas Process Displacement Efficiency Comparisons on a Carbonate Reservoir", SPE n° 81577, Middle East Oil Show, Bahrain, 2003

The replacement costs for the installation of the installation (€): 600 000

TA 10.2 CRC (Caprock Characterization)

The research infrastructure provides advanced techniques for measuring porosity, permeability and entry pressure of caprock formation.

Caprocks may have very low permeabilities, down to 1 nD (10^{-21} m^2). Traditional equipments cannot be used at such low values. IFPEN developed in the recent years specific installations and protocols for measuring liquid permeability in a reasonable amount of time on standard plug sizes, including the effect of confining pressure. Using the same installation, entry pressure can be measured after permeability. In addition, orders of magnitude of permeability can be obtained quickly on cuttings when plugs are not available. This infrastructure is composed of two independent installations

TA 10.2.1 NMR laboratory (Storage, Laboratory: Characterization and processes)

Description of the facilities

The laboratory comprises 4 NMR devices characterized by different resonance frequencies, different diameters and different capabilities:

- a 2.2 MHz device equipped with a 50 mm probe and 1D vertical gradient (50 G/cm)
- a 2.2 MHz device equipped with a 70 mm probe
- a 23.7 MHz device equipped with a 18 mm probe and 1D vertical gradient (300 G/cm), and a 10 mm probe with 3D vertical gradient (300 G/cm)
- a 20.7 MHz imaging system equipped with a 30 mm probe and 3D vertical gradient (150 G/cm)

The laboratory has also several home build interpretation software such as 1D and 2D inverse Laplace transforms, diffusion analysis software. Depending on the size of the probe, inter-echo time as small as 30 µs can be reached, allowing small relaxation time to be detected. The various diameter probes allows the NMR characterisation on powders, cuttings, small, standard or large size plugs. Temperature and pressure cells are also available with some devices.

Figure 3 Two NMR devices: 23.7 MHz (left) and 2.2 MHz (right)

State of the art

The NMR technique is unique for characterizing porous media in a non destructive way; it was initially developed at IFPEN to perform laboratory to log integration but is also used to measure porosity and pore size distribution, as well as pore connectivity from advanced 2-dimensional relaxation experiments. The NMR technique is particularly well suited for characterizing tight formation such as caprocks or coals because water contained in nano-pores can be detected easily.

Services currently offered by the infrastructure and achievements

The installation is used on a every day basis for porosity and pore size distribution measurements, and control of these two quantities at different steps of experiments performed in other laboratories. It can be coupled with centrifuge and resistivity experiments in order to measure saturation and fluid distribution in porous media. For tight rocks, samples need not to be dried, and this is a clear advantage for not perturbing the pore structure of preserved samples containing clays.

Relevant scientific publications

Fleury M., D. Boyd and K. Al-Nayadi, Water saturation from NMR, Resistivity and Oil-Base core in a heterogeneous Middle-East carbonate reservoirs, Petrophysics, vol 47, 1, 2006.

Nicot B., S. Gautier, M. Fleury and S. Durucan, Pore structure analysis of coals using low field NMR measurements and thermogravimetry analysis, Proceedings of International Symposium of the Society of Core Analysts, Trondheim, Norvay, 12-16 September 2006.

Guichet X., M. Fleury, E. Kohler, Effect of clay aggregation on water diffusivity using low field NMR, J. Coll. Inter. Sciences, 327, 2008.

Fleury M., J. Soualem, Quantitative analysis of diffusional pore coupling from T2-store-T2 NMR experiments, J. Coll. Inter. Sciences, 336, 2009.

Berne Ph., P. Bachaud and M. Fleury, Diffusion properties of carbonated caprocks from the Paris Basin, Oil Gas Sci. Technol. – Rev. IFP 65 3 (2010) 473-484

Fleury M., S. Gautier, N. Gland, P. Boulin, B. Norden, C. Schmidt-Hattenberger, Petrophysical measurements for CO_2 storage: Application to the Ketzin site. International Symposium of the Society of Core Analysts, Calgary, Canada, 10-13 September, 2010.

The replacement costs for this installation (€): 300 000

TA 10.2.2 VLP laboratory (Storage, Laboratory: Characterization and processes**)**

Description of the facilities

The VLP (Very Low Permeability) laboratory comprises two experimental set up to measure liquid permeability in the nanoDarcy range (10^{-21} m^2) within one day – one experimental set up to measure gas permeability – one experimental set up to measure entry pressure by more than four different methods – one device to measure low permeability on small size sample (used for screening purpose).

Water permeability measurement is performed using the steady state method with a pump in a push/pull configuration. One device is at a controlled temperature of 20 to 30 °C. The other one is at a controlled temperature of 20 up to 80°C. The confining pressure limit is 350 bar and the pore pressure limit is 300 bar. The measured permeabilities range from 0.1 nD up to 1 µD (10^{-22} m^2 to 10^{-18} m^2). Measurement can be fast (1 nD in one day) since high precision pumps are used. The device uses plugs of 40 to 50 mm diameter and 20 to 50 mm length.

Gas permeability experiments are based on transient and steady state techniques. Klinkenberg effect can also be assessed. Permeabilities from 10 nD up to 100 µD can be measured. The confining pressure limit is 350 bar and the pore pressure limit is 200 bar. The device uses plugs of 40 to 50 mm diameter and 20 to 50 mm length. For cuttings, a specific device called Darcygaz can be used, based on the GRI method. The experiment is made at 1 bar and no confinement is applied. The measured permeability are from 50 nD up to 100 µD (5 10^{-20} m^2 to 10^{-16} m^2). The plugs used here are 15 mm diameter and 20 mm length.

Figure 4 Water permeability measurement device

The experimental set up used for the entry pressure measurement can performe several techniques: step by step approach, dynamic method, dynamic racking method and the residual method. The gas used is nitrogen but the device will be upgraded in 2012 to be able to used supercritical CO_2. The device uses plugs of 40 to 50 mm diameter and 20 to 50 mm length. The confining pressure limit is 350 bar and thus entry pressure estimation limit is 300 bar.

The entry pressure device can be used now but an upgrade will be done in 2012. During one month in 2012, the sensor will be replaced and the system simplified to allow the use of supercritical CO_2. The upgrade is expected in June 2012.

State of the art

The water permeability device allow the measurement of water permeability within an estimate error of 10 to

20% due to the high resolution pump used. The measurement can be fast considering the amount of water that is measured (few µl). This technique is believed to provided more relevant permeabilities than pulse decay test usually performed on very low permeability tests.

The experimental device dedicated to entry pressure measurements can be use with different protocols. IFPEN laboratory is the only one performing the dynamic method that proves to be the most efficient way to measure entry pressure values in caprocks. In addition, the racking method has been implemented this year. This method is not new, not well known but it has a very good accuracy compared to other techniques. To our knowledge the racking method has never been involved in a CSS project.

Services currently offered by the infrastructure and achievements

- Entry pressure measurement / Permeability measurement with gas or water
- Entry pressure and permeability can be assed with 10 to 20 % uncertainties

Relevant scientific publications:

Boulin, P.F., Bretonnier, P., Gland, N., and Lombard, J.M., 2011, Contribution of steady state methods to water permeability measurement in very low permeability porous media, Oil & Gas Science and technology, article in press

Carles, P., Egermann, P., Lenormand, R., and Lombard, J.M., 2007, Low permeability measurements using steady state and transient technics, International Symposium of the Society of Core Analysts, Calgary, Canada, 10-14 September 2007.

Egermann, P., Lombard, J.-M., and Bretonnier, P., 2006, A fast and accurate method to measure threshold capillary pressure of caprocks under representative conditions, International Symposium of the Society of Core Analysts, Trondheim, Norway 12-16 September 2006.

Boulin, P.F., Bretonnier, P., Vassil, V., Samouillet, A., Fleury, M., and Lombard, J.M., 2011, Entry pressure measurements using three unconventional experimental methods, SCA 2011 Symposium, Austin, TX, USA, September, 2011.

The replacement costs for the installation of this installation(€): 250 000

TA 10.3 CO_2 post combustion capture mini-pilot (Capture, Absorption)

Description of the facilities

This apparatus consists in a small laboratory pilot that corresponds to the process of post-combustion CO2 capture via amine based solvents. It mainly consists of two columns : the absorber, where the gaseous and liquid phases flow countercurrently and where the CO_2 contained in a synthetic gas is absorbed, and the stripper, a heated regeneration column where the CO_2 is desorbed.

The flue gas is synthetically prepared and is generally a mix of N_2, O_2 and CO_2. Small amounts of SO_2, NO and NO_2 can also be added. The mini-pilot plant is able to treat up to 1 Nm3/h of flue gas, whereas the solvent (generally an aqueous amine solution) will circulate at a rate of around 2 L/h.

The absorber consists in a glass plate column (10 cm in diameter, 1 m high) where CO_2 chemical absorption between the flue gas and the solvent occurs. The solution collected at the bottom of the column is rich in CO2, it is heated electrically and sent to the desorber column. The desorber is also a glass plate column (10 cm in diameter, 1 m high). There, the rich solution reaches its boiling point while flowing downwards to an electric reboiler. Elevated temperatures reverse absorption. As a result, a mixture of CO_2 and water vapour is released. The water vapour is condensed in the overhead condenser and returned to the regeneration column with total reflux. The stripped CO_2 is released. The regenerated solvent is collected in the storage tank and recycled back to the absorber for further CO_2 removal. The absorption section works at atmospheric pressure while operating pressure in the desorber is 2,5 bara. Reboiler temperature is 120 °C.

The gas flowing in the absorption column and flowing out from both columns can be sampled. The gas selected for analysis is directed towards a cold trap, then heated at 180 °C, in order to minimize condensation in the analysis equipment. In an analyses room located close to the unit, a FTIR module, equipped with a measuring cell with a 5 m optical path, is able to determine compounds such as NH3, NO2, SO2, CO2, H2O or CO. Alternatively, the user can also choose to analyze gas samples by gas chromatography. It is possible to follow

Pag. 738

amines concentration, CO2 loading and degradation products such as Heat Stable Salts by off-line measurements. Except for the glass columns, all the other components of the plant are built in 316 stainless steel.

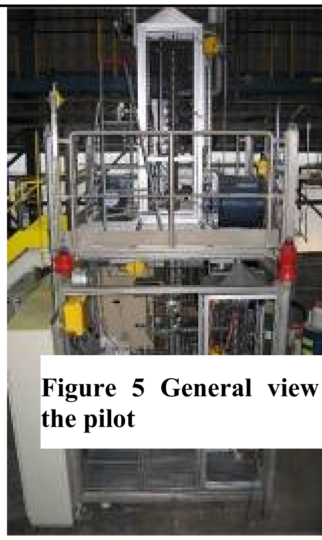


Figure 5 General view of the pilot

State of the art

- The research infrastructure described here is fully automatic and allows to run long-term tests (up to several weeks), in order to study degradation properties of solvents. There is also the possibility to monitor corrosion in several locations of the pilot with corrosion coupons.
- The infrastructure is currently dedicated to CO_2 capture with amine solvents. But, other types of solvents can also be used, as long as the operating conditions are in the appropriate range. The infrastructure can also be used for gas treatment for H_2S capture.

Services currently offered by the infrastructure and achievements

If external users were interested in conducting research on this infrastructure, the access to a certain amount of off-line analyses (ionic chromatography, HPLC, ionic exclusion chromatography) would be allowed. Also, a room for off-line analyses, a control room, a workshop and a changing room would be available on the site of IFP Energies nouvelles.

The infrastructure is mostly used for internal research projects. The research performed on this pilot plant has allowed IFPEN to develop processes such as Hicapt™, Hicapt+™ or more recently, DMX™.

The infrastructure is expected to be upgraded during 2012 and the upgraded pilot could then be made available from mid-2013 on.

The replacement costs for the installation of the Infrastructure (€): 2 000 000 €

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
TransProS	day	3 448	37	6	37	6
CRC	day	3 204	40	8	40	8
U544	day	1 137	39	8	39	8
TransProS	day	3 448	37	6	37	6
CRC	day	3 204	40	8	40	8

Pag. 738

Work package number	WP19-TA11	start date of event:	M6	end date of event:	M48
Work package title	Transnational access @ OGS				
Activity Type	SUPP				

Participant number	11																
Participant short name	OGS																

Description of the infrastructure	
Name(s) of the infrastructure(s):*	Data acquisition systems for terrestrial and marine natural field laboratories
Location (town, country):	ITALY
Web site address:	www.ogs.trieste.it
Legal name of organisation operating the infrastructure:	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS
Location of organisation (town, country):	Sgonico (Trieste), Italy
Annual operating costs (excl. investment costs) of the infrastructure (€):	

Sites where natural CO_2 is produced and leaks are recognised as important field laboratories that provide unique opportunities to understand leakage mechanisms, migration pathways and travel times, chemical reactions, potential impacts of leakage on groundwater and ecosystem, and to test and improve techniques for monitoring and early warning. Italy has many of such sites and some of them have been widely used in previous researches, mostly supported by the EC. So, large data sets are available for these sites, together with the results of such previous studies and a comprehensive set of modern high quality cross-calibrated equipment for the geophysical and geochemical detection of CO_2 in the shallow underground and at the surface, both on land and off-shore, as well as monitoring and evaluating its impacts on marine echosystems.

The infrastructure here proposed, consists in a series of installations for identifying and monitoring CO_2 leakages on land and at sea bottom, imaging the near subsurface, evaluating the effects of CO_2 on marine ecosystems, identifying target species to be used for quick alerts.

TA 11.1 Aircraft and remote sensing isntruments (CO2 detection over large areas)

Description of the facilities

The Piper Seneca II aircraft, of property of OGS, is managed by a team of expert researchers and technitians. It is equipped with the most advanced remote sensing instruments:

- Lidar sensor Riegl LMS-Q560 (full waveform digitizer)
- Hyperspectral sensor Specim Aisa Eagle 1K (Visible Near Infrared field)
- Thermal camera Nec TS9260 (from 8 to 13 µm)

- Digital camera Canon EOS 1Ds MkIII (21 million pixels)

The performance of the installation is very high. The aircraft can operate to a maximum height of 1500 m. The Lidar sensor can reach a spatial accuracy of 40 cm in xy and 15 cm in z axes. The hyperspectral sensor has a pixel of 70 cm for an average flight height of 1000 m; the bands number can be set up to 252. The thermal camera has a pixel of 50 cm for an average flight height of 800 m.

State of the art

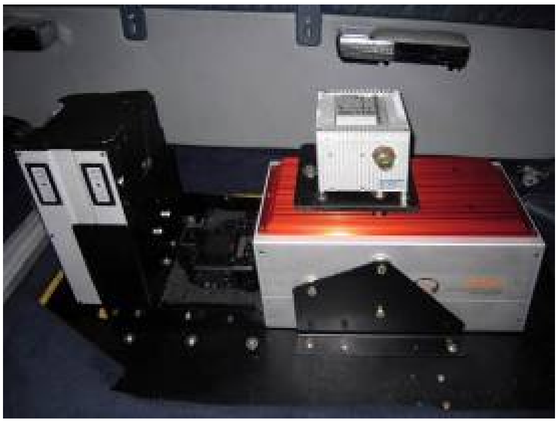
The equipped Piper Seneca II is part of EUFAR (European Facility for Airborne Research); it is inserted and operates in an European context.

The entire instrumental equipment has been used to perform remote sensing surveys during several European projects, among which CO2 GeoNet, to detect leakages at natural field laboratories (Latera, Italy and Laacher See, Germany).

This aircraft is unique because it integrates different instruments on board and can accomodate additional new equipments provided by group of researchers. The data acquired are processed by the Remote Sensing Group at the OGS central site, where specific codes for multiparameters leakages detection has been developed. All these computer programs are available and can incorporate new routines for novel instruments / images processing.

Services currently offered by the infrastructure and achievements

The aircraft can operate over the whole European territory. It can be used to perform accurate remote sensing surveys over wide areas, onshore and offshore (especially coastal areas). Data collected can be easily geographycally referenced and integrated with other data collected over the natural field laboratories, for joint analysis. Flight crews will organise all logistics of the flights and will decide in consultation with the users the suitable time and atmospheric conditions for the acquisition of their data. When necessary, training on the processing and analysis of remote sensing data will be provided as well as support for the inclusion of new routines into the base processing packages.



TA 11.2 Equipment for the geophysical imaging of the subsurface (CO2 pathways to the surface)

Description of the facilities

Geophysical methods are needed to accurately image the subsurface in order to understand the interaction of CO2 with rock formations, its migration mechanisms up to the surface, and to predict maximum CO2 flow rates. To this purpose, many indirect prospecting method may be used, as multichannel reflection seismics, electromagnetic surveys (Ground Penetrating Radar), current measures (Earth Resistivity Tomography) and microgravimetry. The choice of the appropriate method depends on several factors, such as target depth, required resolution, environment characteristics, etc... However the joint availability of all these equipment is unique because it has been demonstrated that the integration of many geophysical methods can produces a better image of the subsurface at various depth ranges. The proposed installation is formed by te following data acquisition instruments.

High Resolution Multichannel Seismic

- DMT Summit telemetric system (24 bit, delta sigma technology) with 300 active stations
- several types of geophones (single, six-geophones arrays, 3 components, with 10 Hz, 100 Hz and 200

Hz natural frequencies)

- various energy sources (accelerated Power Weight Drop truck mounted, MiniVib T2500 IVI truck mounted with plates for P and S waves in the range of f5-500 Hz , various guns and hammers, and dynamite shooting systems)

Ground Penetrating Radar

- SIR2000 GSSI equipped with monostatic and bistatic antennas. The frequencies are 35 MHz and 70 MHz (Subecho), 100 MHz and 200 MHz.

Earth Resistivity Tomography

- Syscal R2 (Iris Instruments) with 64 electrodes, suitable for a multimode line 630 m long or shorter 3D area.

Gradiometer

- G-858G (Geometrics), a walking cesium gradiometer with 2 sensors. This instrument has a very high sensitivity, fast-sampling and GPS conection.

State of the art

The proposed installation is formed by a series of equipments for geophysical surveys that are used also by service companies and can be leased. What is peculiar is their joint availability and the support by a group of expert researchers and technitians involved in projects for CO_2 imaging and can assist new users in similar surveys. The said data acquisition systems have been widelly used to map the subsurface at the Latera field laboratory. Their joint use has allowed there to image the subsurface and to identify very small faults, intepreted as preferential pathways for the leaking CO_2. Moreover, the data processing by Cat3D, a proprietary tomographic package developed by OGS, has identified there velocity anomalies in the near subsurface, in relation with "gas accumulation areas" feeding the leaking points at the surface.

Services currently offered by the infrastructure and achievements

All the data acquisition systems forming the installation are managed by a group of experts, who can provide support for new field campaign in Latera or other natural sites of interest. Such support can consist in one, many of all of the following actions: planning of the surveys, acquisition of the needed pernissions, instruments calibration and test, data acquisition (by field crews), data processing, comparison with the data and results exploited in previous studies, data interpretation.

A large set of poro-visco-elastic 2D modelling programs, developed at the OGS is also available to model the subsurface seismic response and assist the researchers in the interpretation of the seismic data collected in complex geological settings.

TA 11.3 Equipment for studying CO2 leakage at sea, and its impacts on marine biosphere

Description of the facilities

The BiO Department of the OGS offers a wide range of laboratories and technical and scientific facilities. This installation is equipped for studies in the marine biology field concerning biogeochemical analysis of sediments and overlayer water, characterization of plankton community from prokaryotes to zooplankton, characterization of benthic community from prokaryotes to macrobenthos, identification of the role of biological activities in the release (community respiration processes) or in the uptake (photosynthetic processes of phytoplankton and microphytobenthos) of CO2 in the water column and at the sediment-water interface, evaluation of microbial activities variation as consequence of CO2 concentration changes, determination of prokaryotic community structure, toxicological and physiological responses of invertebrates. The installation is complemented by equipments for measurements of physical parameters in the water column (CTD probe, Profiling Natural Fluorometer, etc), for samples collection (e.g rosette, boxcorer, plankton net, grab, etc), and with dark and transparent benthic chambers useful to perform in situ benthic flux measurements and to asses the potential importance of sediment-water nutrients exchanges for respiration and production processes. The equipment and expertise in the installation allow determining the main parameters necessary to describe both the carbonate system and the organic carbon cycle in order to fully characterized marine sites in terms of leakage detection and quantification. This installation may be considered “unique” due to its proximity to the sea, the availability of running seawater and the existing collection of planktonic organisms. Thus, field work at storage sites and natural CO2 seeps that serve as analogues for potential CO2 leaks, can be supported by laboratory experiments as the installation allows performing ecological and ecophysiological studies under controlled conditions (light, temperature, pH, salinity), in order to estimate the immediate and long term effects of CO2 exposure on organisms and communities.

State of the art

The installation has been and is actually used within national and EC-funded research and demonstration projects in the fields of Energy, Environment and Marine Sciences, in the framework of CO2GeoNet Network of Excellence and in other CO2 related projects as RISCS (Research into Impacts and Safety in CO2 Storage - http://www.riscs-co2.eu), ECO2 (Sub-seabed CO2 Storage: Impact on Marine Ecosystems - http://www.eco2-project.eu), MEDSEA (Mediterranean Sea Acidification in a changing climate - http://medsea-project.eu), EUROFLEETS (Towards an alliance of European research fleets - www.eurofleets.eu). Recently, the installation has been used for defining the base-line in the off-shore area considered for the Porto Tolle CO2 storage demonstration project (in Northern Adriatic).

Services currently offered by the infrastructure and achievements

The BiO installation is located in the Gulf of Trieste - Northern Adriatic Sea – Italy. All analytical activities carried out in the Microbiological, Ecology, Primary Productivity, Molecular Biology and Biogeochemistry Laboratories are offered by this installation. The technical and logistic support offered to the users will be guaranteed both inside the laboratories as during the field activities.

TA 11.4 Equipment for characterising and monitoring offshore natural laboratories (oceanographic

parameters)

Description of the facilities

OGS has developed and used over marine field laboratories a series of support vehicles for collecting meteo-oceanographic physical and geochemical data. Flooting buoys have demonstrated to be efficient and flexible, but generally too costly to be maintained at sea for long periods. More recently, OGS has preferred a new family of DeepLab Sea Floor Landers, with a stainless steel structure that allow to place scientific instruments at the sea floor. These stations are equipped with an underwater telemetry system with 5 miles range able to control the releasing of a subsurface buoy for the recovery of the lander. This has to be done at due interval to change batteries, verify and eventally re-calibrate the marine instruments, download the recoded data.

In the current configuration DeepLabs are euqipped with base instruments to measure temperature, conductivity, pressure, dissolved oxygen, pH, dissolved CO2 , sea currents on the water column every 0.5 m and estimate waves height and direction.

The shape, size and weight/thrust of the DeepLabs make them particularly robust and suitable for long-term time-series measures, minimizing damages and data loss caused, for example, by fishing activities.

The modular design of power supply system and data logger, allows an easy intergration with additional instruments provided by new users.

State of the art

The more recent version of the Deeplab Sea Floor Lander has been used successfully for collecting data in Nortnern Adriatic sea, continuasly from November 2010 to July 2011, in the CO2 base-line survey of the Porto Tolle demonstration project .

Services currently offered by the infrastructure and achievements

Support in the use of the Deeplab Sea Floor Landers will consist in: planning surveys, acquisition of the due permissions for the areas of interests (sea natural laboratories), eventual installation of additional equipment, calibration of these new instruments, positioning at sea, maintenence and recovery of data by suitable support boats, pre-processing of the data, their upload to internet for a long-distance access.

An important component of the installation and the given services is the **Oceanographically Calibration Laboratory (OCL)** of the OGS Department of Oceanography.

Thermally-regulated and humidity-controlled, the OCL is currently equipped with primary physical standards, secondary transfer standards and support equipment for performing high-accuracy calibrations of devices and sensors measuring temperature, conductivity and pressure, the fundamental seawater parameters, across the full oceanographic range. It is also endowed with a number of instruments for making standard electrical measurements of various kinds. Recently, the OCL has been evaluated by the Consultative Committee of the Amount of Substance (CCQM) endorsed by the SCOR-UNESCO/IAPSO Working Group, resulting the more accurate (together with the Chinese IMGC) among 11 oceanographic calibration centres of excellence.

Implementation plan						
Short name of installation	**Unit of access**	**Unit cost (€)**	**Min. quantity of access to be provided**	**Estimated number of users**	**Estimated number of days spent at the infrastructure**	**Estimated number of projects**
Aircraft	day	7 137	8	4	8	2
GeoIm	day	3 590	20	4	20	4
BioMarineLab	day	1 410	40	4	40	4
DeepLab	day	1 100	40	4	40	4

Pag. 745

Work package number	WP20-TA12	start date of event:	M6	end date of event:	M48
Work package title	Transnational access MATGAS				
Activity Type	SUPP				

Participant number	12															
Participant short name	MATGAS															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	Gas separation lab, High pressure lab
Location (town, country):	Barcelona, Spain
Web site address:	http://www.matgas.org
Legal name of organisation operating the infrastructure:	MATGAS
Location of organisation (town, country):	Barcelona, Spain
Annual operating costs (excl. investment costs) of the infrastructure (€):	

TA 12.1 Gas separation lab (Separation and conditioning of CO2, absorption - adsorption)

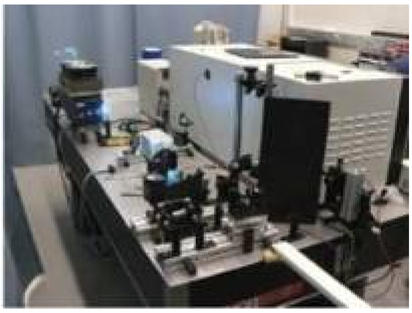
Description of the facilities

The Gas Separation laboratory is a multi-functional facility equipped for the synthesis, characterization and simulation of sorbents for CO_2 separation under ideal and realistic operating conditions. The lab facilities can be split into three main groups: (A) synthesis and characterization of solid and liquid sorbents for CO_2, (B) gravimetric and volumetric equipment for the experimental studies of both equilibrium and kinetic CO_2 separation (either absorption or adsorption) processes and (C) a cross functional computing unit for the simulation of the materials' physic-chemical properties, as well as the interaction mechanism between the CO_2 and the sorbent.

Group A includes standard equipment for materials synthesis and a state of the art pool of equipments for surface and bulk characterization, such as a **Raman spectroscope**, an **Atomic Force Microscope**, a **Mastersizer** and a **Zetasizer** for measuring particle size distributions over a wide range of sizes.

Group B includes: a **Rubotherm Magnetic Suspension Balance** operating from vacuum up to 30 bar and from 5 to 450C, equipped with steam generation and multiple gas switching system, a TA Instruments Q5000IR **thermogravimetric apparatus**, operating at up to 1200C, a **Micromeretics ASAP 2020 BET** analyser with a chemisoprtion module. Finally a **double absorption column** is also available. This consists of 2 reactor of 1 L volume each, working at ambient temperature up to 750C and from vacuum to 30 bar. The rig is equipped with a steam generation system. Typical experiments run in these equipments are Pressure, Temperature and Swing Adsorption tests.

Pag. 746



Raman spectroscope.

Magnetic suspension balance equipped with steam generation and multiple gas inlet systems.

Double 1 L absorption column.

Group C comprises a Computing unit of 60 nodes running in parallel, as well as dedicated simulation software and databases specifically developed for CO_2 separation applications. Furthermore, the lab's simulation capabilities include the implementation of the soft-SAFT equation for simulating fluids' thermochemical properties, as well as Monte Carlo simulation tools to obtain adsorption isotherms and information on the local structural arrangement of CO_2 and other compounds inside the materials. Finally, Molecular Dynamic simulations can be performed to investigate the influence of the transport properties (especially diffusion) on the overall adsorption of CO_2 both in pure form and in the presence of impurities.

State of the art

The Gas Separation Lab provides the implementation of a combined experimental-simulation approach thanks to the available pool of equipment, offering the necessary tools for a full characterization and testing of a sorbent under ***realistic*** CO_2 capture conditions.

This integrated facility allows performing applied research at relevant conditions for industrial applications as well as providing the necessary tools for fundamental research. The Lab currently supports research on novel CO_2 capture technologies, H_2 production and absorption by novel metal hydrides and research on development of carbon nanotubes for gas separation. The experimental work is complemented by using ad hoc simulation tools for modelling thermophysical properties as well as fluid-fluid and fluid-solid interactions.

The lab is physically located in the MATGAS Research Center, which houses three other state-of-the-art laboratories (high pressure, water treatment, food preservation). In particular, the high pressure lab described in TA1.2 supports research on CO_2 transportation and storage, which is complementary to CO2 capture, thereby offering research facilities for the whole CCS cycle.

Services currently offered by the infrastructure and achievements

The Gas Separation Lab is physically located in the MATGAS Research Center building, in the campus of the Autonomous University of Barcelona. The lab belongs to the three partners, Carburos Metálicos, from Air Products group, the UAB and the Spanish National Research Council; it is also open to external users depending on availability. Furthermore the Lab facilities have been employed in collaborative projects with foreign research institutions (Italy, UK, France, Germany and Portugal among others). Projects where the lab facilities have been used are:

- Synthesis and characterization of novel materials for CO_2 capture; synthesis and characterization of novel H_2 absorbents based on metal hydrides; design and commissioning of dedicated lab equipment for both CO_2 and H_2 separation (CENIT SOST-CO2 project, based on a consortium of 14 Spanish companies and 28 research institutions with a budget of 26.4 MM €).

Relevant published articles are:

Pacciani, R.; Torres, J.; Solsona, P.; Coe, C.; Quinn, R, Hufton, J.; Golden, T. and Vega, L. F. Influence of the Concentration of CO2 and SO2 on the Absorption of CO2 by a Lithium Orthosilicate-Based Absorbent. Environmental Science & Technology, 2011, 45, 7083-7088.

Builes S.; Roussel, T; Vega, L. F. Optimization of the separation of Sulfur Hexafluoride and Nitrogen by selective adsorption using Monte Carlo simulations AIChE Journal 2011 57(4), 962-974 DOI: 10.1002/aic.12312.

Llovell, F.; Valente, E.; Vilaseca, O. and Vega, L. F. Modeling Complex Associating Mixtures with [C-n-mim][Tf_2N] Ionic Liquids: Predictions from the Soft-SAFT Equation. Journal of Physical Chemistry 2011 115, 4387-4398

Builes S.; Roussel, T.; Ghimbeu, C.; Parmentier, J.; Gadiou, R.; Vix-Guterl, C. and Vega, L.F. Microporous carbon adsorbents with high CO_2 capacities for industrial applications. Physical Chemistry Chemical Physics, 2011, 13, 16063-16070

TA12.2 High Pressure Lab (Thermophysical properties and Integrity, Transport)

Description of the facilities

Laboratory including several equipments to work with gases up to 500 bars and 400 C ranging from 50 ml to 16 litres, focused mainly on $scCO_2$. The equipments available in the High Pressure Lab are (**Error! Reference source not found.**):

300 ml reactors: equipped with high pressure pump, 300 ml high pressure vessel, magnetic coupling agitator and control box (pressure, temperature and flow); able to work up to 227 bar or 400 C with a maximum flow of 1.8 Kg CO_2/h and 10 ml cosolvent/min.

Pilot plant: equipped with 4 vessels of several volumen in series, able to work in several configurations for extraction, lixiviation, precipitation and recovery of liquids and solids. It includes two high pressure pumps (40 kg CO_2/h and 16 liters cosolvents/h), magnetic coupling agitators and a liquifier to recover and reuse the CO_2. Operating pressure and temperature ranges for each vessel are: 500 bar @ 100 ºC for 16 liters and 500 bar @ 400 ºC.

SCF View Cell Thar: Variable volume (5 to 20 ml), external piston vessel, equipped with a CCD digital camera to monitor the behavior of materials exposed to CO_2 up to 410 bar and 150 C, and an impeller to homogenize operating conditions.

SCF View Cell: Equipment to analyze phase equilibrium and solubilities up to 300 bar in the temperatures range of -40 to 100ºC, 220 mm length sight glasses allow to observe the onset of precipitation or phase separation inside the reactor. The volume of vessel can be varied at constant pressure between 20 and 50 ml. Samples are homogenized by liquid phase recirculation.

SCF Mini reactor: 100 ml vessel able to work up to 200 bar and 200 C, equipped with a magnetic coupling agitator. The CO_2 is pumped by a Dual ISCO 260D pump feeding from 0.01µl to 25 ml CO_2/min.



Equipment available in the High Pressure lab: 300 ml reactor (left), pilot plant equipped with 16 litres high pressure vessel (center) and SCF View Cell Thar (Right).

State of the art

The laboratory allows the characterization of the behaviour of materials in contact with CO_2 for transport and geological sequestration applications by exposing samples (like rocks, metals and other type of materials) to the same environmental conditions (pressure and temperature). The changes on the physicochemical properties can be analyzed in the Gas Separation lab and others facilities in MATGAS. Also, phase equilibrium could be characterized determining solubilities of solid-liquid or liquid-liquid and the number of phases present at a specific pressure and temperature.

The equipments have been used in Carbon Capture and Storage (CCS) related projects for: (i) the characterization of pipeline materials for CO_2 transport; (ii) investigating the behaviour during CO_2 injection of rocks typically found in saline aquifers; (iii) employing supercritical CO_2 for applications such as extraction of natural products, degreasing, synthesis of biofuels, micronization, polymers foaming.

Services currently offered by the infrastructure and achievements

The High Pressure Lab offers a long research experience (more than 15 years) in applications of CO_2 at high pressure, near or above the critical point, and development of clean and safe technologies: in addition to MATGAS employees the lab facilities are also available to external users (currently more than 65 users are authorized to work in our laboratories). Services we offer are:

- Characterization of materials compatibility for CCS
- Characterization of rock behaviour for CO_2 sequestration (Salts precipitation, reduction on CO_2 permeability, chemical reactions, lixiviates, etc.)
- Determination of the optimal parameters and performance for high pressure CO_2 utilization
- Engineering and safety support for managing CO_2 at high pressures

Projects run in the lab include:

- Experimental characterization of $SCCO_2$ injection into storage materials located in Hontomín (Burgos), where the Geologic Sequestration Development Plant will be built. Funded by CIUDEN (Spanish Government)
- Singular studies related to the CO_2 purity definition and materials to be used for CO_2 pipelines for the Compostilla plant. Funded by ENDESA (Spanish Power Company)
- SOFC CCHP With Poly-Fuel: Operation And Maintenance (SOFCOM). Funded by UE FP7
- Sustainable Surface Technology for Multifunctional Materials (SURFACE T). Funded by UE FP6
- Supercritical Carbon Dioxide Processing Technology for biodegradable polymers targeting medical applications (PROTEC). Funded by UE FP6

Relevant published articles include:

Ana M. López-Periago, Roberta Pacciani, Carlos García-González, Lourdes F. Vega, and Concepción Domingo. A breakthrough technique for the preparation of high-yield precipitated calcium carbonate. *The Journal of Supercritical Fluids* **2010** 52(3), 298-305, doi: 10.1016/j.supflu.2009.11.014

C. Domingo, García-Carmona, J. Torres, J. Llibre, R. Rodríguez. Adsorption of low vapour pressure organic acids into amorphous and crystalline. Supercritical Fluids: Materials and Natural Products Processing 397-402 (1998) ISBN:2-905-267-28-3

Nora Ventosa; Santiago Sala; Jaume Veciana; Joaquim Torres; Juan Llibre. Depressurization of an expanded liquid organic solution (Delos): A new Procedure for obtaining submicron or micron-sized crystalline particles. Crystal Growth & Design 2001 299-303

P. López-Aranguren, J. Saurina, L.F. Vega, d and C. Domingo. Sorption of tryalkoxysilane in low-cost porous silicates using a supercritical CO2 method. Microporous and Mesoporous Materials, 2012,148, 15-24, DOI: doi:10.1016/j.micromeso.2011.06.035

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Gas Separation Lab	day	635	135	27	135	27
High Pressure Lab	day	398	135	27	135	27

Work package number	WP21-TA13	start date of event:	M6	end date of event:	M48
Work package title	Transnational access @ METU-PAL				
Activity Type					

Participant number	13																
Participant short name	METU-PAL																

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**METU-PAL PVT Analysis Lab,**
Location (town, country):	Ankara, TURKEY.
Web site address:	www.pal.metu.edu.tr
Legal name of organisation operating the infrastructure:	Middle East Technical University, Petroleum Research Center
Location of organisation (town, country):	Ankara, TURKEY.
Annual operating costs (excl. investment costs) of the infrastructure (€):	285000

Petroleum Research Center (PAL) is established in 1991. The center is a part of the Middle East Technical University in Ankara. Routine fuel quality control analyses are performed in the laboratories of the center for gasoline, diesel, biodiesel, fuel oil, LPG and natural gas (more than 3000 samples per year). PAL laboratories are accredited according to ISO 17025. PVT laboratory is fully adequate to perform gas analysis including carbon dioxide using gas chromatography. Total sulphur in the gas samples is measured by ultra violet detector. The analytical equipment as well as core displacement test systems are used for academic research as well as contracted research. PAL manages a national inter-laboratory proficiency-testing program. The participant laboratories receive twice a year gasoil, gasoline, biodiesel, fuel oil, mineral oil and LPG samples. The statistical evaluation and reporting of these schemes are performed in METU-PAL. Center is also conducting researches related to oil/ gas and geothermal reservoir evaluations as well as natural gas demand modeling. Several case studies were conducted for fields in Turkey on natural gas storage and Kızıldere geothermal and for oil fields in Azerbaijan and Kazakhstan. Recently PAL has conducted a national research project jointly with Turkish Petroleum Corporation about the assessment of the availability of Turkey's geologic CO_2 storage sites that involved reservoir-modeling studies. For reservoir modeling purposes CMG-GEM, Schlumberger-Eclipse, Schlumberger-Petrel, LBNL-ToughReact and LBNL-Tough2 software are used.

The research activities related to MSc and PhD degrees have contributed to the understanding of fundamentals of CO_2 storage in different media, such as coal, saline aquifers or depleted gas fields.

TA 13.1 METU-PAL PVT Analysis Lab (Transport and Storage of CO_2, Gas Analysis, Site Characterization)

Description of the facilities

- *In the PVT lab CO_2 composition analysis is performed using gas chromatography according to ASTM D1945 method.*
- *Total sulphur in gas samples is analysed using ultra violet detector.*
- *Fluid displacement test systems are used for academic and research studies. High-pressure cells are available for this reason. Ambient temperature is also controlled using air and fluid baths.*
- *Formation and dissociation of methane and CO_2 hydrates can be studied in PVT lab as well.*

Figure 1 Composition analysis using GC

Figure 2 Total sulphur analysis using UV detector.

State of the art

- METU-PAL is the first established fuel quality control laboratory in Turkey. It is also the first one that was accredited according to ISO 17025 standard. Research Center is the only institution that manages inter-laboratory proficiency testing schemes in between national fuel analysis laboratories. In addition to the fuel quality control analyses performed in METU-PAL, center conducts researches related to oil/gas and also geothermal reservoir evaluations.
- Completed and ongoing academic and research study topics related with CCS are well cement integrity under CO_2 storage, geochemical and geomechanical effects, multiphase flow modeling, CO_2 natural analogues and monitoring and site characterization. CO_2 storage under the deep sea sedimentary basins is another study subject conducted in the PVT laboratories.
- METU-PAL is a part of Middle East Technical University and is managed by the teaching staff of Petroleum and Natural Gas Engineering Department. This close relation of research center and the department helps METU-PAL be a vivid scientific environment. Visiting scientists are able to access department owned software and work facilities. The campus supplies all the needs related to the accommodation of the visiting scientists.

Services currently offered by the infrastructure and achievements

- More than 3000 fuel samples a year are analysed in METU-PAL requested both public and private sector. The interlaboratory proficiency-testing scheme has more than 60 participants. Every year new analytes are added. Several research projects has been completed and some are on-going including Turkey's natural gas demand assessment, evaluation of oil fields located in Azerbaijan and Kazakhstan, Kızıldere geothermal field evaluation. Due to the close ties between department and the research center, many MSc and PhD studies were performed using the center's facilities. Core displacement, PVT analysis and core tomography facilities are used to carry out these studies. Static and dynamic reservoir simulation software packages including CMG's GEM, Schlumberger's Petrel and Eclipse as well as LBNL's Tough2 and ToughReact are used for the validation of experimental and reservoir characterization studies.
- The center has been involved in the European 7^{th} Framework project named as Pan-European Coordination Action on CO_2 Geological Storage.
- Following is a list of some of the major project and thesis conducted by the research team in PAL.
- Assessment of CO_2 storage potential in Turkey, modeling and a prefeasibility study for injection into an oil field, presented in GHGT-10.
- Sayindere cap rock integrity during possible CO_2 sequestration in Turkey, presented in GHGT-10.
- The Effect of CO_2 Injection on Cap Rock Integrity (PhD thesis work)

- Modelling of Enhanced Coalbed Methane Recovery from Amasra Coalbed (PhD thesis work)
- Simulating CO_2 Sequestration in a Depleted Gas Reservoir (MSc Thesis work)
- Experimental and Numerical Investigation of Carbon Dioxide Sequestration in Deep Saline Aquifers (MSc Thesis work)
- Simulating Oil Recovery During CO_2 Sequestration Into A Mature Oil Reservoir (MSc Thesis work)
- Development of a Predictive model for Carbon Dioxide Sequestration in Deep Saline Carbonate Aquifers (MSc Thesis work)

The replacement costs for the installation of the Infrastructure (€):

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
PVT Lab	day	1 291	40	4	40	4

Pag. 753

Work package number	WP22-TA14	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@BGS				
Activity Type	SUPP				

Participant number	14															
Participant short name	BGS															

Description of the infrastructure	
Name(s) of the infrastructure(s):	BGS National Physical Properties and Processes Laboratory (NP^3L)
Location (town, country):	Keyworth, Nottingham, UK
Web site address:	www.bgs.ac.uk
Legal name of organisation operating the infrastructure:	UK Natural Environment Research Council (NERC)/British Geological Survey (BGS)
Location of organisation (town, country):	Keyworth, Nottingham, UK
Annual operating costs (excl. investment costs) of the infrastructure (€):	~€500k (excluding OHs)

BGS National Physical Properties and Processes Laboratories (Storage, Characterisation and Processes)

Description of the facility

The NP^3L is one of two centres of excellence that showcase BGS's laboratory based research, the other being the National GeoEnvironmental Laboratories (NGEL). The NP^3L undertakes research on physical properties and processes in the subsurface, with a focus on key science challenges such as radioactive waste disposal, carbon storage, clean coal technologies, groundwater and pollution modelling, and engineering hazards. The facility is comprised of a series of complementary laboratories with unique, specialist, state-of-the-art equipment and capability, and years of expertise in research relevant to CO_2 storage. The facility is part of the UK's National Capability, and receives about half of its funding for in-house research through its parent body, the Natural Environment Research Council (NERC). Other funding is secured through commissions from a wide variety of government, industry, and academic sources, including EC research grants. The BGS undertakes most of its research using its dedicated laboratory staff, but also collaborates widely with other partners and researchers across Europe and the rest of the world.

The facility welcomes the CCS research community to access its facilities via the ECRI transnational access programme. The laboratories will be open to access both individually for focussed studies on one aspect of research, or collectively for multi-disciplinary studies. Much of the research within the NP^3L is underpinned by specialist supporting expertise in sample handling, geochemical analysis and mineralogical and petrographical characterisation that is conducted within BGS's other centre of excellence, NGEL. Access will be given to facilities within the NGEL where necessary. All of the facilities accessible to researchers under ECRI are fully operational.

A more detailed description of the installations that comprise the overall facility infrastructure is given in the following sections:

Pag. 754

BGS Physical Properties Laboratories

MTS rig in the Physical Properties Laboratory

Characterisation of rock properties is an area of research that has a long history at BGS. The facility specialises in advanced geotechnical rock engineering and geomechanical testing, including measurement of strength (triaxial and uniaxial), deformability, porosity, permeability, thermal properties, geophysical properties and density. The centrepiece of this facility is a recently purchased MTS 815 rock testing system, the only installation of its type in Europe. This is a geotechnical system for determining the strength, deformation and other engineering properties of rock specimens under both unconfined and triaxially confined conditions. In addition, the system is capable of determining permeability, P&S wave velocities, thermal properties and Brazilian indirect tensile strength. The system has an operating range of up to 140 MPa and 200°C. Research in this laboratory has been used to improve the understanding of material behaviour and processes related to the mechanical and physical properties of rocks, and hence contribute to process models and performance assessment related to CO_2 storage and other applications. Recent studies have focussed on the geomechanical parameters of reservoir and cap rocks from CCS sites in Austria (Atzbach Schwanenstadt), Norway (Snovite) and Spain (Casablanca), as part of the EU funded CASTOR project.

BGS Transport Properties Research Laboratory (TPRL)

Intrinsic permeametry measurement in the TPRL

The TPRL is one of the leading centres in Europe for the study of fluid movement in ultra-low permeability media. The facility is well known within the radwaste and CO_2 sequestration sectors for long-term high quality experimental work and process-based interpretation. The main emphasis of the laboratory's output has been on multi-phase flow in ultra low permeability materials (such as reservoir seals, well bore cements and reservoir traps), and their associated hydromechanical (deformation) behaviour. Properties measured include: saturation and consolidation properties; intrinsic permeability (or transmissivity); anisotropy; specific storage; coupled flow parameters (e.g. osmotic permeability); capillary entry, breakthrough and threshold pressures; gas permeability function; drained and undrained compressibilties; and rheological (creep) properties. Laboratory experiments are performed under simulated in situ conditions of stress, pore pressure, temperature and chemical environment. Experiments are aimed at the provision of quantitative data for mathematical modelling of leakage and migration, together with an understanding of the principal transport processes. Key equipment includes: high pressure isotropic permeameters (70 MPa); high pressure triaxial permeameter (70 MPa); heavy duty shear-rigs; high temperature high pressure geochemical flow reactor (130 MPa at 140 C); and novel tracer systems (nano particle injection or radiological tagging of gas) to help identify and characterise potential leakage pathways.

BGS Hydrothermal Laboratory

Pag. 754

The 'Big Rig' reactor in the Hydrothermal Laboratory

The Hydrothermal Laboratory has over 30 years experience in the experimental study of fluid-rock reactions under conditions of temperature and pressure typical of the upper few kilometres of the Earth's crust. The facility's range of capability and expertise are unique, and it is highly regarded nationally and internationally for its research into geothermal energy and storage of radwaste and CO_2. The laboratory has undertaken CO_2-water-rock reaction studies for over 15 years, and is one of the leading centres in Europe for such experimental research. The laboratory contains a variety of equipment capable of maintaining controlled conditions of temperature (up to 400°C) and pressure (up to >500 atmospheres) for timescales of months to several years. Reactor volumes range from 1 ml to 12 litres. Studies include: investigation of pure CO_2-fluid-rock and CO_2-fluid-borehole (cement-steel interfaces) reactions occurring within the reservoir and cap rocks under in situ conditions, including kinetics of mineral dissolution in CO_2 rich fluids. Reactions are followed by various means, including: visual observations, monitoring fluid chemical changes over time, and detailed mineralogical analysis of the reaction products. Full analytical support (e.g. mineralogical and fluid chemical), is provided by other laboratories at the BGS. Various arrangements of reactors are available, and include: batch reactors, column reactors, high pressure windowed reactors for optical studies, and high pressure/temperature direct sampling batch reactors (Dickson-type autoclaves).

BGS Hydrates and Ices Laboratory

This laboratory provides temperature-controlled chambers within which relatively low temperature experiments can be carried out that can simulate processes occurring within permafrost, seafloor and deep subsurface environments. The chambers are large enough to accommodate high pressure equipment or other testing rigs, and have a range of operating conditions (-20°C to +60°C) controllable to better than 0.5°C. The facility is relevant to storage of CO_2 as a hydrate (either by design or as a secondary backup trapping mechanism) and as liquid CO_2, e.g. sub-permafrost or below the bed of deep seas. Most of the focus of the laboratory over recent years has been the investigation of how CO_2 hydrate behaves within sediments and the impact the hydrate has on the physical properties of the sediments. The research has been directed towards understanding processes that might exist if CO_2 were to be stored in cool, deep-water sediments – an alternative and somewhat novel approach to underground CO_2 storage. Indeed, although the equipment in this laboratory is relatively 'standard', it is its application to more novel underground CO_2 storage methodologies and the expertise and experience of the facility staff that make this laboratory unique.

Walk-in freezer chamber in the Hydrates and Ices Laboratory

BGS Geomicrobiology Laboratory

This is a Class 2 bio-containment facility specialising in evaluating the impacts of CO_2 injection on deep subsurface indigenous microbial populations and the effects of those organisms on the movement of CO_2, solutes and contaminants. The facility has conducted extensive research in both the UK and overseas for over 5 years, and is currently involved with several EU projects assessing the environmental issues relating to the geological storage of CO_2. The laboratory is unique in examining the impacts of CO_2 injection on deep subsurface microbial populations and the impacts of those organisms on CO_2 movement in the deep subsurface using the in-house developed Biological Flow Apparatus (BFA). It is the first research centre in Europe to be able to provide quantitative information on interactions between microbes and injected CO_2 in fractured or intact rock cores under realistic pressure and temperature conditions. In addition, the facility has extensive experience of working in the field on evaluating the environmental impacts of CO_2 on surface ecosystems, e.g. botany, followed by laboratory based microbiology, e.g. epifluorescence and microtox.

Anaerobic chamber in the Geomicrobiology Laboratory

BGS Near-Surface Gas Monitoring Facility

CO_2 measurement with a mobile open path laser system

This facility includes a wide range of state of the art equipment for field measurement and sampling of CO_2 and other gases. Capability includes innovative survey methods for CO_2 leakage detection, such as the use of mobile open path laser systems, innovative use of techniques more usually applied in different fields of study, e.g. eddy covariance and continuous flux monitors, and a capability to determine the origin of gases through examining the relationship of CO_2 to other gases and the use of carbon isotopes. The monitoring techniques available can capture data at high rates (1 Hz, 10Hz), lower rates (e.g. hourly or half hourly) or as part of data collection through one-off surveys or repeated, e.g. seasonal, observations. These techniques directly address the need to monitor large areas rapidly with sensitive equipment in order to detect and determine the extent of leakage, quantify the amount of leakage, and assess temporal variability of the gas emissions. Gas measurements are also an essential part of ecosystem impact studies, being used to define affected areas and exposure levels and to assess when recovery conditions apply. The facility has gained extensive experience in the use of these methods through their use at natural analogues sites (where natural seepage of CO_2 is taking place) in Italy, Germany and Greece and at industrial scale CO_2 storage sites such as Weyburn, Canada and In Salah, Algeria.

Selected publications

Bateman K, Rochelle CA, Lacinska A, Wagner D, Taylor H and Shaw R. 2011. CO2-porewater-rock reactions - Large-scale column experiment (Big RIG II). *Energy Procedia*, **4**, 4937-4944.

Cuss RJ, Harrington JF and Milodowski AE. 2011. Fracture transmissivity as a function of normal and shear stress: first results in Opalinus Clay. *Physics and Chemistry of the Earth* (in press).

Harrington JF, Noy DJ, Horseman ST, Birchall JD and Chadwick RA. 2009. Laboratory study of gas and water flow in the Nordland Shale, Sleipner, North Sea. In: M Grobe, JC Pashin and RL Dodge (Eds), Carbon dioxide sequestration in geological media - State of the science. *AAPG Studies in Geology*, **59**, 521– 543.

Kjøller C, Weibel R, Bateman K, Laier T, Nielsen LH, Frykman P and Springer N. 2011. Geochemical impacts of CO2 storage in saline aquifers with various mineralogy - Results from laboratory experiments and reactive geochemical modelling. *Energy Procedia*, **4**, 4724-4731.

Krüger M, West JM, Oppermann B, Dictor M-C, Frerichs J, Joulian C, Jones D, Coombs P, Green KA, Pearce J, May F and Möller I. 2009. Ecosystem effects of elevated CO_2 concentrations on microbial populations at a terrestrial CO_2 vent at Laacher See, Germany. *Energy Procedia*, **1**, 1933-1939.

Maul P, Beaubien S, Bond A, Limer L, Lombardi S, Pearce J, Thorne M and West JM. 2009. Modelling the fate of CO_2 in the near-surface environment at the Latera natural analogue site. *Energy Procedia*, **1**, 1879-1885.

Rochelle CA, Camps AP, Bateman K, Gunn D, Jackson P, Long D, Lovell MA, Milodowski AE and Rees J. 2009. Can CO_2 hydrate assist in the underground storage of carbon dioxide? In: D Long, J Rees, MA Lovell and CA Rochelle (Eds) Sediment-hosted gas hydrates: new insights on natural and synthetic systems. Geological Society Special Publication 319, 171-183.

West JM, McKinley IG, Palumbo-Roe B and Rochelle CA. 2011. Potential impact of CO_2 storage on subsurface microbial ecosystems and implication for groundwater quality. *Energy Procedia*, **4**, 3163-3170.

Contribution to EU and other major CO2 storage related projects

BGS co-ordinated the ground-breaking Joule 2 project in the mid-1990s and since then has taken a leading role in CCS research via a number of major projects. In the last two years BGS has carried out more than 50 CO_2 storage projects for a range of customers, including the EU, industry and the UK and overseas governments. Examples of recent CCS laboratory-based research projects include:

International Energy Agency (IEA) Weyburn project – researching the feasibility of long-term geological storage of CO_2 as part of an enhanced oil recovery (EOR) operation in south-eastern Saskatchewan, Canada. .

NASCENT – EC Framework 5 project led by BGS studying storage processes associated with natural accumulations of CO_2.

CASTOR (CApture to STORage) – EC project addressing issues associated with capture and sequestration of CO_2. Research involved provision of mass transport parameters for assessment of gas field sealing, evaluation of geomechanical parameters and assessment of chemical reactivity of reservoir and cap rocks.

CO2GeoNet – EC project co-ordinated by BGS. Various JRA projects including: investigation of possible mechanisms controlling gas flow in unlithified sediments; interaction of CO_2 with borehole infrastructure and host rocks; impacts of CO_2 leakage on ecosystems; and surface gas measurements.

CO2ReMoVe – an ongoing EC project dealing with monitoring and verification of CO_2 storage. BGS are involved in the development of new monitoring tools for surface gas monitoring and their testing at natural analogue sites (in conjunction with CO2GeoNet) and application at storage sites such as In Salah and Weyburn.

CRIUS – A NERC funded research project with Cambridge, Manchester and Leeds universities investigating CO_2-water-rock reactions in laboratory experiments, natural analogues and via theoretical modelling.

National capability (NERC) funded research on formation and stability of gas hydrates, and mechanisms governing movement of CO_2 through low permeability materials such as reservoir seals and well bore cements.

ECCSEL – A wide range of BGS laboratories are contributing to this EC FP7 Capacities funded European CO_2 Capture and Storage Laboratory Infrastructure consortium.

Replacement cost for the Infrastructure (€): ~3m

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
BGS NP3L	day	578	433	30	433	30

Work package number	**WP23-TA15**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@PGI-NRI**				
Activity Type	**SUPP**				

Participant number	15															
Participant short name	PGI-NRI															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**Injection field lab**
Location (town, country):	Dziwie, POLAND
Web site address:	www.pgi.gov.pl
Legal name of organisation operating the infrastructure:	Panstwowy Instytut Geologiczny - Panstwowy Instytut Badawczy
Location of organisation (town, country):	Warsaw, Poland
Annual operating costs (excl. investment costs) of the infrastructure (€):	1000000

TA15.1 Injection field lab (Laboratory: Characterization and processes, Site characterization and monitoring)

Description of the facilities
The site is located in central Poland, in a halfway between Warsaw and Poznań, Koło county. It consist of an aquifer with following characteristics:

- **Class**: Lower Jurassic sandstones (injection into Upper Pliensbachian – depth 1250-1380, Lower Toarcian caprock – depth 1140-1250 m;
- **Total depth**: 1430 m (approximate), Temperature at the aquifer top: 42-44 C, Pressure: hydrostatic
- **Effective porosity:** 18-20%, Permeability: (sandstones) 200-500 mD

The following type of measurement can be performed:

- **Laboratory measurements (samples from the injection well):** soil gas, physical and chemical properties of the drill core samples, microfauna, petrology, brine, mud and comparative fluids, cement parameters.
- **Well logging measurements**: diameter, curvature, resistivity, acoustic, density, gamma, neutron porosity, self potential, cementometer, cavernometer, gamma spectrometric, dip, induced, temperature, neutron-gamma spectrometric, magnetic resonance, dipole acoustic, ultrasonic scanner, acoustic scanner, cable RTF/MTF logs. Also time-lapse VSP and micro-frac (optional).
- **Well tests**: minifrac for the storage complex; RST – brine samples for RSA, pore pressure and approximate vertical and horizontal permeability; Johnson filter for the reservoir range (optional, depending on reservoir properties); brine probes with optional test pumping; production logging (pressures, temperature, flow),

polycyclic hydrodynamic production & interference tests.

Injection schedule: first phase, just after drilling, of total 3300 t CO_2 (~6 weeks); second phase of 10 000 – 12 000 t (continuously for year 1); third phase (year 2, full scale monitoring); total injection up to 30 000 t, two tracers are to be applied in order to investigate CO_2 migration to the research well at distance of 50 m and to exclude migration to the soil groundwater (to be investigated in shallow wells) . CO_2 will be transported in liquid phase, by trucks.

- Modeling of the injection: dynamic simulations for a model of the storage complex
- Monitoring: geophysical (microseismology, microgravity, cross-well EM & VSP 3C); geochemical (soil air composition measured by probes and in shallow wells; also chromatography and isotopic laboratory analyzes of soil air; piezometers, groundwater sample measurements, tracers' measurements), biomonitoring (microbiological, other).
- Expected start of drilling - beginning of 2012, injection - Autumn/Winter 2012

State of the art

The infrastructure refers to pilot injection into Jurassic aquifer same as in case of the first Polish demo project - Bełchatów but the site is independent, not the part of demo project. By now it was preliminary agreed cooperation with Ketzin site because results of the injection in conditions similar to these at demo site will be complementary to Ketzin achievements and experiences from existing pilot site will be valuable for operations at the new site.

•

Services currently offered by the infrastructure and achievements

Infrastructure to be built. Awaiting contract signatures of all funding parties.

The replacement costs for the installation of the Infrastructure (€):

The total cost of the infrastructure (CAPEX, OPEX for 3 years provided by domestic funding - ~17 M€)

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Pilot Injection installation	day	1 257	40	4	40	4

Work package number	WP24-TA16			start date of event:		M6			end date of event:			M48
Work package title	**Transnational access @ SINTEF ER**											
Activity Type	**SUPP**											
Participant number	16											
Participant short name	SINTEF ER											

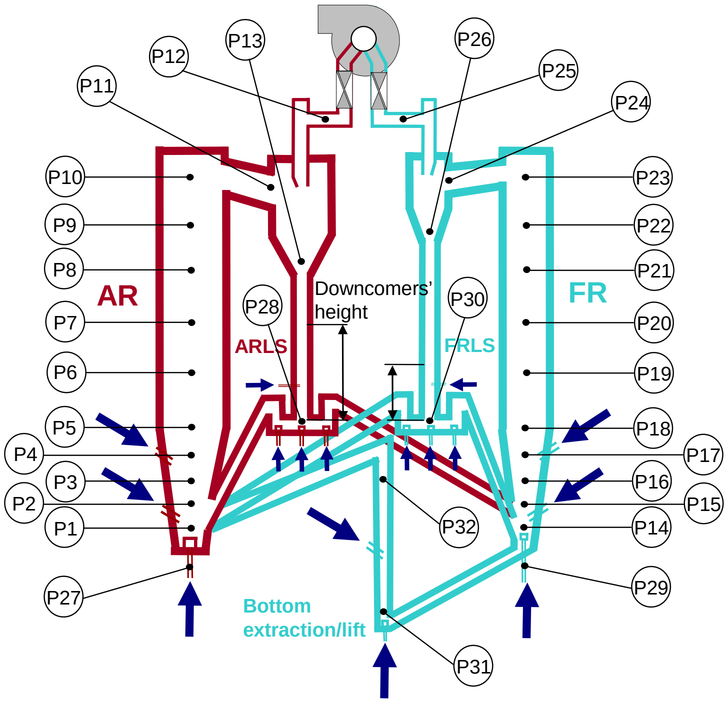
Description of the infrastructure	
Name(s) of the infrastructure(s)*:	Chemical Looping Combustion Cold Flow Model (CLC-CFM); High Pressure Oxy-Fuel Combustion Facility (HIPROX); SINTEF Combustion Lab (SCOM Lab)
Location (town, country):	Trondheim, NORWAY
Web site address:	www.sintef.no/home/SINTEF-Energy-Research/
Legal name of organisation operating the infrastructure:	SINTEF Energi AS
Location of organisation (town, country):	Trondheim. Norway
Annual operating costs (excl. investment costs) of the infrastructure (€):	27 125 (CLC-CFM) [(A+B)/4] 159 088 (HIPROX) [(A+B)/2] 109 200 (SCOM Lab) [(A+B)/4]

TA 16.1 CLC – CFM (Chemical Looping Combustion, Large-scale Cold flow Model)

Description of the facilities

The cold flow model is a transparent version in scale 1 to 1 of a 150 kW CLC rig. It consists of a Double Loop Circulating Fluidized Bed (DLCFB) reactor system made of two Circulating Fluidized Bed (CFB) reactors, Air Reactor (AR) and Fuel Reactor (FR), interconnected by divided loop-seals and a bottom extraction (lifter). The divided loop-seals give the possibility for internal recirculation within each of the CFB loops. The loop-seals are operated with fluidization only, i.e. without a cone valve. Part of the solids flow from FR to AR can be exchanged by means of the bottom connection/lifter. The air and fuel reactors have a height of 5 meters and respectively a diameter of approximately 0.25 and 0.15 meters, i.e. a rather large scale cold flow model. The rig is equipped with 36 differential pressure transmitters and 14 automatic mass flow controllers. The fluidizing gas is air. The air is fed from a compressed air network in the lab. The air flow to the reactor system is about 10000 Nl/min at maximum reactor velocities. The system is controlled through a LavView control program with a user-friendly operator interface. The solid flows are measured using high speed automatic butterfly valves in both the downcomers and visually detecting particle accumulation during a short time interval. The reactors are equipped with large flanged openings up along the height for mounting of internal panels to mimic the hydrodynamics when inserting cooling panels or other flow restrictions to create flow variations. The outgoing air after the cyclones flows to a filter unit with fine filters in order to avoid particles to the atmosphere. The filter unit is placed on an accurate scale so that particle losses from the reactors can be easily detected. The filter is equipped with a frequency controlled fan in order to control the cyclone outlet pressure, as well as a filter cleaning system.

The unit has been built equal to a designed hot CLC reactor system. (The hot unit is planned for 2013). The cold flow model has been used to validate and improve the design with respect to gas/particle hydrodynamics and solid exchange between the reactors. But the system is quite general with respect to interconnected fluidized reactor systems.



State of the art

The cold flow model is a mature facility where different kind of hydrodynamic and particle related investigations can be performed. Accurate control and measurement systems are in place. In addition there is a high standard particle lab in a neighbouring building (the Particle laboratory of NTNU and SINTEF Materials & Chemsitry) where detailed particle measurements such as PSD, density, composition and other particle properties can be analysed.

Services currently offered by the infrastructure and achievements

The facility is part of BIGCCS, a large international research centre with SINTEF Energi as host institution. The infrastructure is highly relevant to activities on "looping particle systems" related to CCS. Reference is made to the IEA Greenhouse Gas High Temperature Solid Looping Cycles Network.

Some references:

- Bischi, A.; Langørgen, Ø; Saanum, I.; Bakken, J.; Seljeskog, M.; Bysveen, M.; Morin, J. X.; Bolland, O. Design study of a 150kWth double loop circulating fluidized bed reactor system for chemical looping combustion with focus on industrial applicability and pressurization. International Journal of Greenhouse Gas Control, Volume 5, Issue 3, May 2011, Pages 467-474.
- Bischi A., Langørgen Ø., Morin J.-X., Bakken J., Ghorbaniyan M., Bysveen M., Bolland O.. Performance analysis of the cold flow model of a second generation chemical looping combustion reactor system. Energy Procedia Volume 4, 2011, Pages 449-456.
- Bischi A., Langørgen Ø., Morin J.-X., Bakken J., Ghorbaniyan M., Bysveen, M., Bolland O.. Hydrodynamic viability of chemical looping processes by means of cold flow model investigation. ICAE2011 Perugia, Italy 16-18 May 2011

The replacement costs for the installation of the Infrastructure (€): **200 000**

TA 16.2 SINTEF Combustion Lab (Capture, Combustion)

Description of the facilities

The SINTEF Combustion Laboratory (SCOM lab) is a combination of a small and a medium scale combustion rigs aimed at studying combustion and flames from burners through the measurement of combustion performance. For the small scale unit, a comprehensive network of gas distribution lines allows for study of complex gas mixtures both for the fuel or oxidiser thus avoid the need for ordering special gas mixture. Two sets of gas pre-heaters allow independent heating of mixtures up to 600 C. The burner block is exchangeable, and some burners are available at the lab: jet nozzle in co-flow and variable swirl burner (so called IFRF Moveable block burner). The measurement capabilities cover emissions of pollutants by conventional a gas analysers or FTIR, flame stability by visualization methods, thermo-acoustic instabilities study by use of microphones and PMT. The combustion chamber can be equipped with optical accesses making the use of laser diagnostics possible. Such a method offered for transnational access is for example 2D Laser Doppler Velocimetry. The infrastructure is operative, however it is planned to be upgraded for more flexibility and higher pressure capability. The upgrading is planned in 2013. At medium scale, the SINTER Combustion Lab offer a Central European Norm (CEN) boiler, where burners and fuels or mixtures can be tested at a scale of 250 kW and in real boiler conditions. The infrastructure is equipped with fuel management of gaseous, liquid oil and heavy oil fuels. Access to in-boiler measurement is possible through port holes. Probes are developd to measure heat flux and a FTIR instrument is hooked on the flue gas exhaust line.

State of the art

The gas management system of the small scale facility is composed of 11 gas lines and two pre-heaters, and therefore allows for variable composition and temperature mixtures. When coupled with the FTIR instrument, able to measure several species simultaneously, the facility is particularly well suited for combustion studies with complex gas mixtures that can be found in post, pre and oxy-fuel combustion processes. Although with somewhat flexibility on the gas management, similar capabilities are available for the 250 kW CEN boiler with an oxy-fuel oxidizers preparation unit and steam from a 800kW/15 bar steam boiler. Several patented low NOx burners have been developed and tested in the CEN boiler.

Services currently offered by the infrastructure and achievements

The infrastructure is well adapted for proof of concept, prototype testing of burner or process concept. It has been used for developing new burners; characterize stability and emission performance in unconventional gas mixtures relevant to both the power and process sectors. The infrastructure has been used in the earlier EU FP6 funded program “ENGAS RI” for 2 activities hosting international researchers and various Norwegian industrial projects. On average the infrastructure is used by 3 international users, researchers or students per year. The infrastructure has generated several confidential technical reports and publications, such as:

- Investigation on the in-flame NO reburning in turbine exhaust gas, M. Ditarantoet al. Proc. Comb. Inst. 32(2):2659-2666, 2009.
- A comparison of low-NOx burners for combustion of methane and hydrogen mixtures, G. J. Rørtveit et al., Proc. Comb. Inst. 29(1):1123-1129, 2002.
- Experimental and Numerical Investigation of NOx Emission Characteristics of Swirled Hydrogen Rich Flames, J. Ströhle et al., GHGT-8, 2006.

The replacement costs for the Infrastructure (€):250 k€ for the small scale unit and 300 k€ for the CEN boiler

TA 16.3 HIPROX (Capture, Oxy-Fuel Combustion)

Description of the facilities

The High Pressure Oxy-fuel combustion facility (HIPROX) is a pressurized combustion rig for the study of combustion in oxy-fuel atmospheres, i.e. CO2 and O2 oxidizers. The combustion chamber is particularly suited for gas turbine type combustion system, where the gas streams can be distributed between primary and dilution zones. The defined power load with methane or natural gas as fuel is 125 kW at 10 bar with pre-heating of CO2 up to 300 C at 90 g/s. The installation can also be operated with air which can be heated up to 400 C at 150 g/s. The flexibility of the installation is such as custom design burner can be adapted to the pressurized unit, allowing external users to bring a burner provided it has been followed our construction specifications and necessary approval. The fixed monitoring of the unit is composed of dynamic pressure and total pressure, heat flux probe, internal chamber wall temperature, exit gas temperature, and an averaging sampling probe that can be coupled with conventional gas analyzers or FTIR unit. In addition, four sides optical accesses around the flame zone allows for combustion radicals chemiluminescence imaging.

The infrastructure is at its “on-going start” stage and will be available to external users in the course of 2014, thus for a period of only 2 years.

State of the art

HIPROX is the possibility of using one stream of pure oxygen and 2 streams of pure CO2 at controlled mass flow and pre-heat temperature in a pressurized environment, and offers flexibility in the gas streams management. When coupled with the FTIR instrument, able to measure several species simultaneously, the facility is particularly well suited for combustion studies with gas mixtures that can be found in oxy-fuel combustion processes and able to monitor all parameters necessary for the operation of a gas turbine engine.

Services currently offered by the infrastructure and achievements

The HIPROX infrastructure offers assessment of the general combustion performance of oxy-fuel related processes, through the measurements of pollutants emissions or impurities, flame stability, thermo-acoustic instabilities, and in-chamber heat transfer. The parameters that can be easily varied are the CO2 and oxygen distribution, individual stream temperature, and the conventional combustion parameters (power, equivalence ratio).

The replacement costs for the Infrastructure (€): 1.2 M€

Implementation plan						
Short name of installation	**Unit of access**	**Unit cost (€)**	**Min. quantity of access to be provided**	**Estimated number of users**	**Estimated number of days spent at the infrastructure**	**Estimated number of projects**
CLC-CFM	day	2 501	15	3	15	3
SCOM Lab	day	2 724	40	4	40	4
HIPROX	day	8 850	10	2	10	2

Work package number	WP25-TA17	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@SINTEF PR				
Activity Type	SUPP				

Participant number	17															
Participant short name	SINTEF PR															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**Reservoir Laboratory**
Location (town, country):	NORWAY
Web site address:	www.sintef.no
Legal name of organisation operating the infrastructure:	SINTEF Petroleum Research
Location of organisation (town, country):	Trondheim, Norway
Annual operating costs (excl. investment costs) of the infrastructure (€):	400 000 Euro

The Reservoir laboratory will offer special core flooding studies and fluid studies at relevant conditions for CO_2 storage (i.e.: high pressure and high temperature, HPHT conditions). The laboratory is well equipped to cover a wide range of applications within flow processes in porous media and measurements of fluid properties relevant for CO_2 storage. The laboratory has been servicing the oil industry within research and development related to various recovery processes including CO_2 injection for enhanced oil recovery. The laboratory has been further developed to perform specific flow and fluid experiments for CO2 storage. The reservoir laboratory offers two installations for Transnational activities: Core flood (SCAL) laboratory and Fluid (pVT) laboratory.

TA 17.1 Installation no. 1: Core flood (SCAL) laboratory

Description of the facilities

The special core analysis laboratory consists of several high pressure flooding rigs. The flooding rigs are equipped to perform 2- and 3-phase floods on core samples up to a pressure of 700 bars and temperature of 160 ^{o}C with a maximum core length of 120 cm (Fig. 1). Studies may include compositional analysis of produced fluids as well as additional chemical analysis of fluids as well as characterization of the core material. There is an on-going development of in-situ measurements of fluid saturation by gamma attenuation techniques. The laboratory has access to X-ray tomography for rock characterization as well as for in-situ fluid visualization.

A special 2D visual cell has been constructed in order to perform visual flow experiments in special designed porous media at ambient conditions. Fluid flow relevant for CO2 movement (migration, segregation, accumulation) in heterogeneous porous media can be studied in this apparatus.

Numerical modelling of the core floods is usually an integrated part of experiments.

Fig. 1: Core flooding apparatus

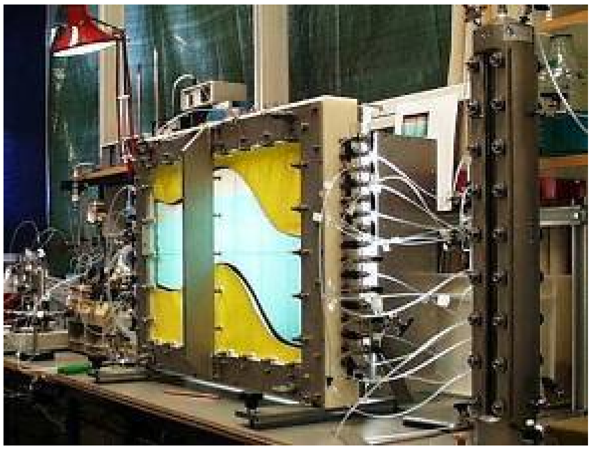


Fig. 2: 2D visual cell apparatus

State of the art

- The core laboratory has flexible set-ups of flooding rigs which may easily adapt the specific needs regarding porous medium (sand packs, core sizes, etc.) and flooding conditions (volume rates, type of fluids, fluid phases, pressure and temperature). The laboratory may also offer support for rock characterization and in-situ fluid saturation. Experiments may be performed at high pressure and high temperature conditions.
- The laboratory is doing research within multiphase flow processes in porous media. This work is mostly related to enhanced oil recovery (EOR) processes including CO_2 injection for EOR as well as studies of CO_2 flow and transport processes. There is a special interest in improvements of in-situ CO2 saturation measurement techniques to reveal new information from core flooding experiments.
- The core laboratory is working in close connection with the fluid laboratory, and most core flooding projects will need fluid analysis to be included. The core laboratory is also working in close cooperation with other SPR laboratories within rock characterization and rock mechanics. In addition, SPF is collaborating with the laboratories of Institute of Petroleum, NTNU and especially on the use of X-ray computer tomography for rock characterization and in-situ fluid saturation.

Services currently offered by the infrastructure and achievements

The laboratory offers a wide range of services and special research type of experiments. Some of the more standard type experiments and tests are listed below:

- Steady-state and un-steady state 2- and 3-phase core flooding relative permeability experiments
- Capillary pressure measurements
- Porous plate experiments
- Migration and diffusion type of experiments for fluid transport in porous media.
- Core flooding experiments for measurements of displacement efficiencies (EOR, etc.)
- In-situ fluid saturation in core flooding experiments
- Rock wettability tests and contact angle measurements

The replacement costs for the installation of the Infrastructure (€): 1 500 000

TA 17.2 Installation no. 2: Fluid (pVT) laboratory

Description of the facilities

The fluid laboratory consists of various fluid cells and apparatus for fluid studies:

- Automated pVT-cell up to 700 bars and 150 oC
- Special HPHT cells with working conditions up to 1400 bars and 210 oC
- Automated slim tube apparatus (700 bars, 150 oC)
- IFT cells (pendent drop, laser light scattering)
- Diffusion cell (temperature- and compositional gradients)
- Viscometers for HTHP conditions
- Additional fluid properties and characterization

Fig. 3: Fluid pVT equipment (working conditions: 700 bar 1nd 150 ^{o}C)

Fig. 4: Fluid cell for IFT-measurements (working conditions: 700 bars and 180 ^{o}C

State of the art

- The fluid laboratory is well equipped to perform a large range of fluid studies a realistic conditions including HPHT conditions up to 1400 bars and 210 ^{o}C. All basic fluid properties may be measured in the laboratory including preparations and recombination of fluid samples.
- The laboratory is doing research within fluid behaviour and fluid properties including miscibility studies. The work is mostly related to enhanced oil recovery (EOR) processes including CO_2 injection for EOR as well as studies of CO_2 behaviour and diffusion properties. The laboratory is also equipped for compositional analysis and various chemical analyses.
- The fluid laboratory is working in close connection with the core laboratory. The fluid laboratory is also working in close cooperation with other SPR laboratories within geochemical analysis and rock characterization and rock mechanics. In addition, SPF is collaborating with the laboratories of Institute of Petroleum, NTNU like fluid analysis and rheology.

Services currently offered by the infrastructure and achievements

The laboratory offers a wide range of services and special research type of experiments. Some of the more standard type experiments and tests are listed below:

- Preparation and recombination of fluids
- Fluid pVT studies (phase envelope, bubble point, fluid formation factor, compressibility, solution gas fluid ratio, etc.)
- Fluid properties like density, viscosity, molecular weight, composition
- Slim tube studies of miscibility
- Surface and interfacial tension measurements
- Diffusion measurements

Achievements (Paper refs.: input of relevant references)

The replacement costs for the installation of the Infrastructure (€): 1 000 000

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Core-SCAL	day	849	60	6	60	6
Fluid-pVT	day	849	60	6	60	6

Work package number	**WP26-TA18**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@SINTEF**				
Activity Type	SUPP				

Participant number	18																
Participant short name	SINTEF																

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	SINTEF MC
Location (town, country):	Oslo and Trondheim, NORWAY
Web site address:	www.sintef.no
Legal name of organisation operating the infrastructure:	Stiftelsen SINTEF
Location of organisation (town, country):	Trondheim , Norway
Annual operating costs (excl. investment costs) of the infrastructure (€):	

SINTEF MC: Two laboratories at SINTEF Materials and Chemistry, TA 1.1 located in Oslo SINTEF site and TA 1.2 located in Trondheim SINTEF site will be made available for external use. In general, the two installations consist of testing facilities for solvents, sorbents and membranes for CCS applications. In addition, parallel techniques for the preparation and characterization of solid sorbents are offered. Such experimental facilities are essential for the development of new and improved capture technologies.

TA 18.1 Sorbent and Membrane characterization and evaluation Laboratory for CCS- (**SINTEF SMLab** in Oslo)(Capture, Sorbents and Membranes)

Description of the facility

The laboratory consists of 9 different units as described below:

1. Automated atmospheric and High Pressure Thermal Gravimetric equipments (TG)
   Both TG units have automated gas feeding, switching and mixing systems (H_2, CO_2, CO, CH_4, N_2, H_2O, Ar) which enable multiple cycle sorption measurements at temperatures from ambient to 1000ºC. The High Pressure TG is placed in a laboratory with separate ventilation system which allows experiments in sulphur environment.

2. Testing units for ceramic and alloy type membranes
   A well equipped membrane permeation characterisation laboratory allows studies of permeation up to 40 bars and 600 °C (e.g. for studies of Water Gas Shift or Methane Steam Reforming). The gas mass flow and pressure controllers are regulated by a PC and the gas composition of feed and permeate is monitored continuously by MS and GC units. An advanced gas distribution infrastructure for multiple gasses (O2, H2, N2, CO, CO2, CH4, Ar, He, ...) and mixtures is installed.

3. CLC rig
   The CLC rig, handling about 3 kg of solid, is been operated as cold rig so far. The hot rig operation, 3 KW,

Pag. 770

is expected by end of 2012.

4. High Throughput material preparation and characterization
Robots are used for material preparation by various techniques (impregnation, precipitation, etc)where also solid handling is possible. A 48 samples in parallel format is used. Individual thermal treatment of 48 samples can be carried out using individual thermal treatment sequences. The solid products can be analysed in one run by a powder X-Ray diffraction unit by fast automated scanning over all 48 samples.

5. High throughput solid material testing,
8 solid can be tested in a fully automated breakthrough unit (0.4 g of each sample) working at temperatures up to 800ºC and at pressures up to 30 atm. This is a unit where external users can have their sorbent samples tested at harsh conditions in an efficient way. An automated gas feeding and mixing system (H_2, CO_2, CO, CH_4, N_2, H_2O, H_2S, misc.) is used. Effluent gas analyses are done by IR or MS.

6. Solid and liquid state NMR
For solid state NMR analyses a Bruker Avance III 500 MHz wide bore spectrometer equipped with four probes for different applications is available: Two MAS probes for solid samples, 3.2 and 4 mm. The 4 mm probe is useable up to about 300 C and has a wide tuning range covering NMR frequencies for all elements. One High Resolution probe for tissue samples, gels, and other liquid-solid dual phase samples. One flow probe for NMR studies of gases reacting with solids (in-situ). Useable up to 400 C. In addition a Bruker Avance III 400 MHz spectrometer is available for liquid samples equipped with one probe with extended tuning range.

7. Automated Breakthrough unit for sorbent evaluation
A two column breakthrough unit operating at temperatures up to m800ºC and pressures up to 30 atm with bed volume between 5 and 10 ml. The fully automated unit can perform multicycle testing. A variety of gas composition can be mixed by an automated gas feeding and mixing system (H_2, CO_2, CO, CH_4, N_2, H_2O, H_2S, misc). Effluent gas analyses are done by IR or MS.

8. In-situ powder X-Ray diffraction
A PANalytical Empyrean instrument equipped with an in situ cell can be used to get mechanistioc information on sorbnet function and possible degradation during operation. A variety of gas composition can be mixed by an automated gas feeding and mixing system (H_2, CO_2, CO, CH_4, N_2, H_2O, misc). Effluent gas analyses can be done by IR or MS.

9. Volumetric adsorption Isotherm measurement units (From vacuum to 100 bar)
A series of Belsorp instruments (Mini, Max, HP) are used to measure single component adsorption/desorption isotherms on solids with gases such as H_2, CO, CO_2, CH_4, N_2, Ar, misc over a pressure range from high vacuum to 100 atm and temperatures from -195ºC to 400ºC.



State of the art

The major part of the infrastructure contains various experimental techniques used to evaluate the performance of sorbents and membranes. All techniques offered are modern and the results obtained are expected to be of high scientific quality. The experiments can be conducted under realistic conditions at high temperatures, pressures, and under high partial pressures of steam. Also tests at sulphur environment can be carried out. The equipments are followed by skilled technicians/scientists. The choice of the right experiment/experimental conditions for a specific test can also be done in discussion with our experts.

Services currently offered by the infrastructure and achievements

We offer the above mentioned experiments to be carried out in one infrastructure. Skilled scientists and technicians are available to assist visiting partners. Also, a desk with internet access will be available during the stay.

We have in our laboratory analysed the extreme adsorption capacities that are achievable with metal-organic frameworks. We also have analysed the extremely high hydrogen fluxes that are possible to obtained using ultrathin Pd-Ag membranes (see publication list below).

The infrastructure has been central in the accomplishment of several national and international projects, and 6th and 7th FP projects such as DECARBit, CAESAR, CACHET, CACHET II, Democlock, iCap.

Some relevant recent publications:

- Egil Bakken, Paul D. Cobden, Partow Pakdel Henriksen, Silje Fosse Håkonsen, Aud I. Spjelkavik, Marit Stange, Ruth Elisabeth Stensrød, Ørnulv Vistad, Richard Blom
  "Development of CO_2 sorbents for the SEWGS process using high throughput techniques"
  Energy Procedia, **2011**, 4, 1104-1109.
- T.A. Peters, M. Stange, R. Bredesen
  - "On the high pressure performance of thin supported Pd–23%Ag membranes—Evidence of ultrahigh hydrogen flux after air treatment"
  - Journal of Membrane Science 378 (2011) 28– 34
- Pascal D. C. Dietzel, Vasileios Besikiotis and Richard Blom,
  "Application of metal–organic frameworks with coordinatively unsaturated metal sites in storage and separation of methane and carbon dioxide "
  J. Mater. Chem., **2009**, 19, 7362-7370; DOI: 10.1039/b911242a
- Pascal. D. C. Dietzel, Rune E. Johnsen, Helmer Fjellvåg, Silvia Bordiga, Elena Groppo, Sachin Chavan and Richard Blom
  "Adsorption properties and structure of CO_2 adsorbed on open coordination sites of metal-organic framework Ni_2(dhtp) from gas adsorption, IR spectroscopy and X-ray diffraction"
  Chem. Commun., **2008**, 5125-5127.

TA18.2 Lab scale absorption pilot plant (Capture, Absorption) (SINTEF AbsLab, Trondheim)

Description of the facility

The lab scale pilot plant is located at the Gløshaugen campus in Trondheim, Norway. It has been operated since 1998 for testing of new solvent and providing data for advanced process modeling. It is fully automated with continuous logging of the liquid and gas flows, the temperature profiles in the packed columns (8 probes in the absorber and 5 probes in the stripper), the CO2 concentrations in and out the absorber, the reboiler heat duty and temperatures and pressures in the pipes. The absorber has an internal diameter of 0.15 m and a packing height of 4.26 m whereas for the stripper the height and diameter are 3.89m and 0.10m. The water wash section has packing height of 2.1m and internal diameter of 0.15m. The pilot is operated continuously (24-hours) and no operator is needed present in the evenings/nights. The complete plant is run as a closed system, thus all CO2 that is absorbed is transferred back to the absorber. The laboratory is operated by SINTEF Materials and Chemistry, CO2 capture processes team and NTNU/Department of Chemical engineering.

Lab scale absorption pilot plant

State of the art

At the moment the plant is dismounted because the hall where it is located is under renovation. The facility is planned to be operational in spring 2012. In-house process models can be used to model the experimental results. The analyzing facility is very good including advanced analysis of degradation products because of a very well equipped analytical laboratory at the place (SINTEF Biolab).

Services currently offered by the infrastructure and achievements

The pilot is very well suited for testing of new promising solvents before they are tested on larger units. Estimates of energy requirement, column heights, and operational aspects of the solvent will be revealed by pilot plant as well as data for process modeling. Researchers at SINTEF and NTNU have used the pilot for many years and will give valuable experience and help in operating and interpretation of the results.

Some relevant recent publications:

- Hanna Knuutila, Ugochukwu E. Aronu, Hanne M. Kvamsdal, Actor Chikukwa. Post combustion CO2 capture with an amino acid salt. 10th International Conference on Greenhouse Gas Technologies, GHGT10, Amsterdam, The Netherlands , 19th-23rd September 2010.
- Ugochukwu E. Aronu, Hallvard F. Svendsen, Karl Anders Hoff, Hanna Knuutila, Inna Kim, Øystein Jonassen. Amine Amino Acid Salts for Carbon Dioxide Absorption. The 5th Trondheim Conference on CO2 Capture, Transport and Storage, 16-17 June, 2009, Trondheim Norway.
- Tobiesen, F.A., Juliussen, O., Svendsen, H.F. 2007. Experimental validation of a rigorous model for CO2 post combustion capture using monoethanolamine (MEA). AIChE J. 53 (4), 846-865.
- Tobiesen, F.A., Juliussen, O., Svendsen, H.F. 2008. Experimental validation of a rigorous desorber model for CO2 post-combustion capture. Chem. Eng. Sci. 63, 2541-2656.

The replacement costs for the Infrastructure (€):

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
SINTEF SMLab	day	2 090	58	10	58	10
SINTEF AbsLab	day	2 249	49	8	49	8

Work package number	**WP27-TA19**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Experimental Laboratories @ UEDIN**				
Activity Type	**SUPP**				

Participant number	19															
Participant short name	UEDIN															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	1. COFR: CO2 Flow Rig 2. GREAT: GeoReservoir Experimental Analogue Technology 3. COFP: CO2 Flow at Pore Scale Laboratory 4. FoAM: Fundamentals of adsorption and membranes Laboratory 5. AMP: Adsorption and Membranes Processes Laboratory
Location (town, country):	Scotland
Web site address:	http://www.eng.ed.ac.uk/carboncapture/ http:// www.see.ed.ac.uk/~xfan1/Xianfeng_Fan.html http://www.geos.ed.ac.uk/homes/cmcdermo
Legal name of organisation operating the infrastructure:	University of Edinburgh
Location of organisation (town, country)	Edinburgh, Scotland
Annual operating costs (excl. investment costs) of the infrastructure (€):	COFR: 31616 , GREAT: 54556 , COFP: 80488 ,FoAM: 206325 , AMP: 211200

TA 19. 1 COFR: CO2 Flow rig, Transport and Storage, Laboratory: Characterization and processes

High pressure flow through cell for multiphase experimental work on rock cores of up to 38mm in diameter and 75mm in length and is rated to 10,000psia, 90°C and suitable for CO_2 and brine being made of 316 stainless steel. The heating bands keep the temperature constant at 80°C so that in situ reservoir conditions can be recreated experimentally. The pump is designed for supercritical CO2 and all wetting parts are in 316 stainless steel or PEEK to limit corrosion. We have the possibility of creating multi-phase flow systems, accurately measuring pressure, flow rates and masspectromotery analysis of tracer behaviour. Mass spectrometer connection still pending, should be available April 2012. State of the art & Services Currently Offered and Achievements: In situ reservoir conditions of fluid flow, pressure and temperature, unique flow through fractured caprock. Publications in preparation.

Pag. 774

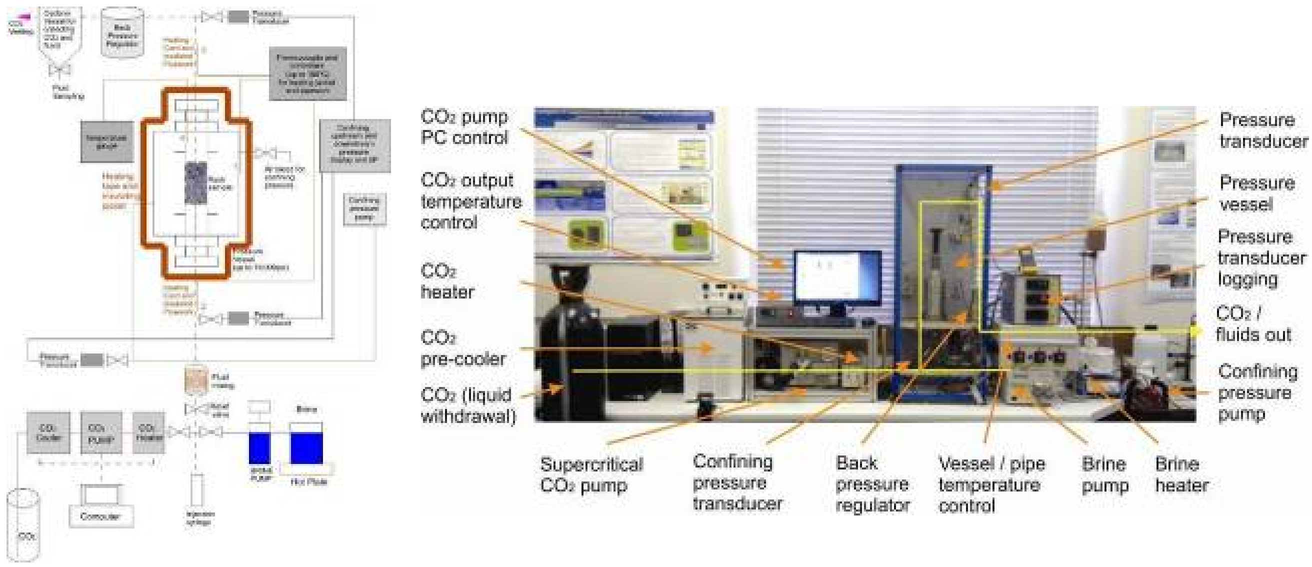


Fig 1 .COFR: CO2 Flow rig Transport and Storage, Laboratory

TA 19.2 GREAT: GeoReservoir Experimental Analogue Technology

Experimental equipment to simulate in situ reservoir conditions of true tri-axial conditions, fluid pressure, temperature, chemistry and fluid flow for the experimental investigation of coupled-reservoir processes. Effective stress of at least 80 MPa pressure, temperature at least 100°C (in situ reservoir conditions circa 3 Km deep) on samples with a diameter of 15 to 20 cm capable of containing fracture networks. Equipment under construction, and should be available by January 2013.State of the art & Services Currently Offered and Achievements: Unique in-situ conditions for large scale fractured samples**.**

TA 19.3 COFP: CO_2 Flow at Pore Scale Laboratory: Characterization and processes of CO_2 flow at pore scale

Investigation of pore wettability, the displacement of pore fluids by supercritical CO_2 and gas CO_2 at pore scale, and for investigation of the impact of mineralogy, interfacial chemistry, pore wettability, pore structure on the displacement, reservoir seal capacity, reservoir storage capacity and three-phase flow in pores and core samples under reservoir conditions.

State of the art: direct measurement of the displacement of pore fluids by CO_2, pore wettability and the impact of mineralogy, pore size, CO_2-water-mineral interfacial properties on the seal capacity of caprocks and minerals under insitu conditions. The working pressure can be upto 10,000psia. The temperature can be upto 90^0C.

TA 19.4 FoAM: Fundamentals of Adsorption and Membranes Laboratory

The adsorption and membrane fundamentals lab provides a complete characterisation of the basic properties of solid materials for carbon capture all in one place – equilibrium isotherms; heats of adsorption; diffusion in nanoporous solids; macropore diffusion in structured materials; influence of water; stability to SOx and NOx. It comprises

- Quantachrome PoreMaster 33 Mercury Porosimeter study from >950 micron to 0.0064 micron pore diameter.
- Quantachrome AutoTap and Ultrapycnometer For bulk and skeletal density measurements
- Quantachrome Autosorb-iQ-C For BET surface and volumetric adsorption isotherm system
- Setaram Sensys Evo TG/DSC For gravimetric and calorimetric measurements (equilibrium and kinetic).
- Two Zero-Length Column (ZLC) systems. Rapidly rank the capacity of adsorbents using small quantities of sample (<15 mg) and low gas consumption (image below)

Pag. 774

Pag. 775

Fig 2 . FoAm Lab

The installation has been used for several projects funded by the Engineering and Physical Sciences Research Council (UK) and the US-DOE: EP/G062129/1 – IGSCC-Innovative Gas Separations for Carbon Capture; EP/F034520/1 – Carbon Capture from Power Plant and Atmosphere; EP/I010939/1 – FOCUS – Fundamentals of Optimised Capture Using; EP/I016686/1 – Carbon Nanotubes for Carbon Capture; and DE-FC26-07NT43092 – Carbon Dioxide Removal from Flue Gas Using Microporous Metal Organic Frameworks (US-DOE). The lab will also be used for the EU funded project OFFGAS – OFFshore GAs Separations (FP7-PEOPLE-2011-IRSES, 252000 € starting in May 2012)

The achievements include several publications, a selection of which are

- Wang H., Brandani S., Lin G. and Hu X. Flowrate Correction for the Determination of Isotherms and Darken Thermodynamic Factors from Zero Length Column (ZLC) Experiments, *Adsorption*, **2011**, *17*, 687-694.
- Brandani S., Hu X., Benin A.I. and Willis R.R. *A Semi-Automated ZLC System for Rapid Screening of Adsorbents for Carbon Capture*. Fundamentals of Adsorption 10, Awaji, Japan, May 23-28, 2010.
- Brandani S., *Experimental adsorption and diffusion in nanopores*. Gordon Research Conference on Nanoporous Materials, Invited Plenary Lecture, Waterville, Maine, USA on June 15-20, 2008.
- Brandani S. On the Chromatographic Measurement of Equilibrium Isotherms Using Large Concentration Steps, *Adsorption*, **2005**, *11*, 231-235.
- Brandani F., Rouse A., Brandani S. and Ruthven D.M. Adsorption Kinetics and Dynamic Behavior of a Carbon Monolith, *Adsorption*, **2004**, *10*, 99-109.

TA 19. 4 AMP: Adsorption and Membranes Processes Laboratory

The facility consists of different apparatuses that allow the characterisation of solid materials for next generation carbon capture in dynamic conditions. These include

- Dual Piston Pressure Swing Adsorption / Vacuum Swing Adsorption System (DP-PSA)

- Quantachrome Porometer 3G zh

- Permeation Cell

- Multibed Pressure Swing Adsorption system

State of the art & Services Currently Offered and Achievements: The unique Dual-Piston apparatus allows for testing of rapid adsorption cycles up to 1.5 Hz with a single column. The system is closed and can test the performance of adsorbent materials without using large amounts of gases. The Multibed PSA can be utilised to test various cycle configurations where multi-stage pressure equalisation, light or heavy reflux, and backfill can be included. As the columns are contained in a temperature-controlled oven, the effect of temperature variance of the surroundings can be minimised and an in-situ regeneration of the columns is possible.

The Quantachrome Porometer 3Gzh is the first system of this kind installed in the UK. It can be used to test the porosity of both selective film and supports as flat membranes as well as fibres. It allows for the characterisation of the porosity both inside and outside the fibre and for the detection of defects.

The installation has been used for several projects funded by the Engineering and Physical Sciences Research Council (UK) and the US-DOE: EP/G062129/1 – IGSCC-Innovative Gas Separations for Carbon Capture; EP/F034520/1 – Carbon Capture from Power Plant and Atmosphere; EP/I010939/1 – FOCUS – Fundamentals of Optimised Capture Using; EP/I016686/1 – Carbon Nanotubes for Carbon Capture; and DE-FC26-07NT43092 – Carbon Dioxide Removal from Flue Gas Using Microporous Metal Organic Frameworks (US-DOE).

Pag. 775

The lab will also be used for the EU funded project OFFGAS – OFFshore GAs Separations (FP7-PEOPLE-2011-IRSES, 252000 € starting in May 2012)

The achievements include several publications, a selection of which are

- Ferrari, MC; Galizia, M; De Angelis, MG; Sarti, GC. Gas and Vapor Transport in Mixend. *Ind. Eng. Chem. Res.* **2010**, *49*, 11920-11935
- Fiandaca G., Fraga E.S. and Brandani S. A Multi-Objective Genetic Algorithm for the Design of Pressure Swing Adsorption, *Engineering Optimization*, **2009**, *41*, 833-854.
- Ahn H. and Brandani S. A New Numerical Method for Accurate Simulation of Fast Cyclic Adsorption Processes, *Adsorption*, **2005**, *11*, 113-122.
- Ahn H. and Brandani S. Analysis of Breakthrough Dynamics in Rectangular Channels of Arbitrary Aspect Ratio, *AIChE J.*, **2005**, *51*, 1980-1990.
- Ahn H. and Brandani S. Dynamics of Carbon Dioxide Breakthrough in a Carbon Monolith Over a Wide Concentration Range, *Adsorption*, **200**5, *11*, 473-477.

The replacement costs for the installation of the Infrastructure (€)::

COFR: 150,000, GREAT: 605,000, COFP: 80,000, FoAM: 520000, AMP: 325000, EP: 1,202,500, PoSTCap: 450,000

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CO2 Flow Rig	day	169	90	8	90	8
GeoReservoir Simulator	day	292	100	10	100	10
CO2 porescale	day	431	100	10	100	10
Membrane lab	week	4 415	15	5	75	5
AdsMembLab	week	4 520	15	5	75	5

Pag. 777

Work package number	**WP28-TA20**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational access@UNOTT**				
Activity Type	**SUPP**				

Participant number	20														
Participant short name	UNOTT														

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	1. Monitoring Infrastructure, both field and laboratory 2. Geochemical Trapping and Mineral Carbonation Infrastructure 3. Capture Infrastructure
Location (town, country):	Nottingham, UK
Web site address:	www.nottingham.ac.uk
Legal name of organisation operating the infrastructure:	University of Nottingham
Location of organisation (town, country):	Nottingham, UK
Annual operating costs (excl. investment costs) of the infrastructure (€):	

TA 20.1 ASGARD (Monitoring test facility)

Description of the facilities

Based at the University of Nottingham, ASGARD (Artificial Soil Gassing and Response Detection) (52°49’60N, 1°14’60E, 48m a.s.l.) is a specialist field facility designed to simulate such a leak so that ecosystem responses to CO_2 can be assessed under controlled conditions (figure 8). The soil at the site is a sandy loam down to ca.

60 cm where 20 cm gravel layer overlays clay. Small pipelines have been permanently installed into the field so that a controlled release of CO_2 can be injected into the soil at a depth of 60cm. Gas concentrations can be measured using permanently installed sampling tubes The field has been subdivided into different plots and a mixture of different crops, interspersed with fallow areas are planted each year. Ecosystem responses are then studied on a variety of different crops. Measurements of parameters such as gas concentrations and fluxes, isotopic signatures, soil moisture, root growth, and photosynthesis can be made. ASGARD also has the facility to photograph the roots of the plants whilst they are in the soil.

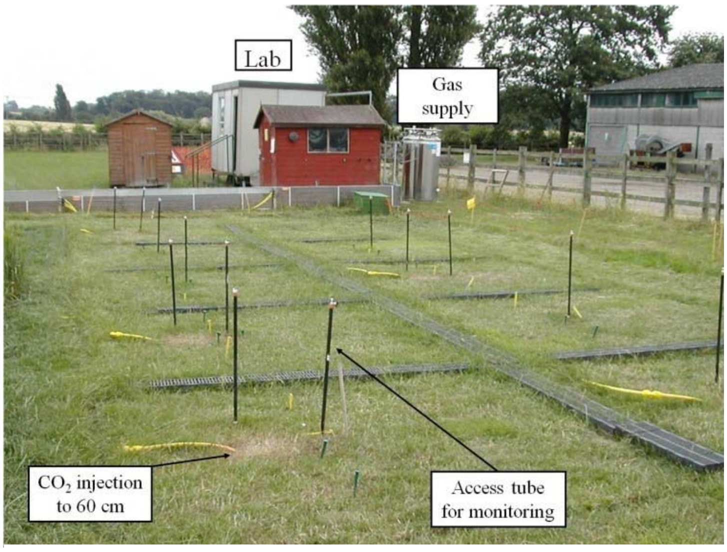


Fig 1 ASGARD testing facility

State of the art

This facility offers researchers the chance to study the real effects of CO_2 on a natural habitat. This is a field testing site rather than a controlled lab experiment. Previous research has concentrated on looking at the effects of CO_2 on different plants. The field also offers researchers to test different monitoring techniques and possible develop new sensor equipment for CO_2.

Services currently offered by the infrastructure and achievements

The facility has permanently installed pipelines to deliver CO_2 and permanently installed pipes to insert monitoring equipment of the researcher's choice. It is one of the few field test sites in the world and it is continually being updated with new equipment and more data, which will allow the researchers' to design increasing advanced experiments. The field is currently being used in the RISCS project.

Recent publications:

1. West, J.M., Pearce, J.M., Coombs, P., Forda, J.R., Scheiba, C., Colls, J.J., Smith, K.L., Steven M. 2009 The impact of controlled injection of CO_2 on the soil ecosystem and chemistry of an English lowland pasture Energy Procedia 1 (2009) 1863–1870.
2. SMITH KL, STEVEN MD AND COLLS JJ, 2005. Plant spectral responses to gas leaks and other stresses. International Journal of Remote Sensing, 26, 4067-4081.

The replacement costs for the installation of the Infrastructure (€):

TA 20.2 Apparatus for laboratory monitoring

The main effect of an increased level of CO_2 is the lowering of the pH. The resultant acidification may modify the chemistry of the environment with mobilization of potential pollutants such as heavy metals and alterations in the availability of nutrients in the sediments and soils. Pollutants may also migrate toward the groundwater reservoirs. Lab rigs have been developed to analyse these effects in a controlled and simplified environment; the results of the lab experiments are also compared with observations from a field-lab facility (ASGARD) and from the Panarea marine area (natural analogue).

Two rigs are used for simulating seepage in terrestrial environments (storage site or pipelines). The columns can be filled with soils and at the base of the column CO_2, both as gas and dissolved in water, is injected. Sensors monitor pH variations and the soil-moisture. Interstitial water and sediment samples are collected to verify the potential chemical modifications due to the presence of CO_2.

A third rig is used to simulate sub-seabed seepage. In this case the sediments occupy the first 60 cm of the column, and the upper part is filled with water. A plume of bubbles can be generated and particle imaging velocimetry (PIV) and passive acoustic techniques are applied for the study of the physical features of the plume and the interactions with the surrounding water. In both the columns the CO_2 concentration in the head-space is monitored by IR analyzers and by discrete sampling.

State of the art

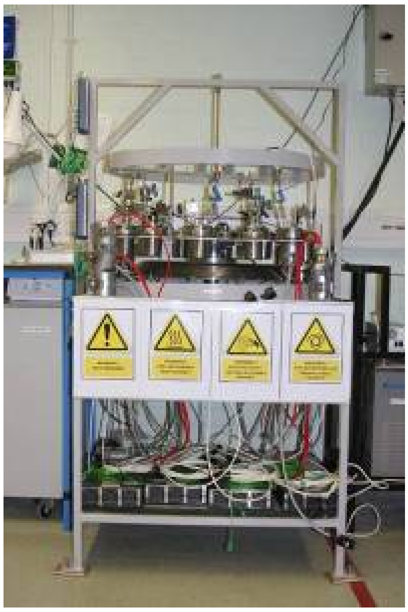
These unique rigs give researchers the opportunity to test monitoring equipment for both the terrestrial and marine environment. They are very versatile, with opportunities to look at different types of soils and sediments and compare results to field sites. They also provide the opportunity to test and develop new monitoring equipment.

Services currently offered by the infrastructure and achievements

These rigs have only recently been completed are currently being used to compare results from Panarea and ASGARD. Publications are expected soon.

TA 20.3 Geochemical Trapping and Mineral Carbonation Infrastructure

The University has 2 Parr 600ml high pressure/high temperature bench stand stirred reactors (model series 4545) with a temperature and stirrer controller (model series 4843). These reactors are used to study carbonation reactions at different temperature and pressure conditions for both underground and above-ground. Each reactor is manufactured in Alloy C276 and fitted with high torque seals magnetic stirrer drive unite in Alloy C276 and 1/8 hp variable speed electric motor. It offers working pressures to 5000psi (345 bar) at temperatures to 350 ^{o}C that can cover all the range of T/P conditions for current mineral carbonation reaction. Each reactor has an individual pressure control, individual temperature control and Integrated mixing for all vessels (shaking table). Max pressure: 200bar. Suitable for corrosive gas injection as well as mixtures



Services currently offered by the infrastructure and achievements

The reactors can be used to study carbonation reactions (both for underground mineral trapping and above ground mineral carbonation), including the assessment of the effect of impurities (such as SO_2, NO_2, and O_2) on CO_2 storage by changing the different gas cylinder for mix gases injecting. Moreover, it could be used to identify the extent of mineral carbonation reaction with corresponding reaction time by using $^{13}CO_2$ isotope.

Recent Publications:

Liu Q., and Maroto-Valer M. 2011 Parameters affecting mineral trapping of CO_2 sequestration in brines Greenhouse Gases: Science and Technology Volume 1, Issue 3, pages 211–222

Garcia, S., Rosenbauerb, R.J., Palandric, J. and Maroto- Valer, M. Experimental and simulation studies of iron oxides for geochemical fixation of CO_2-SO_2 gas mixtures. Energy Procedia 4 (2011) 5108–5113

TA 20.4. Capture Infrastructure

Description of the facilities

CO_2 adsorption and/or desorption performance is measured using a thermogravimetric analyser coupled with a mass spectrometer (TGA-MS). Studies can be conducted to determine temperature versus CO_2 adsorption tests (thermogravimetric analysis under flux of CO_2), time versus CO_2 adsorption tests (isothermal tests) and multi-cycle of CO_2 adsorption tests. To analyse the influence of the CO_2 partial pressure, also different gas mixtures of CO_2 can be employed, e.g. pure CO_2 flow and a ternary mixture of 15% CO_2, 5%O_2 and 80% N_2 that could simulate a real flue gas stream in a power station. In the thermogravimetric analysis, the weight change of the adsorbent (wt.%) was recorded to evaluate the effect of the temperature (from 25 to 120 °C at 5 °C min−1) upon adsorption capacity. In the isothermal tests the weight change (wt.%) of the adsorbent is recorded versus time. CO_2 capture steps at different temperatures can also be conducted followed by regeneration step to determine the long-term performance of the materials tested.

TGA: Thermo-gravimetric analysis (TGA) is a well-known method of quantitatively studying the loss/uptake of weight from a sample. This can be done isothermally to study weight loss during operation or with a temperature ramp. Techniques that can be used include: multiple step ramps, isothermals, auto stepwise methods, special pans (e.g. laser pierced pans for controlling volatiles). The Q500 we used is the world's selling, research-grade thermo-gravimetric analyzer. Its field-proven performance arises from a responsive low-mass furnace, ultra-sensitive thermo-balance, and efficient horizontal purge gas system (with mass flow control).

MS: Cirrusfrom MKS offers the versatility of state-of-the-art quadrupole mass spectrometry in a convenient bench-top configuration. Cirrus systems are ideal for the on-line monitoring and analysis of gases and gas mixtures including trace contaminants in process gases; solvent vapors; hydrocarbons and atmospheric and inorganic gas species. Gas compositions can be tracked over a wide dynamic range (ppb to percentage levels) with a speed of up to 250 data points per second. The heated silica capillary inlet ensures a rapid response to changes in gas composition.

State of the art

TGA-MS: Coupled together, the TGA and MS represent a powerful instrument that can be used to investigate performance of capture sorbents during the adsorption/stripping cycles and also it can be used to determine the selectivity of the investigated material on different probe molecules (e.g. CO_2, O_2, SO_2, NOx etc.).

This equipment can also be used to supprt or activites under section 2 above to quantify the amount of CO_2 sequesteredin above and under-ground processes. Moreover, the instruments can also be used to ascertain whether “impurities” such as SO_2, NOx etc. are mineralised together with the CO_2.

Services currently offered by the infrastructure and achievements

M. Olivares-Marín, T.C. Drage, M. M. Maroto-Valer, Novel lithium-based sorbents from fly ashes for CO_2 capture at high temperatures, International Journal of Greenhouse Gas Control, 2010, 4(4), 623-629

M. Olivares-Marín, M.M. Maroto-Valer. Preparation of a highly microporous carbon from a carpet material and its application as CO_2 sorbent. Fuel Processing and Technology, 2010, 92, 3, 322-329

M. Olivares-Marín, S. García, C. Pevida, M.S. Wong, M. M. Maroto-Valer, CO2 capture capacity of carpet waste-based sorbents, Journal of Environmental Management, 2011, 92 (10), 2810-2817

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Monitoring field	day	350	30	6	30	6
Monitoring lab	day	300	30	6	30	6
Geomechanical trapping and mineral carbonation	day	450	35	6	35	6
Capture Infrastructure	day	125	30	6	30	6

Work package number	**WP29-TA21**	**start date of event:**	**M6**	**end date of event:**	**M48**
Work package title	**Transnational Access @ TUV**				
Activity Type	**SUPP**				

Participant number	21															
Participant short name	TUV															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	**100-150kW Chemical Looping Pilot Plant (CLPP150)**
Location (town, country):	Vienna, AUSTRIA
Web site address:	www.chemical-looping.at, www.vt.tuwien.ac.at
Legal name of organisation operating the infrastructure:	Vienna University of Technology Institute of Chemical Engineering
Location of organisation (town, country):	Vienna, AUSTRIA
Annual operating costs (excl. investment costs) of the infrastructure (€):	371670

TA 21.1 CLPP150 (Energy conversion systems, Chemical Looping)

Description of the facilities

General description:

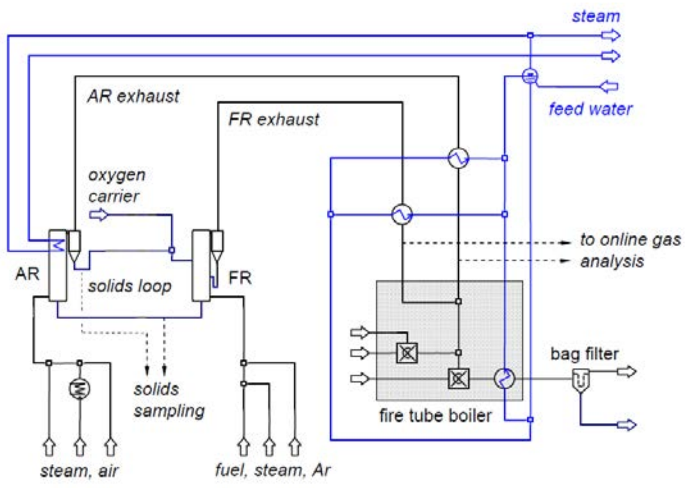
The 120-200 kW dual circulating fluidized bed, pilot plant at Vienna University of Technology is the worldwide largest, currently operating facility for experiments in the field of chemical looping technologies. It was designed to feature chemical looping combustion as well as chemical looping reforming operation with utilization of gaseous fuels. In Figure 1 a sketch of the pilot plant (a), an overview of the pilot plant arrangement (b) as well as a photograph of the upward view of the non-insulated pilot plant (c), are shown. The pilot plant design is optimized in terms of gas-solids contact, overall solids inventory and solids circulation rate, whereby particular emphasis was placed on the scale-up potential of the reactor configuration.

Pilot plant arrangement and instrumentation:

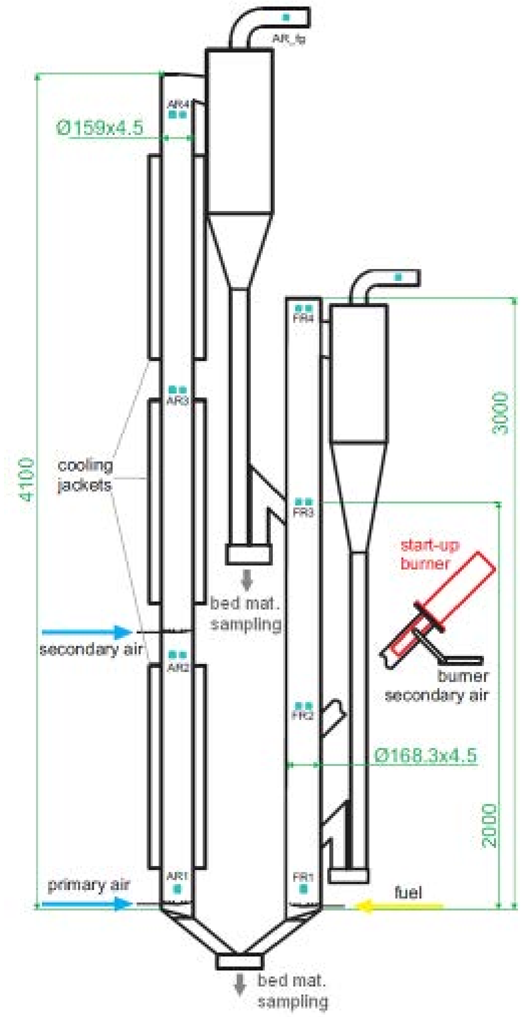
A natural gas driven start-up burner together with an electric air-preheater are usually operated to reduce starting procedure to about 4 hours. The system is equipped with 30 online measurement points for temperature and pressure. Operation and monitoring of data points is performed by computer-integrated process control. The system temperature can be controlled via three air/steam cooled jackets attached to the air-reactor. Measurement of reactor pressure profiles allows online determination of the actual solids inventory. Although the pilot rig is designed for natural gas (98,7 vol% CH_4), the fuel reactor can also be operated with mixtures of CO, CO_2, H_2 and C_3H_8. The measurement and flow rate control of fuel gases is performed by rotary instruments (Elster Instroment RVG). The exhaust gas streams of both reactors are analyzed to evaluate the fuel conversion efficiency and possible gas leakages through the loop seals connecting both reactors. The fuel reactor exhaust gas is analyzed within a Rosemount NGA 2000 for determination of CO- (0-100%), CO_2- (0-100%), O_2- (0-25%), H_2- (0-100%), CH_4- (0-100%) concentrations. In addition a Syntech Spectras GC 955 online gas chromatograph for N_2 measurements and cross-checking of carbon species is used.

Pag. 782

•

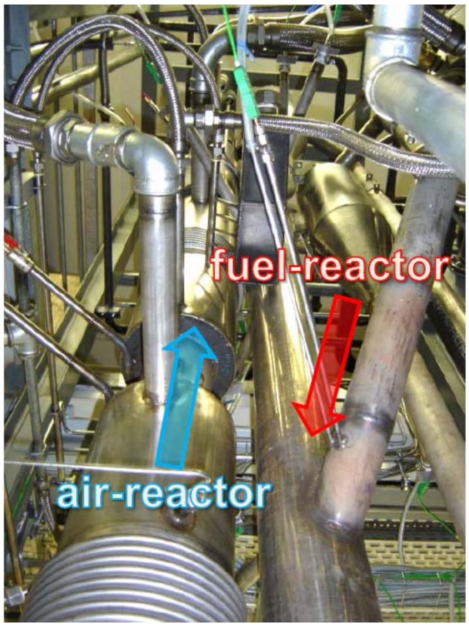


• (b)



• (a)

•



• (c)

• Figure 1- Chemical looping pilot plant at Vienna University of Technology

The air reactor exhaust gas stream is analyzed using a Rosemount NGA 2000, determining gas fractions of CO (0-100%), CO_2 (0-100%) and O_2 (0-25%). Downstream to the gas analysis units the exhaust gases are sent into a post-combustion unit. After passing a bag filter they are released into a chimney. One uniqueness and great advantage of the present pilot rig is that it allows simultaneous online measurement of exhaust gas concentrations together with bed material sampling from the loop seals. Therefore determination of particle oxidation state for each operating point is possible. This allows calculation of the overall solids circulation rate for accurate interpretation of experimental results.

Preparation of data:

Experimental data are recorded and afterwards evaluated within a mass and energy based process model implemented in a process simulation software. Each operating point is determined within a time range of about 30min under steady-state operation. The mean values during a steady state operation period of 10-20 minutes constitute the data base for evaluation of the operating point. Data reconciliation methods are used in combination with the mass and energy balance requirements. Thus, a consistent data set is available for each operating point which represents the true values operated best in statistical terms.

Results from experimental campaigns:

The analyzed data sets are usually documented within a standard report, including measurement point conditions (fluidization velocities, pressure profile, gas composition in reactor inlets, ...) , oxygen carrier oxidation states (neccessary for determination of solids circulation rate) and exhaust gas compositions.

Pag. 782

Pag. 783

State of the art

The 120-150 kW pilot plant in Vienna is the largest successfully operating facility for chemical looping combustion and chemical looping reforming. Since the erection of the plant, several experiments designated to process demonstration, oxygen carrier performance, fuel type influence, operating temperature influence and so forth have been conducted. Therefore, the staff working at Vienna University of Technology has large experience in plant operation as well as in evaluation of experimental data (see references below, more publications available at www.chemical-looping.at).

Future test campaigns

The development of oxygen carrier materials for chemical looping combustion and reforming has not yet come to fully satisfactory conclusions. The main requirements to be met are (i) high reactivity in the fuel reactor, (ii) high stability against attrition and fragmentation, (iii) no agglomeration in fluidized beds, (iv) environmental and safety risks, (v) cost of production, and (vi) access to the necessary raw materials. It is expected that new oxygen carrier candidates will be developed during the next years and testing at relevant operating conditions will be necessary to assess the application potential of these materials in full scale chemical looping. In this area, the need for sharing the pilot plant infrastructure is expected.

Further experiments may be conducted for example to investigate:

- Performance of novel oxygen carriers (reactivity, deactivation, attrition, …)
- Influence of sulphur components (including slight adaption of measurement equipment)
- Influence of higher hydrocarbons (including evaporated tar substances)
- Chemical looping combustion of liquid fuels
- Chemical looping reforming (CLR)
  -

List of CCS related EU/national funded projects where the infrastructure was developed or used

- ***GRACE (EU/FP6)*, CCCC (EU/RFCS) .**
- **CLC GAS POWER (EU/FP6)**
- **CACHET (EU/FP6)**
- **UNIQUE (EU/FP7)**
- **G-volution (Austrian Climate and Energy Fund)**
- **INNOCUOUS (EU/FP7)**

Achievements (original contributions to knowledge based on the infrastructure)

- Original modelling of chemical looping combustion by combining air reactor and fuel reactor
  - Prediction of the dynamic equilibrium governing the mean degree of oxidation of the oxygen carrier
- Development of the dual circulating fluidized bed (DCFB) design approach combining two circulating fluidized bed reactors in a novel way
  - High global solids circulation rates
  - Improved gas-solids contact for lower specific solids inventories
  - Stable solids distribution between air reactor and fuel reactor
  - Improved scalability avoiding bubbling bed reactors
- Successful construction and operation of the chemical looping pilot plant, the largest with successful operating data presented so far

Pag. 783

- High fuel conversion in CLC at reasonable specific oxygen carrier inventories
- Demonstration of CLR with full CH_4 conversion in the fuel reactor and quantitative oxygen removal from the air stream in the air reactor

Bibliography

- Pröll, T., Kolbitsch, P., Bolhàr-Nordenkampf J., Hofbauer, H., 2009, *"A novel dual circulating fluidized bed (DCFB) system for chemical looping processes"*, AIChE Journal, 55 (12), 3255-3266.
- Kolbitsch, P., Pröll, T., Hofbauer H., 2009, *"Modeling of a 120kW chemical looping combustion reactor system using a NiO oxygen carrier"*, Chemical Engineering Science, 64 (1), 99-108.
- Kolbitsch, P., Pröll, T., Bolhàr-Nordenkampf, J., Hofbauer, H., 2009, *"Design of a Chemical Looping Combustor using a Dual Circulating Fluidized Bed Reactor System"*, Chemical Engineering and Technology, 32(3), 398-403.
- Kolbitsch, P., Pröll, T., Bolhàr-Nordenkampf, J., Hofbauer, H., 2009, *"Characterization of chemical looping pilot plant performance via experimental determination of solids conversion"*, Energy and Fuels, 23(3), 1450–1455.
- Pröll, T., Bolhàr-Nordenkampf, J., Kolbitsch, P., Hofbauer, H., 2010, *"Syngas and a separate nitrogen/argon stream via chemical looping reforming – A 140 kW pilot plant study"*, Fuel 89, 1249-1256.
- Kolbitsch, P., Bolhàr-Nordenkampf J., Pröll, T., Hofbauer, H., 2010, *"Operating experience with chemical looping combustion in a 120kW dual circulating fluidized bed (DCFB) unit"*, International Journal of Greenhouse Gas Control, 4 (2), 180-185.

The replacement costs for the installation of the Infrastructure (€): 950 000 €

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
CLPP150	week	77 024	2	2	10	1

Work package number	WP30-TA23	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@UniRoma1				
Activity Type	SUPP				

Participant number	23															
Participant short name	UniRoma1															

Description of the infrastructure	
Name(s) of the infrastructure(s)*:	Terrestrial and marine natural field laboratories – access and support
Location (town, country):	ITALY
Web site address:	www.uniroma1.it
Legal name of organisation operating the infrastructure:	Università di Roma "La Sapienza"
Location of organisation (town, country):	Rome, Italy
Annual operating costs (excl. investment costs) of the infrastructure (€):	75000

Sites where natural CO_2 is produced can be studied to make geological CO_2 storage sites safer. As some of these sites store the CO_2 in deep geological strata, they can be studied to understand what conditions permit long-term underground isolation. As some of these sites leak, these locations can, instead, be used to understand leakage mechanisms, migration pathways and travel times, chemical reactions, potential impacts of leakage on groundwater and ecosystem, and to test and improve techniques for monitoring and early warning. Most researchers do not have access, however, to these "natural" laboratories because these sites are concentrated in specific regions where the geology and tectonics are presently active. One such area is central Italy, where a large number of cutting edge CCS research projects (NASCENT, CO2GeoNet, CO2ReMoVe, RISCS, ECO2) have been conducted. Due to this work a strong scientific foundation exists for these sites on which new CCS research projects could be built.

The present work package consists of access to this natural laboratory infrastructure and logistical / scientific support for the associated CCS research. The various installations making up this infrastructure consist of individual sites, each having a unique geological, structural, hydrogeological setting. This variability allows for results to be extended beyond the confines of a single locale, and thus to develop generalised approaches / methods / results that can be applied to real-world CCS sites in different geological settings throughout Europe. Services offered include site access, logistical support, geological knowledge, access to historical and present-day site data, training facilities, and geochemical analysis equipment from UniRoma1, as well as the remote sensing, geophysics, biological, and oceanographic installations offered by OGS in WP19-TA11

TA 23.1 Field laboratories and support (Storage, Site characterization and monitoring / safety)

Description of the facilities – Field laboratories

The chosen natural laboratories provide the opportunity to study gas migration in different structural and geological settings. In general, Italy can be divided into two main stress domains. The area to the east is dominated by compression and hosts the main Italian oil and gas reservoirs; to the west the stress regime is extensional and is geologically active with volcanoes, high seismicity, and both non-leaking and leaking CO_2 caused by mantle degassing and thermo-metamorphic reactions. The chosen natural laboratories include both terrestrial (Latera, San Vittorino, Vasto/Maiella, Pecore, Fucino) and marine (Panarea) sites.

The Latera caldera, within the western extensional regime, is an agricultural valley about 60 km from Rome where naturally-produced CO_2 is leaking to the atmosphere. This extinct volcano has a high geothermal gradient which forms CO_2 via thermo-metamorphic reactions in carbonate rocks. This gas migrates along faults to the surface where it is released from gas vents. The site is unique because of the large data-set describing the deep subsurface (from geothermal exploration) and CO_2 leakage to the atmosphere (from various EC projects). The site has been studied for site characterisation, to understand the link between gas migration and faults, to test geophysical, geochemical, biological, and remote sensing methods for CCS leakage monitoring, and to study potential ecosystem impacts of leakage (Fig. 1a).


a) b) c)

Figure 1. Photos of a gas vent at Latera that impacts vegetation (a), a sinkhole at San Vittorino (b), and gas bubble leakage at Panarea (c).

The San Vittorino plain, located about 75 km from Rome, is an intermountain basin filled with up to 170 m of fluvial-lacustrine sediments, surrounded by peaks of carbonate and foredeep sediments, and cut by several regional faults. Large volumes of CO_2 migrate along these faults and are released at surface both from gas vents and bubbling mineralised springs, which are often associated with sinkholes (Fig. 1b) that were likely formed by CO_2-acidified ground waters. This site has been examined using various geophysical and geochemical tools and is particularly well adapted for the study of gas migration in plastic sediments and the potential impact of CO_2 on groundwater quality.

The Vasto natural gas field, located about 150 km from Rome in the Adriatic foredeep, is an example of a micro-leaking site where deep gas leakage to the atmosphere can only be defined using sensitive analytical equipment. About 100 small hydrocarbon fields have been discovered in this area since 1950, in what is primarily an over-pressured, gas prone province. Soil gas surveys in the area prior to, and 17 years after, major exploitation of one reservoir showed a decrease from high to low soil-gas helium values, implying that reservoir de-pressurising caused by hydrocarbon extraction resulted in reduced gas leakage. The outcropping carbonate rocks of the Maiella mountain to the west can be considered analogous of the buried hydrocarbon reservoirs, thus they can also be studied for structural, fluid migration, and fluid-rock reactivity purposes.

The Piano di Pecore (180 km from Rome) and Fucino Basin (90 km from Rome) are intramountain basins located in the Apennine chain that are seismically active, with the former being affected by the large 1980 Irpinia earthquake and the latter by the 1915 Avezzano earthquake. The geometry of soil-gas anomalies at the surface reflects the different gas-bearing properties of the seismogenetic versus the shallow-buried faults, with radon highlighting brittle fracture zones while helium defines better buried faults covered by surface sediments. Temporal variations related to seismic activity have also been observed at both sites.

The only marine natural laboratory is located near the island of Panarea (Aeolian Islands), where natural, thermo-magmatic CO_2 is leaking at substantial rates from the seafloor (Fig. 1c) at water depths ranging from 5 to 30 m. This natural CO_2-release field has been active for centuries, with gas emanating from a series of NW-SE and NE-SW trending fractures. In the early 1980's researchers began to conduct gas geochemistry surveys of the area, showing that the system was relatively stable in both gas chemistry (e.g. 98% CO_2, 1.7% H_2S plus trace gases) and flux rates. This site has been studied to better understand the potential impact of a CO_2 leak on water chemistry and biology, and to test marine leakage monitoring methods.

Description of the facilities – Support

The Department of Earth Sciences at the Università di Roma "La Sapienza" has conducted research at the described sites for many years, and will use this knowledge and experience to support researchers wishing to conduct research at the natural laboratory sites. To begin with, classrooms and meeting rooms will be made available for training purposes prior to leaving for the field. This could involve informative meetings to describe the sites to be visited, or could involve the teaching of methods for best practice, consultancy, and training courses. Various laboratories within the department will also be made available, including an aqueous chemistry lab equipped with ion chromatographs and an ICPMS, a gas chemistry lab equipped with various gas chromatographs, and a geotechnical laboratory for petrophysical testing. Innovative CO_2 monitoring probes and stations have been developed by UniRoma1, and are presently deployed at a number of the natural laboratory sites; these units, and others if required, will be made available to the researchers for real-time, continuous monitoring of CO_2 in the groundwater, the soil, or the atmosphere. A mobile laboratory can be used by the visiting scientists to conduct measurements or experiments; this vehicle is equipped with a diesel power generator and there is space to mount various laboratory instruments that can be provided by UniRoma1 (e.g. GC, IC, He spectrometer, etc.) or by the visiting researchers. Access will be provided during the summer months to avoid problems and difficulties related to the weather and to avoid overlap with courses taught at the university.

State of the art

Cutting edge research conducted at these sites has included testing of novel monitoring and site assessment technologies (remote sensing, open-path infrared lasers, soil gas and flux, seismic, GPR, EM, hydroacoustics, etc.), examination of potential impacts of leaking CO_2 in the near surface environment (botany, microbiology, mineralogy, groundwater chemistry, surface water chemistry, etc.), and the study the migration of gas along faults and fracture networks (field measurements, modelling with COMSOL and PETREL, etc.). Much of this work is published, and there has been extensive interest in the results due to the need for concrete "real-world" data.

This type of data, compared to that obtained in laboratory experiments or via computer modelling, is a much more realistic representation of natural geological complexities, of large spatial and temporal scales, of interacting site parameters, etc. In addition, as the CO_2 has been leaking for hundreds of years, and will continue to leak at the same rate for the foreseeable future, site experiments can be conducted for extended periods of time without being concerned with environmental permissions, permits, and CO_2 costs that would be associated with a man-made CO_2 leakage experiment.

Each site is unique, and provides characteristics that will allow for a very wide range of studies. Latera exhibits gas vents that appear to be aligned along fault structures, with channelled gas migration and spatially variable flow caused by different fracture-zone morphologies. Outcrops of faults allow for study of mineralogy related to gas-induced alterations and shear mechanical activity related to gas permeability, while a wide variety of vegetation allow for ecosystem impact studies. San Vittorino has gas leakage through plastic sediments, along intersecting fault systems, with the formation of sinkholes and the alteration of groundwater quality in correspondence with the CO_2 leaks. The presence of trace gases associated with the CO_2 can also be studied in terms of CO_2 stream impurities. Vasto is an area of hydrocarbon reservoirs where slow gas microseepage appears to have occurred in correspondence with seismically-defined faults, but where exploitation of these units appear to have affected gas migration towards the surface via a change in subsurface pressure conditions. At the outcropping analogue of the Vasto reservoir, at Maiella mountain, the reservoir and cover rocks can be sampled in the field for petrophysical studies (porosity, permeability, Young module, etc.). The Piano di Pecore and Fucino Basins are seismically active areas where gas migration has been shown to have a temporal variability due to movement along the structure, and where various gas species have given different types of information for the different fault styles. Finally, the Panarea site can be studied for the impact of CO_2 on surface water bodies, for testing sea and sub-sea monitoring technologies, and for examining the fate of released CO_2 and its eventual transfer to the atmosphere.

Besides studies addressing the types of issues given above, opening areas of research that could also be applied at these sites include new monitoring techniques, the study of impurities associated with injected CO_2, impact on different biological species, more detailed and realistic modelling of gas migration processes in reservoir rocks and overlying stratigraphy, secondary storage in aquifers, the vadose zone, and water water bodies, risk assessment, and public perception, to name just a few.

Services currently offered by the infrastructure and achievements

The services offered include logistical support (e.g. land access and permits, translation, transportation, finding accommodations, etc.), access to each site's historical data set (gas leakage locations and rates, geology, structure, chemistry, hydrogeology, etc.), and access to geochemical/geophysical monitoring data collected during the study via instrumentation already installed on site. In addition this can also be integrated with the other infrastructure offered by UniRoma1 described above (training facilities, mobile and laboratory geochemical analyses) and by OGS described in WP19-TA11 (geophysics, remote sensing, and biological / oceanographic monitoring). All the proposed terrestrial sites are centred within a range of between 100-200 km of the Department of Earth Sciences facilities at the University of Rome, whereas the marine site is located at a greater distance in the south of Italy off the coast of Sicily. It is expected that there will be significant interest in the use of these sites by European and international users based on the large number of researchers that have conducted "hands-on" research at the sites, which has been estimated to more than 50 people from across Europe over the last 5 years.

Regarding EU-funded CCS projects, the sites of Latera and San Vittorino have been used in NASCENT, CO2GeoNet, and RISCS, while Panarea has been used in CO2GeoNet, CO2Remove, RISCS, and ECO2. The other sites have been studied in national research initiatives, not always focused on CCS.

Achievements (include the most relevant scientific publications, up to 5)

- E. Pettinelli, S.E. Beaubien, A. Zaja, A. Menghini, N. Praticelli, E. Mattei, A. Di Matteo, A. Annunziatellis, G. Ciotoli and S. Lombardi, 2010. Characterization of a CO2 gas vent using various geophysical and geochemical methods. Geophysics, 75(3): B137-B146.
- B.I. Oppermann, W. Michaelis, M. Blumenberg, J. Frerichs, H.M. Schulz, A. Schippers, S.E. Beaubien and M. Kruger, 2010. Soil microbial comuity changes as a result of long-term exposure to a natural CO2 vent. Geochimica et Cosmochimica Acta, 74: 2697-2716.
- S. Lombardi, A. Annunziatellis, S.E. Beaubien and G. Ciotoli, 2009. The study of CO2 natural reservoirs to develop criteria for risk assessment and safety strategy. First Break, 27: 61-70.
- C. De Vittor, P. Del Negro, A. Paoli, C. Falconi, M. Celussi, B. Cataletto, C. Comici, C. Fabbro, K. A., G. Caramanna and S. Lombardi, 2008. Field experiment to evaluate impacts of pH decrease on marine microbial assemblage, EAGE CO2 Geological Storage Workshop, Budapest Hungary.
- A. Annunziatellis, S.E. Beaubien, S. Bigi, G. Ciotoli, M. Coltella and S. Lombardi, 2008. Gas migration along fault systems and through the vadose zone in the Latera caldera (central Italy): Implications for CO2 geological storage. Int. J. Greenhouse Gas Control, 2/3: 353-372.

The replacement costs for the installation of the Infrastructure (€): Not Applicable

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
Natural field laboratories	day	896	70	7	70	7

Work package number	WP31-TA23	start date of event:	M6	end date of event:	M48
Work package title	Transnational access@USTUTT				
Activity Type	SUPP				

Participant number	23															
Participant short name	USTUTT															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	**KSVA, BTS**
Location (town, country):	GERMANY
Web site address:	www.ifk.uni-stuttgart.de
Legal name of organisation operating the infrastructure:	Universität Stuttgart
Location of organisation (town, country):	Vaihingen, Stuttgart, Germany
Annual operating costs (excl. investment costs) of the infrastructure (€):	approx. 1.4 Mio €

TA23.1 Pilot scale 0.5 MWth combustion facility - KSVA (Energy Conversion Systems, Combustion)

Description of the facilities

The scheme shown in **Figure 1** depicts the KSVA in oxy-fuel configuration, which essentially simulates the flue gas side of a power plant in small scale including a flue-gas cleaning path with a high-dust SCR catalyst, an electrostatic precipitator (ESP) and a baghouse filter. Combustion air or recirculated flue gas is provided by a forced draught (FD) fan, an induced draught (ID) fan ensures the transport of the flue-gases through the flue-gas system towards the stack. Modifications essential for oxy-fuel operation are described in the following.

The combustion chamber consists of six cylindrical segments with a total length of 7,060 mm and an inner diameter of 800 mm.

The combustion chamber is covered with a burner plate of 1,400 mm in diameter. In the center the burner is installed.

Refractory lining covers the inner surface of the upper four segments of the combustion chamber to a distance of 4,000 mm from the burner. A water jacket is integrated into the double-wall of the reactor. Numerous measurement openings are integrated into the reactor wall with distances between each level of 150 to 170 mm. In several segments there are up to three ports per level, shifted by 90° one to another. Flame detectors are installed with inclined view to the combustion flame core. Either air or CO_2 is used for cooling of the detectors, depending on the applied combustion modes: conventional or oxy-fuel.

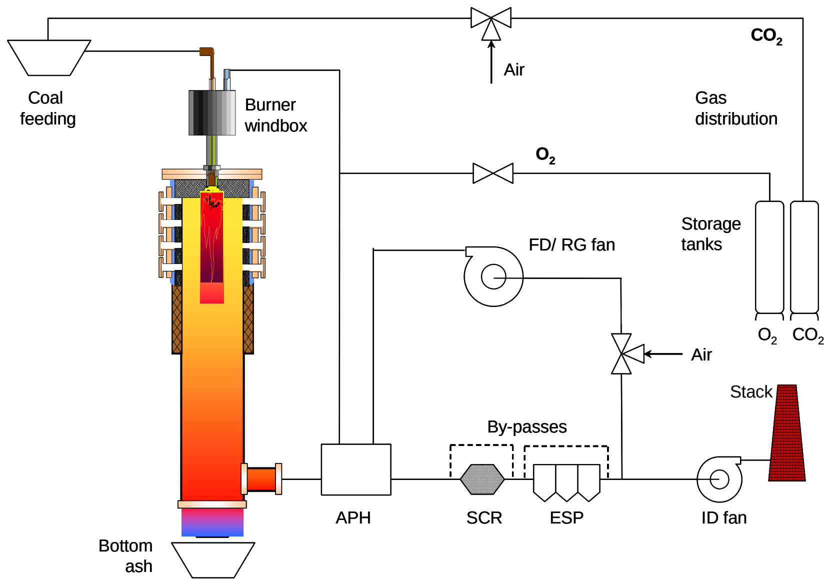


Figure 1. Scheme of 500 kWth test facility (KSVA)

State of the art

Advantages/Special Features:

- Fuel flexibility: due to different dosing systems, it is possible to fire different solid fuel or blends.
- Flue gas recirculation
- Modular Flue Gas Cleaning (FGC) system: ESP, DeNOx (SCR), Fabric Filters and possibility to introduce Flue Gas Desulphurization (FGD) unit.
- The combustor is equipped with a flexible char and gas sampling system and in addition with a flexible overfire air/oxidant injection system. Both enable the performance of combustion tests over a broad residence time (1s-5s) and stoechiometrie (air ratio 0.7-1.3) range. Stage or unstaged combustion tests can be carried out.
- Furthermore, material testing with corrosion probes can be performed.

Areas of research:

High efficiency and CO_2-free combustion processes, co-combustion of biomass/RDF in coal-fired power plants, optimization of burner setup and burner parameters, HCl, SOx behaviour, NOx reduction, slagging/fouling processes, high and low temperature corrosion, performance of FGC system (e.g. ESP, DeNOx, etc.), fly ash characterization. *Future areas:* biomass co-combustion in oxy-fuel

Scientific environment:

This test facility is one of several pilot test installations available at IFK and is surrounded by a very complete infrastructure. For instance, fuel pre-treatment facilities and several continuous flue gas analyzers are readily available. Also, a well equipped laboratory for fuels, ashes and slag characterisation operates at IFK. Additionally, other useful techniques for characterization of different solid samples (e.g. fuel, fly ash, etc.), such as XRD and SEM, are available at other institutes within the University. Furthermore, the facility is operated by experienced scientists and technicians and is equipped with state-of-the-art measurement equipment. Within several years of successful operation, it has proved to deliver high quality reliable results. This allows for the comparison of newly gained data against the experiences collected at IFK within the previous years and provides a possibility for better interpretation of data.

Services currently offered by the infrastructure and achievements

Every year up to 10 different projects (EU, national or industrial projects) make use of this facility. For instance, some ongoing EU-Projects at KSVA are RECOMBIO, DEBCO and Flox Coal. Specifically, some recent CCS related EU funded projects, where the infrastructure was used, are ENCAP, OxyCorr, Oxyburner and Oxymod. Besides other CCS related projects can be mentioned: OxyVal (industrial project) and ADECOS, KW21 (national projects).

A minimum of 3 publications per year are based on experimental results obtained in this facility. Here a list of the most recent scientific publications is presented:

1. Spörl, R.; Stein-Brzozowska, M.; Maier, J.; Scheffknecht, G.: *Schwefeloxidkonzentrationen bei Kohlenstaubfeuerung im Oxyfuel-Betrieb*. 43. Kraftwerkstechnisches Kolloquium. October 2011. Dresden
2. Stein-Brzozowska G., Babat S., Maier J., Scheffknecht G., *Influence of oxy-coal on fly ash transformations and corrosion behavior of heat-exchangers*, 2nd Oxyfuel Combustion Conference, Australia 2011
3. Grathwohl, S.; Maier, J.; Scheffknecht, G.: *Testing and Evaluation of advanced Oxyfuel Burner and Firing Concepts*. 2nd Oxyfuel Combustion Conference Australia 2011
4. Stein-Brzozowska, G.; Maier, J.; Scheffknecht, G.: *Impact of the oxy-fuel combustion on the corrosion behavior of advanced austenitic superheater materials* Energy Procedia 4 (2011) 2035-2042, ISSN 1876-6102, DOI: 10.1016/j.egypro.2011.02.085; 2011
5. Stein-Brzozowska, G.; Maier, J.; Scheffknecht, G.: *Deposition behavior and superheater corrosion under coal fired oxyfuel conditions*. IEAGHG Special Workshop on SO_2, SO_3, Hg and Boiler Corrosion under Oxy-fuel Combustion. 25/26th January 2011, London.

•

The replacement costs for the installation of the Infrastructure (€): 1.5 Mio.

TA23.2 Technical scale 20 kW electrically heated combustor - BTS (Energy Conversion Systems, Combustion)

Description of the facilities

The electrically heated part of the ceramic tube has a length of 2500 mm and a diameter of 200 mm. The electrical heating with a overall electrical power of 57 $kW_{th\ el}$ makes it possible to adjust a constant wall temperature as well as a temperature profile along the furnace. This enables reliable investigations of a variety of temperature related combustion parameters from 800°C up to 1400°C. For the conventional air firing the pulverized coal is supplied by carrier air to the top-mounted burner through which it is injected into the combustion chamber. The feeding system consists of a volumetric conveyor and a screw feeder. The coal feed rate ranges from 1 to 2 kg/h and it depends on a thermal input of 8.5 kW_{th} and corresponds to approximately 1 kg/h for bituminous coals and about 1.5 kg/h for lignite. The combustion air is injected through annular clearances, divided into primary and secondary air. The facility provides a good environment to investigate staged combustion conditions because burnout air can be added at each position along the reactor axis by a probe from below. **Figure 2** shows a schematic outline of the BTS combustion chamber. For the oxy-fuel firing the combustion air is replaced by a mixture of O_2 and CO_2 from the gas storage tanks. The flue gas is extracted at the final section of the heated reaction tube. Standard emissions analysed are O_2, CO_2, CO, SO_2, NO and NO_X. Profile measurements of the flue gas composition can be taken by means of an oil-cooled sampling probe which transports the extracted flue gas to the standard analyzers or a FTIR system.

State of the art

Advantages/Special Features: The test rig is equipped with a flexible char, fly ash and gas sampling system and in addition with a flexible overfire oxidant injection system. Both enable the performance of combustion tests over a broad residence time (1s-4s) and stoechiometrie (air ratio 0.7-1.3) range. Due to that, staging can also be implemented in this facility.

Areas of research: Investigation of combustion behavior of different coal qualities, combustion and co-combustion of various solid fuel mixtures (biomass, SRF, coals), coal burner development (flameless oxidation), oxyfuel combustion

Scientific environment: As in the case of KSVA, this test facility is also surrounded by a very complete infrastructure (fuel pre-treatment facilities, laboratories, etc.) and an experienced team of scientists and technicians.

Services currently offered by the infrastructure and achievements

Every year up to 10 different projects (EU, national or industrial projects) make use of this facility. Some ongoing EU projects at BTS are RECOMBIO, DEBCO, Flox Coal 2. Specifically CCS related recent EU-Project are ENCAP, OxyCorr, Oxyburner and Oxymod. Other national and industrial projects that have made use of the facility are ADECOS, KW21 and Oxyval.

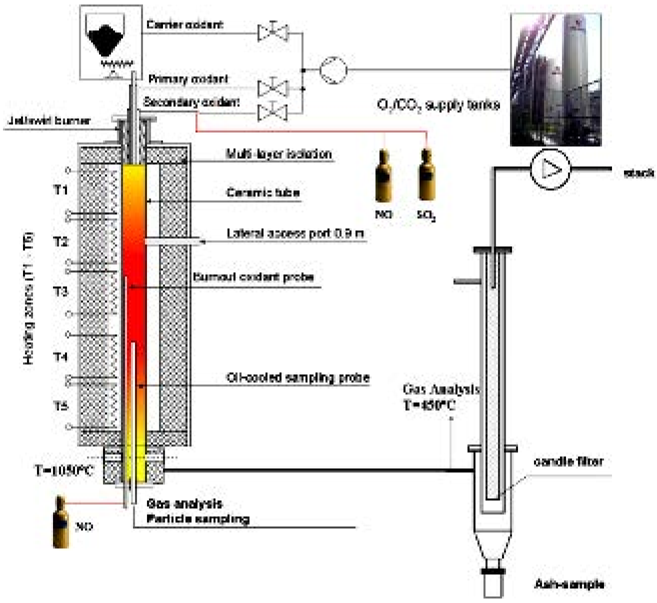


Figure 2. Schematic outline of BTS combustion

A minimum of 3 publications per year are based on experimental results obtained in this facility. Here a list of the most recent scientific publications is presented:

1. Dhungel, Bhupesh. *Experimental Investigations on Combustion and Emission Behaviour During Oxy-Coal Combustion*. Dissertation Universität Stuttgart, 2010.
2. Al-Makhadmeh, Leema. Coal *Pyrolysis and Char Combustion under Oxy-Fuel Conditions* . Dissertation Universität Stuttgart, 2009.
3. Dhungel, B.; Mönckert, P.; Maier, J.; Scheffknecht, G.: *Investigation of oxy-coal combustion in semi-technical test facilities*. Tagungsband: Third International Conference on Clean Coal Technologies for our Future, 15 - 17 May 2007, Sardinia, Italy; 2007
4. Dhungel, B.; Maier, J.; Scheffknecht, G.: *Emission behaviour during oxy-coal combustion in a 20 kW once through furnace*. Tagung: Ninth International Conference on Energy for a Clean Environment, 2-5 July 2007, Povoa de Varzim, Portugal; Veröffentlichung auf CD-ROM; 2007
5. Maier, J.; Dhungel, B.; Mönckert, P.; Scheffknecht, G.: *Combustion and emission behaviour under oxy-fuel condition*. Tagung: 39. Kraftwerktechnisches Kolloquium 2007, 11 und 12. Oktober 2007, Dresden; Veröffentlichung auf CD-ROM; 2007

The replacement costs for the installation of the Infrastructure (€):500k

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
500 kW Pilot scale Combustor	day	6 878	30	6	30	6
20 kW Combustor	day	2 168	30	6	30	6

Work package number	WP32-TA24	start date of event:	M6	end date of event:	M48
Work package title	Transnational access @ TNO				
Activity Type	SUPP				

Participant number	24															
Participant short name	TNO															

Description of the infrastructure	
Name(s) of the infrastructure(s):*	1. TNO PILOT PLANT CO2 CATCHER 2. MINI/MICRO PLANT DEMONSTRATOR 3. QSCAN SOLVENT TEST STREET 4. CLC FIXED BED FACILITY **5.** HIGH PRESSURE ABSOPTION AND DESORPTION PILOT PLANT
Location (town, country):	Netherlands
Web site address:	www.tno.nl
Legal name of organisation operating the infrastructure:	TNO
Location of organisation (town, country):	Delft Netherlands
Annual operating costs (excl. investment costs) of the infrastructure (€):	

Access is offered to state of the art, from lab to pilot scale, demonstration technology for testing and optimization of carbon capture processes and the testing of new solvents:

1) Pilot plant at Rotterdam connected to a modern coal fuelled power plant, build in 2008 and highly successful test results with very promising Solvents. Installation is in operation.

2) TNO lab at Delft with the following unique facilities which are available and can be used on requested
   a. Micro- and Mini Plant for solvent preparation and testing
   b. High throughput solvent screening rig
   c. Chemical looping fixed bed facility
   d. High pressure absorption and desorption pilot plant

TA 24.1 TNO PILOT PLANT CO2 CATCHER (Capture, Absorption)

Description of the facility

The TNO Pilot plant CO_2 Catcher uses post combustion capture technology. New technology and solvents, which are developed in the laboratories can be tested with this pilot plant at real flue gas conditions from a coal fuelled power station. The Rotterdam pilot plant serves as a flexible research and demonstration to test different types of solvents. The location, at the coal-fired power station of E.ON at Rotterdam was chosen because of the opportunity to obtain flue gas derived from coal. The pilot installation makes it possible to investigate the performance of CO2 removal under real industrial conditions. The TNO pilot plant CO2 catcher tests novel gas scrubbing methods and new solvents.

The pilot plant is directly linked to the stack of the second unit of the power plant, which is situated behind the desulphurisation process, which removes the sulphur from the flue gases. A small fraction of the flue gases are directed to the CO2 capture pilot plant for carbon dioxide removal. A maximum of 250 kg CO2 per hour can be removed from the stack. The installation in itself enables different CO2 capture techniques to be evaluated, monitoring all process conditions such as temperature, pressure, flows and content of CO2, SO2 and soot. Other parameters (such ast he stability of the solvents that are used) can be measured separately. The pilot plant consists of a scrubber column for removing traces of SO2, which might damage the solvents, a 23-metre-high CO2 absorber column and an 18-metre-high desorber column) as illustrated in picture below. In the first stage, the SO2 is removed from the flue gas and the treated gas is transported to the absorber where the CO2 is removed by absorption in a liquid in a continuous operational mode.. The purified flue gas is emitted to the stack of the power plant. The absorption liquid is regenerated in the desorber and is ready for use again in the absorber. For bringing gas and liquid into contact, in addition to packed columns, membrane contactors are also tested for both desulphurisation and CO2 absorption.

State of the art

The fact that the installation is directly linked with a world top quartile coal fuelled power plant makes the pilot plants a pivotal point in the scale-up of post-combustion capture technologies.

This has also led to a methodology of finding and improving absorption liquids, based on statistical methods in combination with detailed analysis of the effects of different groups present in the absorption molecule on overall performance. Detailed models are available describing the power plant operations.

The construction of the pilot plant at the premises of the Rotterdam power plant has been a joint effort of TNO – as research partner - and E.ON Benelux – as industrial partner.

Services currently offered by the infrastructure and achievements

With this pilot plant major bottlenecks in the implementation of post combustion capture technologies can be analyzed and studied obtaining detailed knowledge in a wide spread of areas e.i.: New Solvent testing, material testing, scaling-up of reactor design, effect of trace elements in the flue gas, dynamic response times, etc. Different solving test programmes with the Pilot plant are planned or are in progress.

The pilot plant is equipped with the latest technologies regarding process monitoring and process measurement. Furthermore the pilot plant offers good accessibility, user friendly operations and a smart process data collection system. Plant can be remotely controlled with advanced process control system. This enables smooth reporting, data evaluation, monitoring of all process conditions such as temperature, pressure, flows and content of CO_2, SO_2 and soot. Other parameters (such as the stability of the solvents that are used) can be measured separately.

- In the Dutch CATO very interesting results with CORAL, the pilot plant is successful used for Business to Business projects
- Achievements (include the most relevant scientific publications, see link below
- http://www.carboncapturejournal.com/issues/CCJ8web.pdf

The replacement costs for the installation of the Infrastructure 3 mln €:

TA24.2 MICRO/MINI PLANT DEMONSTRATOR (Capture, Absorption)

Description of the facility

The setup of the micro and mini plant consist of a skid with the process equipments [absorber (membranes), desorber, heat exchanger, pump, pipes, CO2 analyzers, flow meters and controller and other small equipment, an automatic data logging / operation system, and a computer (unit)]. The difference of the Micro-plant and Mini plant is the size of the plant. The micro and mini plant are located at the TNO lab in Delft and can be relocated to another location.

Both micro-plant and mini-plant is as such that it is supporting the initial steps e.i.; preparation of the solvents and testing of the solvents stability. The absorption-desorption setup is used to determine the absorption and desorption capacity of CO2 capture solvents. The gas feed system setup is flexible.

The setup consists mainly of the absorption and desorption can be operated in continues operation. Measurement is to be carried out in a standard manner. The gases flowing out of the setup during the absorption or desorption step will be lead to a CO2 analyzer (individually from each beaker).The gas stream can be analyzed for the remaining CO2 content (after absorption) or desorbed CO2. It is possible to add a nitrogen flow which can be used as a sweep gas during desorption. Installation can be 24/7 continuously operated.

The phosphoric acid setup is used for analysis of the CO2 content of the absorption solvents. The principle of this setup is based on boiling phosphoric acid at high concentrations in which the solvent with CO2 is injected. After injection the produced gas is flushed out the beaker with a known nitrogen flow. The gas stream is analyzed with the CO2 analyzer, where the CO2 content of the system is being measured.

State of the art

With the micro and mini plant it is possible to really demonstrate new solvents types within reasonable time.

The micro and mini plant are equipped with the latest technologies regarding process monitoring and process measurement. Furthermore the pilot plant offers good accessibility, user friendly operations and a smart process data collection system.

Services currently offered by the infrastructure and achievement.

Significant amount of successful test runs have been accomplished within the following research programme

Decab,Cato,Icap,Cesar,

The replacement costs for the installation of the Infrastructure: 400 k€ micro plant and 500 k€ mini plant.

TA24.3 QSCAN SOLVENT TEST STREET (Capture, Absorption)

Description of the facility

The Mini AutoClave (MAC) for quick scan purposes is set-up for medium throughput VLE equipment where six experiments can be performed in time. An advantage is the relatively small volume of solvent needed to run a proper test. All six reactors can run independently of each other and can be started and stopped at any time. A typical measurement takes about 24 to 48 hours.

The test set-up is divided into two temperature sections. Three reactors are heated to 40 °C by a water bath and three reactors are connected to an oil bath and can be heated to any temperature between ambient and 120 °C and these three reactors run at the same temperature. Vapour-liquid equilibrium measurements are performed in 0.1 litre reactors, equipped with a magnetic stirrer and a pressure gauche. Typically, 0.05 litre of solvent is used. The solvent in the reactor can be heated up and equilibriums can be determined at a constant temperature of the solvent. From these data so-called pressure-loading (P-α) curves can be constructed. The pressure (P) is obtained as a function of the loading (α). The loading is expressed in mol CO2/mol solvent.

For the glass reactors, measurements have an upper limit of about 7 bars. For safety reasons, a high pressure limit of about 5 bar was chosen. This implies that the P-α curves measured at the VLE set-up range from about 2 to 5000 mbar

State of the art

With the micro and mini plant it is possible to really demonstrate new solvents types within reasonable time.

Services currently offered by the infrastructure and achievements

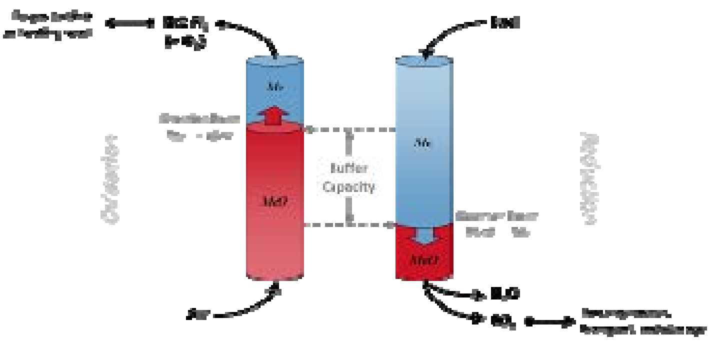
The Qscan solvent test rig is successfully used for Business to Business projects and other research programmes

The replacement costs for the installation of the Infrastructure: approx. 500 k€.

TA24.4 CLC FIXED BED FACILITY (Capture, chemical looping)

Description of the facility

CLC fixed bed facility consist of two circulating fluidized beds.Continuous production of separate streams—hot depleted air and CO2/H2O.Can be operated at elevated pressures.The CLC fixed bed facility is located at the TNO lab in Delft and can be relocated to another location.



State of the art

With the micro CLC fixed bed facility it is possible to really demonstrateMetal/metal oxide bed looped through oxidizing and reducing conditions. Next to this it provides insight in scaling up

Services currently offered by the infrastructure and achievements

The faciltity is successfully used for Business to Business projects and other research programmes such as Greenhouse applications, Production of gases Materials testing w/ international collaboration.

The replacement costs for the installation of the Infrastructure: 150 k€ micro plant

TA24.5 HIGH PRESSURE ABSORPTION AND DESORPTION PILOT (Capture, membrane gas desorption)

Description of the facility

The pilot plant consist of an Absorber and a conventional desorber and MGD, which can be operated in a continuously cycle mode. Currently test runs are in progress as part of the DeCarbit research work package programme. The pilot test facility can be upgraded with next stage MGD technology without large changes to the set-up. The pilot test is skid mounted and is easily to be relocated, due to its compact design. The gas supply setup is flexible and easily to adjusted to specific needs. The Desorber can be equipped with commercial structured packing material.

4-10 Nm3/h gas; 70-110 kg/h liquid circulation

State of the art

With the high pressure absorber and desorber pilot plant it is possible to demonstrate new solvents their stability at different process conditions. The high pressure absorber and desorber pilot plant is equipped with the latest technologies regarding process monitoring and process measurement. Furthermore the pilot plant offers good accessibility, user friendly operations and a very user friendly process data collection system.

Services currently offered by the infrastructure and achievements

Current DeCarbit program in progress.

The replacement costs for the installation of the Infrastructure: 450 k€

Implementation plan

Short name of installation	Unit of access	Unit cost (€)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
TNO Pilot plant CO2 Catcher	day	3 200	20	4	20	4
Micro/Mini Plant demonstrator	day	2 700	20	4	20	4
QSCAN Solvent Test Street	day	1 400	20	4	20	4
CLC Fixed Bed Facility	day	700	45	5	45	5
High Pressure ABS/DES Pilot	day	1 400	20	4	20	4

1.4.8 Risk and contingency plans

The success of ECRI will largely rely on the

- readiness of the consortium to accommodate the sufficient access to the infrastructure
- relevance (and appropriateness) of the portfolio of research facilities
- level of integration of activities (joint research, transnational access and networking)

It is envisaged that joint research and transnational access to the research infrastructure – and to some extent also the networking - will reveal components of significant relevance to the European CCS community. These activities are therefore believed to provide valuable synergy to the consortium, the host institutions and the users. Nevertheless, potential conflicts may arise in the course of the project for various reasons. Some risks may even put the project in jeopardy, depending on their severity and how they are handled. In the preparation of the project, the following aspects have been assessed for contingency:

- **Conflict of interest**
  - The interests of a user, a host institution and also of the project itself may differ and, thus, instigate a conflict. In principle, each partner will be committed to offer a minimum of annual access time to its research facilities. Should this access time be extended, the partner may be free to give preference to own activities (e.g. to conduct further R&D or upgrade the facility).
  - However, in the event that a conflict of interest results from underperforming partners, the coordinator of ECRI will have to interfere accordingly (e.g. by attempting to have priorities changed, or by transferring tasks to another facility). As a last resort, the coordinator will refer conflict to the General Assembly. The General Assembly may then sanction, for instance by withdrawing budget allocations allotted to the underperforming partner.
- **Obsolence and need for upgrading**
  - For various reasons a research facility may become obsolete (e.g. owing to quality, inaccuracy, extended use – beyond the expected life time, or its intended purpose and targets have been achieved, or alternative new approaches may emerge). In such event, the need for a major upgrading and further development of the infrastructure may be raised as an issue. This will be done generally in two ways: i) either the existing research facility is improved – or a new one is provided – or ii) additional partners are invited to be integrated in the consortium.
  - Furthermore, since capital investments are not the responsibility of ECRI, the upgrading of a research facility must be covered by a host partner. According to the rules set out for the Integrating Activities, ECRI is entitled to cover just a part of the operational cost for transnational access.
- **Partner withdrawing from ECRI**
  - A partner may decide to withdraw from the consortium before the project is terminated. Such a situation will be duly covered by the grant agreement and consortium agreement.
  - The situation will, however, allow for replacement of the withdrawing partner - either by one or more new partners - to ensure a smooth transformation of the project and to keep the research infrastructure under ECRI readily available.
- **Dissatisfaction with services provided**
  - User satisfaction/dissatisfaction will be monitored by requesting users to complete a questionnaire (addressing i.a. the quality of services, the uniqueness of the research facilities and the services offered, competition and availability of facilities elsewhere, suggested improvements to the operation of ECRI).
- **Internal risks pertaining to the research infrastructure**
  - The coordinator will be responsible for identifying risks and for assessing the actual mitigation action - either by accepting, preventing or reducing the risk. This must be made in due consideration of the resulting impact(s) of each risk identified.
  - Risk assessment also includes a contingency plan suggesting adequate corrective actions. This approach will be pursued to assess risks pertaining to networking, transnational access and joint research activities. Any corrective actions will be appliedin the yealy updated implementation plan.
  - The coordinator will furthermore require that proper risk assessment - based on the same approach - be presented by each and every host institution before implementing existing (or new) features to a research facility being part of the project. This will also apply to any transnational access project, or joint research activity, or test case, to be conducted within the research infrastructure.

2. Implementation

2.1 Management structure and procedures

2.1.1 Governance

The final decision on ECRI's management structure will be subject to the Consortium Agreement (CA). However, the following structure is quite a mature working model and has proved successful in several Integrated Projects executed under the EU-based framework programmes 6&7and recommended by DESCA. The project is organised with a clear-cut management structure following the line of influence from the highest level (General Assembly) to working level (Work Packages).

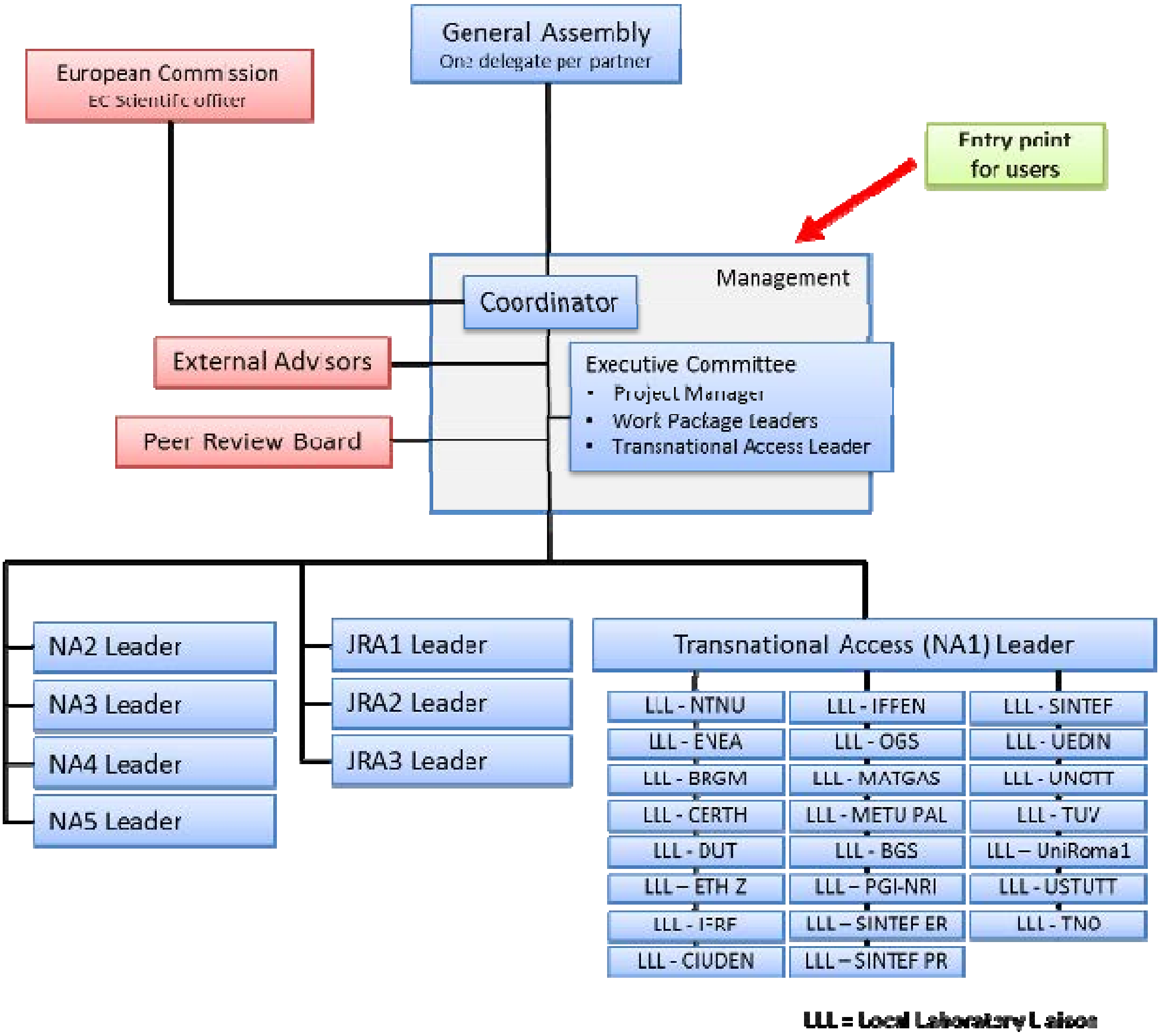


Figure 2.1: *Organisation plan of ECRI*

General Assembly (GA): All parties signing the Consortium Agreement will become full and equal members of the General Assembly (GA). The Project Coordinator will nominate the person to chair the GA. The GA shall meet at least once per year, and GA members and the Project Coordinator have the right to summon extra GA meetings if deemed necessary. The Scientific Officer of the European Commission will be invited to attend all GA meetings.

The General Assembly is the ultimate decision-making body on formal aspects relating to the project:

- Content, finances and intellectual property rights;
- Proposals for changes to Annex I of the Grant Agreement – to be accepted by the European Commission;
- Changes to the Consortium Plan (including the Consortium Budget), evolution of the Consortium (entry of a new Party to the Consortium and approval of the conditions of the access for such a new Party, withdrawal of a Party from the Consortium and the approval of the conditions of withdrawal, declaration of a Party to be a Defaulting Party, remedies to be performed by a Defaulting Party, termination of a Defaulting Party's participation in the Consortium and measures relating thereto, proposal to the European Commission for the change of Coordinator, proposal to the European Commission for suspension of all or part of the Project, proposal to the European Commission for termination of the Project and the Consortium Agreement).

Voting in the GA is by 2/3 majority in all decisions except critical decisions which require unanimous approval. Critical decisions are decisions deemed crucial to reach the stated overall objective of the project or decisions on issues that may put the completion of the project in danger.

The progress and the results of the project will be presented by the Project Coordinator to the GA at the GA meetings. The GA will approve all deliverables of the project. The General Assembly will meet once a year in connection with the annual project meetings.

Project Coordinator: The role of the Project Coordinator is to sign the Grant Agreement with the European Commission on behalf of the consortium, and to obtain from each participant a signed accession to the grant agreement (forms A). On this basis, the Project Coordinator shall be in charge of the execution of the project as the responsible partner. The Project Coordinator is the only partner authorised to exchange information with the European Commission (Scientific Officer) in any event that may concern the project and/or its Consortium. The Project Coordinator has the overall responsibility for the progress of the project and for the quality of its deliverables. All deliverables and any formal report pertaining to the project shall be submitted to the European Commission by the Project Coordinator.

The Project Coordinator will form an Executive Committee (see below) empowered to execute the project on a day-to-day basis according to duties as stated under WP1 (Project Management).

The Project Coordinator furthermore undertakes to

- **Manage the financial contribution from the Commission**. The respective share shall be distributed among the partners according to the Consortium Agreement and the Executive Board decisions, and the Project Management Group shall monitor all financial transactions and inform the Commission about the financial administration, as agreed in the Grant Agreement.
- Monitor the **compliance by participants** with their obligations under the Grant Agreement.
- Provide the Commission with **periodic reports** for each reporting period and **a final report** in order to assist the Commission in approving the fulfilment of the Grant Agreement. The content of these reports shall comply with the Grant Agreement and the reporting guidelines for EC-FP7.
- **Review and submit reports** and other deliverables to the Commission by electronic means.

Executive Committee (ExCo): The Executive Committee is the decision-implementing body of the project. It is made up of the leaders of each Work Package and the Transnational Access Leader, and chaired by the Coordinator. The Executive Committee will be in charge of the operational management of all the activities of ECRI. It will also prepare the decisions to be taken by the GA (concerning the description of work, budget and allocation of the contribution, etc.) and ensure that these decisions are properly implemented and survey ethical and gender issues. The ExCo will also be in charge of financial management of Work Packages.

The ExCo will meet regularly, generally every 6 months, throughout the project period, either physically or via video-/telephone conferences. Agenda and necessary documents will be provided by its Chair in due time.

Work Package Leader (WP Leader): Each Work Package Leader will be responsible for production of the deliverables within their own work package. They will interface with the Coordinator for the purposes of monitoring and control. They will take technical direction from the Coordinator

The WP Leader role is to be the majority contributor in the work package as well as the delegator of tasks across partners (to Task Leaders) who have complementary abilities. This delegation is shown in the work package breakdowns, as the tasks are shared amongst partners with the most appropriate expertise. Each deliverable within the work package has been assigned ownership to the most appropriately experienced partner; however the ultimate responsibility for delivery of the subtasks and the entire work package lies with the Work Package Leader.

WP leaders require frequent communication with partners so as to meet the reporting requirements to the Coordinator. This communication will be done electronically with infrequent personal meetings as required.

Transnational Access Leader (TA Leader): The coordination of Transnational Access within this project is undertaken by NTNU – leader of *WP NA1 Coordination of transnational access.* NTNU has extensive experience of this type of access having been the coordinator of a recent FP6 Infrastructures project ENGAS-RI. The TA leader will be primarily responsible for the efficient operation of selection and implementation of 'the Transnational Access programme' to the ECRI Infrastructures

Local Laboratory Liaison (LL Liaison): The LL Liaison of an individual infrastructure is nominated by the particular partner organisation and is the first contact to the TA leader. The LL Liaison will function as a scientific "guide" and problem solver at the host institute. This person will assist visiting researchers and will act as a helping hand with respect to administrative tasks, provide access to experimental units, laboratory space, technical assistance, and office space and make supporting staff available. The LL Liaison is responsible of finding local accommodation for new users,

Peer Review Board and External Advisors: The selection of the proposal and the allocation of the facility to potential users will be managed by a **Peer Review Board** composed of:

- The Project Coordinator and TA Leader
- Internal Scientific Group from relevant partners
- External Advisors from Industry, Academia and Research Institutions

The **Internal Scientific Group** will consist of up to six members being partners of ECRI and representing the three areas of CCS research in the project (Energy, CO_2 capture, Storage). The membership is ratified by the General Assembly and will be valid for one year. The **External Advisors** will be selected from relevant academic and research organizations and industry. Each member of the Board shall have a documented reference list of expertise within the scientific topics of the project proposals. At least half of the Board members will be made up from external advisors. The external advisors are there to ensure that the research topic is within the scope of ECRI and that the process is fair and the users are treated on equal basis.

Link to the Commission: The Project Coordinator shall be the single interface with the Commission. However, if deemed necessary, the Executive Board can represent the Consortium towards the Commission in pressing issues.

Consortium Agreement (CA): The operation of ECRI shall be based on and mandated by a Consortium Agreement, which will be duly signed by the ECRI consortium members prior to project start. All relevant issues needed for the proper execution of the project will be described in the CA in detail. Relevant issues are the responsibilities (General Assembly, Project Coordinator, Executive Committee, WP-leaders, and individual participants), liabilities, handling of defaulting parties, confidentiality, resolution of conflicts, etc.

2.2 Individual participants

Partner No:	1
Name of legal entity	THE NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY (NTNU)
Short Name:	NTNU

Description of legal entity

NTNU (The Norwegian University of Science and Technology) is a fully integrated university with emphasis on technology and engineering. It is the main technical university in Norway with over 80% of all master- and PhD-degrees awarded in science and technology. Over the last 30 years NTNU and the research institute SINTEF have jointly developed a 8,000 square metre 40 million Euro research facility, where 750 people work at mitigating emissions like CO_2, NOx, SOx and other greenhouse gases. This includes removing them from oil and gas production processes and from use in industry, buildings and transport. A secondary thrust has been to cross-link this research with the development of clean new renewable energy technologies. NTNU is involved in a series of national (BIGCO2, BIGH2, BIGCLC, BIGCCS) and EU projects (ENCAP, DYNAMIS, DECARBit, iCap) and has been coordinator of the FP6 funded ENGAS-RI (Environmental Gas Management Research Infrastructure). NTNU is coordinator of ECCSEL (European Carbon dioxide Capture and Storage Laboratory Infrastructure – www.eccsel.org) that has been recognized by ESFRI (the European Strategy Forum on Research Infrastructure) and was put on the official ESFRI Roadmap in 2008.

Short profile of staff members with major contribution

Dr. Morten Grønli is laboratory director at NTNU within energy technology. Grønli has more than 15 years experiences within the combustion and bioenergy field and has experience in managing research projects as well as laboratory infrastructures at NTNU. He has been project manager of ENGAS RI and is coordinator of the ECCSEL Preparatory Phase Project.

Dr. Olav Bolland is professor in energy and process engineering at NTNU, specialized within power plant engineering and coupling between power cycles and CO_2 capture processes since 1989. He was lead author of the 2005 IPPC Special Report on Carbon Dioxide Capture and Storage. He was, with Dr. Nils Røkke, the main organizer of the 2006 GHGT-8 conference in Trondheim, Norway. He is also co-organiser of the bi-annual Trondheim Conference on CCS. Bolland has published a large number of papers and reports related to CO_2 capture. He is involved, on behalf of NTNU, as partner and work package leader in the FP6 projects ENCAP, DYNAMIS and the FP7 project DECARBit.

Dr. Hallvard F. Svendsen is professor in Chemical Engineering. H. Svendsen has more than 110 refereed journal papers and conference publications on CO2 absorption and multiphase reactor modelling. He is project leader of several national research projects on CO2 capture and supervises presently 12 PhD students in this field. He was member of the CASTOR project Executive Board, and heads the NTNU activity in the CAPRICE, CESAR and CLEO projects and is coordinator of the iCap project. Presently he is referee to about 10-15 international scientific journals, member of the editorial board of one.

Dr. May-Britt Hägg is professor in Chemical Engineering.an has her background both from academia and industry. She is heading the Membrane Research group, Memfo, which counts about 16 researchers, post docs and PhD-students. The focus of research is membranes for gas separation, material development and process simulations. She has 6 patents, published around 50 papers in peer reviewed journals, and around 100 presentations at international conferences. Also chaired 3 international conferences, and been a partner in 8 EU-projects.

Dr. Liyuan Deng is Associate Professor in Environment and Reaction Technology group at Chemical Engineering department, NTNU, has eight years research experience in CO_2 separation membranes and gas membrane separation processes, more than 15 year experience in environmentally friendly processes in general, managed several independent research projects.

Dr. Hanna Knutila: Associate professor at department of Chemical Engineering, NTNU, Trondheim, Norway Current research activities: Solvent based post combustion CO_2 capture, emission control in CO_2 capture plants, Pilot plant operations.

Partner No:	2
Name of legal entity	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE,L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE
Short Name:	ENEA
Description of legal entity	
ENEA's activities involve research, development and testing of technologies equipments and components, and transfer of innovations to industry. ENEA operates in national and international programs on energy saving and sustainable use of fossil fuels, mainly supporting the Italian industry; furthermore, ENEA acts as advisor and supports Ministries of economic development and of environment. In this context ENEA is involved in CCS technologies, where operates in strict coordination with its controlled company SOTACARBO (located in Sardinia island). In this way the "ENEA group" covers all the aspects of CCS, from CO_2 capture to storage, from generation of energy – eventually combined with hydrogen – to system integration, and also the fields of communication and dissemination of results. ENEA works in strict cooperation with its controlled company SOTACARBO both in R/D/D and demonstration activities. Finally, ENEA is partner of of ECCSEL Project (www.eccsel.org)	
Short profile of staff members with major contribution	
Giuseppe Girardi (ENEA) is respondible of sustainable fossil fuels and CCS programs at ENEA, and manages several CCS programs in cooperation with industry, Universities and research organizations. He's VicePresidente of Sotacarbo, and member of several Italian and international organizations. He has more than 20 years of experience in combustion, advanced power plants, low and zero emissions technologies,. **Stefano Giammartini (ENEA)** is responsible of Combustion Processes Laboratory, specialized within combustion, advanced diagnostics and power generation; he has been coordinator of several research projects financed by ENEA and by EC, and is in the Board of the Italian Section of the Combustion Institute **Antonio Calabrò (ENEA)** is expert in thermal and chemical processes modelling and simulation. Actually he's the leader of the ENEA team working in zero emission energy processes, mainly involved in process analysis and power plant design. He's responsible of Zecomix platform project. **Paolo Deiana (ENEA)** Chemical engineer, responsible of research activities carried at ENEA/Sotacarbo gasification platform. He's currently involved in analysis of advanced high efficiency and zero emissions power plants, study and testing of coal gasification systems, syngas cleaning and treatment systems. **Eugenio Giacomazzi (ENEA)**, Ph.D. in ``Theoretical and Applied Mechanics''. His expertice covers CFD, parallel computing, experimental diagnostics, control strategies, and theoretical aspects connected with turbulence and combustion. **Stefano Stendardo (ENEA)** Ph.D on Mathematical-Physical Modelling within Chemical Engineering, he's involved in development and testing of solid sorbents specifically for decarbonisation of syngas from coal and biomass gasification, and in modelling of a fluidised-bed binary-particle reactor system for carbon dioxide capture. **Carlo Amorino (SOTACARBO)** Chemical engineer, he took part in a series of research projects regarding Co-combustion (coal and biomass), gasification, Carbon Capture and Storage (CCS), Clean Coal technologies (CCT). Now is technical manager of all research activities for Sotacarbo Research Centre.	

Partner No:	3
Name of legal entity	UNIVERSITATEA BABES BOLYAI
Short Name:	BBU
Description of legal entity	
Babes-Bolyai University (BBU) is an academic educational public institution aiming to promote and sustain the development of specific cultural components within the local, regional, national and international community. Babes-Bolyai University is ranked within the first two university of Romania taking into account	

the research activity (fundamental and applicative research, developing of services, products and prototipes and implementation in socio-economical environment). On international level, BBU is one of the most representative university from Central and Eastern Europe being within the first 600 universities of the world. With 21 faculties, more than 53000 students and with an experienced teaching staff of 1700, BBU is now an active participant in most of the European and American academic associations.

In proposed project, BBU will be involved with Chemical Engineering Department. Chemical Engineering Department has gain international recognition in the field of mathematical modeling, simulation, optimisation and control of industrial processes and could be involved in the project proposal with advanced modeling and simulation expertise in energy conversion processes and carbon capture and storage as well as model validation with experimental data collected from the project partners, integration of infrastructure into virtual facilities, e-infrastructure, scientific services etc. Babes-Bolyai University could be involved in bringing togheter and integrate, on a European scale, key research infrastructure in field of carbon capture and storage (CCS) being involved in all activities of the FP7 call namelly: (1) Transnational access and/or service activities, (2) Networking activities and (3) Joint research activities.

Short profile of staff members with major contribution

Dr. Calin – Cristian Cormos got a PhD in 2004 in chemical engineering in the field of modelling, simulation, optimization and process integration. He has more than 15 years of experience with scientific research, having also experience as a chemical engineer, plant manager and product development manager. Currently he is Associate Professor Eng. at BBU, being responsible for the disciplines: "*Integrated design of chemical processes*", "*Thermal integration and pinch analysis*", "*Chemical Reaction Engineering"* and "*Bioreactors*". He has published 62 scientific articles in prestigious international journals and peer-review conferences. Presently, he is coordinator of Babes-Bolyai University's "Energy" research and post-doctoral programme and Process Engineering Department in the Institute of Technology within the same university. Calin – Cristian Cormos was involved in research teams and also leading national and international research projects in the field of energy with carbon capture and storage, e.g. FP6 project "*Dynamis: Towards hydrogen and electricity production with CO_2 capture and storage*" (project coordinator: Sintef). He is scientific referent for many prestigious journals e.g. International Journal of Hydrogen Energy; Energy; Industrial & Engineering Chemistry Research; Environmental Science & Technology; Energy & Fuels etc., being also involved as project evaluator for national and international (e.g. FP7) competitions.

Dr. Paul Serban Agachi is the director of Research Center – Computer Aided Process Engineering being professor in the field of advanced process modeling, control and optimisation. He was involved along the years in coordination of many national and international research and industrial projects having many scientific publications (more than 100). Prof. Agachi is supervisor of PhD students involved in this project.

Dr. Ana-Maria Cormos got the PhD in 2005 in chemical engineering in the field of modelling, simulation and optimization of chemical processes (limestone decomposition process in vertical kilns). She has more than 15 years of experience in scientific research being involved in national research and industrial projects (e.g. "*Improvement of techno-economical and environmental performances of chemical processes by mathematical modeling and simulation*"). She published more than 20 articles devoted to energy conversion processes and carbon capture and storage.

Partner No:	4
Name of legal entity	BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES
Short Name:	BRGM

Description of legal entity

BRGM, France's leading public institution in the Earth Science field, has three main activities: scientific research, support for government policy, and international cooperation and development assistance. BRGM has been among the pioneers in research on CO_2 geological storage, participating from 1993 in the first European research project (Joule II) and in the first pilots worldwide (Sleipner, Weyburn, In Salah, etc.). BRGM is also carrying out research activities at natural CO_2 fields, such as Montmiral in France, and at natural CO_2 seepage areas in Italy, Germany and France. Its fields of expertise are site selection and characterisation, predictive modelling, risk analysis, monitoring and safety management, thus addressing a wide range of the issues related to CO_2 geological storage. BRGM has been manager of the CO_2GeoNet European Network of Excellence on the geological storage of CO_2, initiated in 2004 through an EC FP6 contract, now a legally registered Association under French law. As a continuation BRGM is currently the coordinator of the FP7 coordination action CGS Europe that brings together research institutes working on CO2 geological storage from whole Europe.

Short profile of staff members with major contribution

Dr. Isabelle Czernichowski-Lauriol (PhD in Geosciences and Engineering Degree in Geology) has been involved since 1993 in many European projects on CO_2 geological storage and has been managing the BRGM research activities in this field. She has been CO_2GeoNet Network Manager under the FP6 contract. She is currently President of the CO_2GeoNet Association and coordinator of CGS Europe. She has responsibilities in the ZEP Technology Task Force, the CO2NET Board, IEA GHG Executive Committee and EERA initiative.

Dr. Hubert Fabriol (PhD in Applied Geophysics) currently manages the Safety and Impacts of CO_2 storage unit at BRGM. He has been involved in CO_2 storage research since 1993 (projects Joule II, SACS, Weyburn, GRASP, CO2ReMoVe, CO_2GeoNet). He has coordinated the 'Géocarbone Monitoring' project funded by the French Agency for Research. He is member of the CSLF Risk Assessment Task Force and the IEA GHG monitoring network. He gave advice to the French Ministry of Environment for the London Convention and OSPAR discussions on CO_2 sub-sea bed geological storage, the transposition of the European directive, etc.

Partner No:	5
Name of legal entity	CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS
Short Name:	CERTH / ISFTA

Description of legal entity

Centre for Research and Technology Hellas (CERTH) is a legal, non-profit entity, under the auspices of the General Secretariat for Research and Technology of the Greek Ministry of Education. The Institute for Solid Fuels Technology and Applications (CERTH/ISFTA) is the main Greek organisation for the promotion of research and technological development aiming at the improved and integrated exploitation of solid fuels and their by-products.

CERTH/ISFTA is actively involved in clean coal technologies and CCS technologies and represents Greece in the Carbon Sequestration Leadership Forum and in the European Technology Platform on CCS. CERTH/ISFTA has recently initiated a techno-economic study related to the feasibility of a CCS Demo project in North Greece. The assessment of the Health-Safety-Environmental (HSE) risks associated with potential CO_2 geological storage projects is one of the main tasks included in this study. CERTH/ISFTA was also partner at the EUROFLEET FP7 Panarea natural CO_2 seeps: fate and impact of the leaking gas (PaCO2) involved in sampling and analysis of water samples for chemical parameters (TOC, alkalinity, etc.).

Current participation:

1. FP7 Project RISCS ("Research into Impacts and Safety in CO_2 Storage") leading the WP – Naturally-leaking sites in southern Europe (Assessing potential impacts in the terrestrial environment – southern

Europe) through the conduction of sampling, field measurements and geochemical, biological, and botanic analyses of natural CO2 seeps in Greece and Italy (Florina, San Vittorino, Latera).

2. RFCS Project UCG-CO2 ("Study of Deep Underground Coal Gasification and the Permanent Storage of CO_2 in the Affected Areas").
3. FP7-SCIENCE-IN-SOCIETY-2011-1

Short profile of staff members with major contribution

Mr. Nikolaos Koukouzas is a Geologist and holds a MSc and PhD in Industrial Mineralogy. He has more than 20 years of experience on power production, CO_2 emissions, carbon capture and storage technologies, industrial mineral applications, coal mining, coal combustion by-products utilisation, co-combustion of coal with biomass related topics. He was appointed to the European Commission, DG Energy & Transport, as Detached Expert in Coal Technology (1999-2003). Nowadays, he is a Senior Researcher (and Director of Research since 2007) in CERTH/ISFTA, managing the research activities of the Institute. He is an author of over 100 publications in scientific journals and conferences.

Mrs Vassiliki Gemeni has a Master in Applied Environmental Geology and the last three years she is working as and scientific researcher in CERTH/ISFTA involved mainly in CCS R&D projects. Her recent scientific activities include on-going European projects such as FP7 RISCS ("Research into Impacts and Safety in CO2 Storage") and UCG-CO2.

Mrs Fotini Ziogou is a Chemical Engineering and holds a Master's Degree in Business Administration. She has a long experience record as she has been working for 7 years in the French multinational company AIR LIQUIDE HELLAS as a Production Engineer of air and CO_2 liquefaction plants in North Greece and supervising engineer at the Florina natural CO_2 deposits for the commercial exploitation of CO_2 as an industrial gas. Since 2006 she is a Scientific Cooperator of CERTH/ISFTA, implementing European and national R&D projects dealing with CCS technologies (ENCAP, FENCO - ERA.NET, Greece-Czech and Greece-USA bilateral projects, RISCS etc.).

Partner No:	6
Name of legal entity	DELFT UNIVERSITY OF TECHNOLOGY (DUT)
Short Name:	DUT

Description of legal entity

TU Delft is a state university, founded in 1842 and is the oldest, largest and most comprehensive technical university in The Netherlands. This technical university is characterized by cutting edge research and providing first class education. With ~16,000 students and academic staff of 2,100, TU Delft is the largest technical university in The Netherlands. The University's research yearly results in about 185 PhD theses and >4,000 publications in journals.

The energy technology section, part of the faculty of mechanical engineering and the department Process & Energy has more than 12 years of experience in fuel characterization, modelling and validating atmospheric/pressurized (C)FB gasification of several fuels, ranging from old fossil to biomass. Hot gas cleaning has been studied for decades in the group along with solid fuel combustion. Within the EU FP6 Chrisgas project, the EU FP7 GreenSynGas project and the EU Marie Curie project INECSE 4 PhD students work on a steam-O_2 blown 100 kW_{th} CFB gasifier. The ET section is also the center of gas turbine research in the Netherlands. Current research projects, sponsored by major energy companies like Electrabel and Vattenfall, study the operation of gas turbine under strongly fluctuating loads and changing fuel composition.

The Engineering Thermodynamics section, also part of the faculty of mechanical engineering and the department Process & Energy, adopts a fundamental and mostly molecular viewpoint in order to solve applied engineering problems in the field of (non-)equilibrium thermodynamics. Methods for predicting phase behavior (e.g. molecular simulations) are being enhanced – but that in the context of a distinct research goal, like optimizing solvents or nanoporous hosts for carbon dioxide removal from gaseous streams. Our experimental research is performed with world-class facilities for high-pressure thermodynamics, e.g. cailletet setups, autoclaves, and gravimetric equipment. The section takes part in large national Dutch programs like ADEM and Cato2, the latter focused on CO2 capture and storage. A grant of 600k-euro was obtained from the ADEM innovation platform for additional investments in our thermodynamic equipment. A large STW project is carried out (3 PhD students, total investment >600k-euro) on the use of novel process solvents for CO2 capture, and involves both experimental and theory approaches.

Short profile of staff members with major contribution

Prof.Dr.ir. Bendiks Jan Boersma studied mechanical engineering at Twente University and obtained his MSc degree in 1993. From 1993 till 1997 he was a PhD student at Delft University of Technology. The PhD research focused on computational fluid mechanics and turbulent flows. From 1997 till 1999 he was a postdoctoral research fellow at Stanford University in the USA. From 1999 till 2003 he had a research fellowship from the Royal Netherlands Academy of Science and arts with as research subject aeroacoustics. In 2003 he obtained a VIDI grant from the national science foundation and became associate professor and later in 2007 full professor at Delft University of Technology. Main research areas are Computational fluid dynamics, combustion, aero and thermoacoustics. He is co-author of >50 journal papers on various topics related to fluid mechanics and energy technology.

Prof.Dr.ir. Thijs J.H. Vlugt (born: 1974) studied chemical engineering at Eindhoven University of Technology and obtained his MSc degree in 1997. From 1997-2000 he was a PhD student with Rajamani Krishna and Berend Smit at the University of Amsterdam in the Netherlands, focusing on molecular simulation of adsorbed guest molecules in nanoporous materials. After postdoctoral research in Mainz (Max Planck Institute for Polymer Research) and Leiden (Instituut-Lorentz for theoretical physics), he became assistant professor at Utrecht University in 2003, obtaining a prestigious VIDI grant in 2005. In 2007, he moved to Delft University of Technology to become associate professor, and later in 2010 he became full professor and chair engineering thermodynamics in Delft. His research is focused on various topics in the field of thermodynamics and molecular simulation. He is co-author of >90 journal papers, which were cited over 2000 times resulting in a h-factor of 22.

Dr.ir. Wiebren de Jong studied chemical engineering at Twente University and obtained his MSc degree in 1991. He carried out a post-graduate study 'process design' and obtained his PdEng degree in 1994. After an EU-funded post-graduate study at the University of Stuttgart (1994-1995), he became PhD student in 1996 at TU Delft within the section ET in the field of modelling/experimentally validating the fate of fuel_N in PFB gasification. In 2005 he received his PhD degree and since then he is assistant professor. He is involved as (senior) researcher in several EU Marie Curie, FP3, 5, 6 and 7 projects in the section and national projects. He teaches 3 MSc energy courses and is co-author of >40 journal papers on thermo-chemical conversion.

Other key personnel: Dr.ir. P.V. Aravind (fuel cells) and Ir. M. Siedlecki (gasification), Dr. Theo de Loos (high pressure thermodynamics), Prof.dr. Signe Kjelstrup (Irreversible Thermodynamics and Sustainable Processes). Note that Prof.dr. Kjelstrup is also full professor at NTNU.

Partner No:	7
Name of legal entity	EIDGENÖSSISCHE TECHNISCHE HOCHSCHULE ZÜRICH
Short Name:	ETH Zurich

Description of legal entity

Founded in 1855, ETH Zurich is a science and technology university with an outstanding research record. ETH Zurich is the study, research and work place of 20,000 people from 80 nations (25% of which are women). About 4000 professors in 16 departments teach to about 16,000 students (3,500 of which are Ph.D. students) mainly in the engineering sciences and architecture, system-oriented sciences, mathematics and natural sciences areas, and carry out research that is highly valued worldwide. Twenty-one Nobel Laureates have studied, taught or conducted research at ETH Zurich, underlining the excellent reputation of the institute. Maintaining and developing its top standing in the international competition among top universities is an important task of ETH Zurich.

ETH Zurich orients its research strategy around global challenges such as climate change, world food supply and human health issues.

ETH is a member of CO2NET and CO2NET2, the specialised Thematic Network sponsored by the EC under FP5 and FP6, moreover ETH operates in the European Energy Research Alliance (EERA), in DECARBit and in ECCSEL (European Carbon dioxide Capture and Storage Infrastructure), in the framework of the European FP7.

Short profile of staff members with major contribution

Prof. Dr. Marco Mazzotti has been professor of process engineering at ETH Zurich since May 1997. He has a Ph.D. in Chemical Engineering from the Politecnico di Milano. His research activity deals with adsorption based separations and chromatography, and with crystallization and precipitation processes. Mazzotti has been coordinating lead author of the IPCC Special Report on Carbon Dioxide Capture and Storage (2002-2005). He is also an active member of the AIChE, of the Working Party on Crystallization of the EFCE, and vice-President of the International Adsorption Society. He was the chair of the 9th International Conference on Fundamentals of Adsorption FOA9 (Italy, May 20-25, 2007), and of the 18th International Symposium on Industrial Crystallization (Switzerland, September 15-16, 2011). His refereed publications include more than 180 journal articles, 20 articles in books and 6 book chapters.

Dr. Alba Zappone, received her PhD at the University of Milan in 1993. Since then she works in the field of laboratory measurements of physical parameters in of rocks**.** In the last years she devoted her attention to the topic of seismicity induced by fluid injections (geothermal plants and CO_2 storage sites) In 2010 she joined the group of Prof. Mazzotti and works in projects in the fields of CCS.

Partner No:	8
Name of legal entity	FONDAZIONE INTERNAZIONALE PER LA RICERCA SULLA COMBUSTIONE - ONLUS
Short Name:	IFRF

Description of legal entity

The International Flame Research Foundation is since more than 50 years well established in the R&D business of industrial combustion. Many important initiatives on the field of industrial combustion development have been born by the IFRF. A unique network comprising nine national flame research committees (Deutscher Verein f. Verbrennungsforschung, British Flame Research Committee, American Flame Research Committee, Comitato Italiano,, etc.) and more than 250 members will be available to disseminate the available information. This network reaches more than 80% of the European power industry. The Foundation has access to state-of-the-art experimental combustion facilities, from lab to industrial scale, operated by dedicated personnel and with large availability of strategically important fuels, in Livorno Research Station. Training of young engineers and scientists has been a hallmark of the Foundation since its inception. The Foundation regularly reviews the state-of-art in specific topic related to flame research. The results of such reviews are transferred to the members through conferences, IFRF Meetings, technical reports and external publications. Most important is the role of the IFRF's premises as a place where people meet and exchange information.

Short profile of staff members with major contribution

Prof Leonardo Tognotti Director of International Flame Research Foundation since October 2006. Chemical Engineering Graduate at the University of Pisa 1981, Visiting Scientist (post-Doc) at Department of Chemical Engineering, Massachusetts Institute of Technology, 1988-89. Full Professor since November 2001 at University of Pisa. Great experience in coordination of national and international Research Projects. Co-author of more than 150 publications in the field of combustion, gasification, biofuels, environmental protection. Reviewer for the international journals and chairman of international scientific Conferences and Events.

Prof. Neil Fricker: IFRF Superintendent of Research since 2009 and former IFRF Director. He is a member of the Editorial Board of the Journal *Industrial Combustion* and Editor in Chief of the IFRF *Combustion Handbook*. Neil Fricker has a PhD in radiophysics. Three years as an investigator with the IFRF working mostly on combustion aerodynamics and natural gas combustion were followed by two years developing new steel making processes with CSM, Italy. Over the next 25 years, Neil worked on a wide range of gas utilisation activities with British Gas R&D. This period included time as the Manager of Heating Plant Division, as Business Area Manager for Natural Gas Vehicles, and as Manager of Gas Certification Services. He left BG Technology in 1999 and he is currently a visiting Professor of Combustion Technology at the University of Glamorgan, UK.

Dr Giovanni Coraggio Investigator at International Flame Research Foundation since 2002. Graduated in Physics from the University of Pisa, and has gained experience at ENEL Research Station and at IFRF in combustion measurements and in flame research. He is author of several Technical Reports on conventional

and advanced combustion technologies.

Partner No:	9
Name of legal entity	FUNDACIÓN CIUDAD DE LA ENERGÍA
Short Name:	CIUDEN
Description of legal entity	
The Fundación Ciudad de la Energia (CIUDEN) is a public law body created by the Spanish Government in 2006 to support and promote international cooperation to enhance European competitiveness through strategic research partnerships with industry, SMEs, Universities and research institutions. In this sense, CIUDEN is involved in the development of several Research Infrastructures, most of them being in the commissioning phase. They are the Technology Development Plant for CO_2 Capture, the CO_2 transport test rig, the CCS analytical laboratory and the so-called PISCO2 plant, related to safety in CO_2 storage through the study of bio-monitoring of controlled diffuse vents. Furthermore, CIUDEN takes part of the so-called as OXYCFB300 Compostilla Project funded under the European Energy Programme for Recovery (EEPR), currently in the development phase.	
Short profile of staff members with major contribution	
Modesto Montoto is the Director of the CO_2 Geological Storage Programme of CIUDEN since May 2007. Associated Professor in the University of Barcelona, Professor in the Universities of Sevilla and Oviedo, in Oviedo: Director of the Dept. of Petrology, Dean of the Faculty of Sciences and Vice-Rector for Planning and Development. His main area of Research is Petrophysics at the rock matrix scale, in this subject he created an internationally recognised workgroup. **Pedro Otero** is Technical Director of CIUDEN, formerly Head of Technical Department of 1312 MW Compostilla PS., has worked for the cement industry and for more than 25 years in power generation, participating in more than 20 projects of applied research. BS in Chemistry (Chemical Engineering) by U. of Santiago de Compostela; MS in Engineering & Environmental Management and MBA by the Industrial Organization School (Madrid). **Daniel Fernández-Poulussen** has a Degree in Geology. 3 years of experience in technical management for the CO_2 Geological Storage Programme of the Fundación Ciudad de la Energía (CIUDEN). Currently working on the Spanish EEPR-Project for the CO_2 Geological Storage Programme of CIUDEN. **Tomás Coca** is a project engineer at CIUDEN Technology Center was the Worksite Manager of the erection of CIUDEN´s facilities and Coordinator of CIUDEN´s team during the construction. Chemical Engineer by the University of Nottingham and MSc on Water technologies by Cranfield University, has extensive experience on the water and refining sector. **Manuel Gómez** is a project engineer of CIUDEN with former experience in process engineering. Integrated Design of Chemical Plant, Postgraduate course at Leeds University and MSc in Chemical Engineering at University of Cantabria.	

Partner No:	10
Name of legal entity	IFP ENERGIES NOUVELLES
Short Name:	IFPEN
Description of legal entity	
IFP Energies nouvelles is a public-sector research, innovation and training center active in the fields of energy, transport and the environment. Its mission is to provide public players and industry with efficient, economical, clean and sustainable technologies to take up the three major challenges facing society in the 21st century: climate change and environmental impacts, energy diversification and water resource management. It boasts world-class expertise. IFP Energies nouvelles sets out 5 complementary, inextricably-linked strategic priorities that are central to its public-interest mission. **Renewable energies**: producing fuels, chemical intermediates and energy from	

renewable sources. **Eco-friendly production**: producing energy while mitigating the environmental footprint **Innovative transport**: developing fuel-efficient, environmentally-friendly transport. **Eco-efficient processes**: producing environmentally-friendly fuels and chemical intermediates from fossil resources. **Sustainable resources**: providing environmentally-friendly technologies and pushing back the current boundaries of oil and gas reserves

An integral part of IFP Energies nouvelles, its graduate engineering school prepares future generations to take up these challenges.

Short profile of staff members with major contribution

Dr. Andreas Ehinger (Scientific Management Unit, IFPEN) has a scientific background in geophysics (PhD). He has 15 years of experience in project and R&D management. During the last 7 years he has been actively involved in CCS research. From 2005 to 2008 he was in charge of the coordination of the French CCS R&D program, acting on behalf of the Agence Nationale de la Recherche. He is currently involved as work package leader in ECCSEL preparatory phase project I and in the European coordination action CGSEurope. He is a member of ZEP Technology Task Force. Since 2010 he is the coordinator of the CCS Joint programme of the European Energy Research Alliance (EERA). In this function he participates in the European Industrial Initiative on CCS and in the Advisory Forum of the CCS Project Network.

Dr. Hervé Quinquis has a PhD in structural geology and geophysics (1980). He joined Shell International in 1981 where he occupied various positions in Oil &Gas exploration around the world (UK, New Zealand, Brunei, Gabon). He joined IFP Energies nouvelles in 1999 as Business Development Manager. His current activities are directly oriented towards the acceleration of the deployment of the CCS technologies and the development of advanced technologies addressing CO_2 storage in particular. He is a member of AAPG and EAGE and has been involved in the organisation of numerous international events including CCS forums, workshops and conferences. He has also participated actively in the elaboration of the EERA CCS program and is IFPEN focal point for the newly formed Tri4CCS research alliance between IFPEN SINTEF and TNO. He is a member of the Executive Committee of CO2Geonet. He will be the IFPEN representative within the secretariat of the European CCS project network starting early 2012.

Dr. Marc Fleury obtained an engineering degree in Physics at the Ecole Polytechnique de Lausanne (Switzerland) and a PhD degree from the Fourier University of Grenoble (France) in Fluid Mechanics. Before joining IFP Energies nouvelles in 1992, he has worked in the field of Physical Oceanography at the Johns Hopkins University in Baltimore and at the University of Victoria (Canada), studying turbulent mixing and double diffusive instability. He is now working as a Senior Petrophysicist in special core analysis. He received three best paper awards from the Society of Core Analysts for various innovative work on centrifuge capillary pressure and resistivity measurement techniques. He also received the Darcy award from the Society of Core Analysts for his contribution in petrophysics. Presently, his main interest is in NMR applications in porous media.

Partner No:	11
Name of legal entity	ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE OGS
Short Name:	OGS

Description of legal entity

The mission of The National Institute of Oceanography and Applied Geophysics (OGS), a national Italian institute under the control of the Ministry of University and Research, is to promote, co-ordinate and perform, also in collaboration with other national, international, and European institutions, studies and research on the Earth and its resources related to: applied geophysical and environmental disciplines; marine sciences; seismicity, hydrodynamic and geodynamic phenomena.

The institute, with offices in Trieste, Udine and Rome and a staff of about 270 people (about 100 with temporary contracts), has a long tradition in geophysical exploration, on land and at sea, as well as in physical oceanography, marine biology and Earth observation. OGS co-ordinated or participated to more than 70 EU-funded research and demonstration projects in the fields of Energy, Environment and Marine Sciences, among which CO2NET2, Castor, INCA-CO2 , CO2GeoNet, Geocapacity, CO2ReMoVe, MOVE-CBM, RISCS, Sitechar, CO2CARE, CGS Europe, ECO2 and ECCSEL all dealing with CO_2 geological storage. At national level, OGS is participating to all the running projects on CO_2 geological storage (of ENI, ENEL, Carbosulcis) and manages the Secretariat of the Italian CO_2 Club. Moreover, OGS keeps the Secretariat General of the CO2GeoNet Association, the European network of Excellence on the Geological Storage of CO_2.

Short profile of staff members with major contribution

Alessandro Crise, degree in Physics, OGS permanent staff since 1981, is presently the Director of the Department of Oceanography. Author of numerous scientific papers published on highly rated peer-reviewed journals, he is partner of major European projects focused on operational oceanography and biogeochemical modelling of the Mediterranean Sea (among others, MFSTEP, CIRCE, MERSEA, SESAME, MyOCEAN, SESAME, the forthcoming PERSEUS). Dr. Crise is member of relevant Italian and international committees on marine sciences (ESF Marine Board, POGO) and operational oceanography (e.g. EuroGOOS board, MOON). Moreover, he acts as referee for scientific journals and several institutions including Italian Ministry for University and Research, European Commission, French Research Agency, IFERMER, The British National Environmental Research Council and Italian PNRA.

Davide Deponte, degree in Electronic Engineering, is responsible for management and development of electronic instruments in the Oceanogaphy department. In the last 10 years, he has been involved, as responsible for time series data acquisition, in all the main projects of the department, starting with PRISMA1 and up to VECTOR. Since 1998, he has contributed to the development of automatic meteo-oceanographic buoys for coastal monitoring projects. More recently, he has been the coordinator, for the oceanographic part, of the project 'CO2 Pre-injection Off-Shore Baseline Survey', performed by OGS for ENEL.

Paola Del Negro, biologist, master degree in Aquaculture and PhD in environmental science, is leading the OGS research group “Marine Biogeochemistry and Ecosystems”. Her main expertise is in marine microbial ecology and processes, and ecosystem functioning. In the past 3 years, her researches were specifically addressed on the structure and functioning of microbial communities in different habitats and under different environmental stresses (hypoxia, anoxia, chemical contamination, CO_2 increase, pH decrease). These researches were mainly performed in the Adriatic Sea (coasts, open waters and lagoons), in the Ross Sea (Antarctica) and in natural CO2 leaking sites (Panarea-Italy). She participated at numerous national and international research projects as PI and at more than 20 oceanographic cruises along the Adriatic Sea and in the Ross Sea (Antarctica). She has been involved also in several FP7 CO_2 related projects as RISCS (Research into Impacts and Safety in CO2 Storage), ECO2 (Sub-seabed CO_2 Storage: Impact on Marine Ecosystems) and MedSeA (Mediterranean Sea Acidification in a changing climate.

Cinzia De Vittor holds a BSc in Biological Science, a master in Aquaculture and a PhD in Environmental monitoring and methods. Her research mainly focuses on the biogeochemical cycle of carbon in the marine environment and fluxes of organic and inorganic carbon, nitrogen and phosphorous at the sediment-water interface. She took part in several national and international projects and in several oceanographic cruises (included Arctic and Antarctica). She participates in some CO_2 related projects, as RISCS (Research into Impacts and Safety in CO_2 Storage), ECO2 (Sub-seabed CO_2 Storage: Impact on Marine Ecosystems) and Eurofleet - PaCO2 (The Panarea natural CO_2 seeps: fate and impact of the leaking gas). She has been scientific coordinator, for the OGS-BIO department, of the Pre-injection off-shore baseline survey project in an area closed to Porto Tolle (Italy), identified as a potential CCS site, She contributed also to CO2GeoNe,t coordinating the OGS biological research in Panarea (Italy).

Michela Vellico is an Environmental Engineer with a Phd in Applied Geophysics and Hydraulics, has worked at OGS since 2003. Her main expertise is in remote sensing techniques and their use for CCS. She has been involved in the following EC projects: CO2 GeoNet (testing the use of remote sensing methodologies in the leaking sites of Latera and Laacher See), Geocapacity (providing datasets to the European WebGIS of storage sites, and storage capacity calculation), Enhygma (applying remote sensing techniques to hydraulic risk prevention).

She has also contributed to national projects related to CCS (for ENEL and Cesi Ricerca).

Michela. Giustiniani received a degree in Geology at Rome University in 1999. After a period as visiting researcher at Lancaster University (UK), where she developed mathematical modelling tools for fluid and solute transport calculation, she got a PhD on Applied Geophysics at Trieste University, being mainly involved in the acquisition and processing of seismic data to study shallow and deep aquifers. In 2005, she joined the OGS for processing 2D and 3D seismic data. Her main expertise is in acquisition, processing, inversion and interpretation of both crustal and high resolution seismic data, applied to different topics, such as aquifers, gas hydrates and CO_2 storage.

Pag. 812

Partner No:	12
Name of legal entity	MATGAS 2000 AIE
Short Name:	MATGAS

Description of legal entity

MATGAS 2000 A.I.E. (www.matgas.org) is a research centre, legally registered as a non-profit Economic Interest Group dedicated to meeting R+D demands in the field of materials and gases from a broad perspective. MATGAS fosters synergies between the business sector, research centres and universities through extensive market knowledge and the research and teaching capacity of its three members, Carburos Metálicos, the Spanish National Research Council (CSIC) and the Universitat Autònoma de Barcelona. At MATGAS, we bring together basic research projects, technological development and business management models. According to its strategic plan MATGAS is focused in areas related to Energy, Sustainability and Environment, from a broad perspective. In the last year MATGAS has been leading and participating in several projects related to these areas.

Since its creation, MATGAS has been highly active in research projects. MATGAS projects are geared towards industrial needs, covering the basic and applied stages of research, and they have a great focus on sustainability. MATGAS has participated in several EU projects related to its areas of expertise, including CO_2 applications, hydrogen, fuel cells, and materials for specific applications. In the last 5 years MATGAS has actively participated in 5 European projects. At the moment, MATGAS is coordinating the SOST-CO2 CENIT (www.cenit-sostco2.com) project, and it is also participating in the CENIT BioSOS (www.cenit-biosos.es) on "Sustainable Biorefinery".

Part of the uniqueness of MATGAS is its layout in six versatile laboratories where the different research projects are conducted: Supercritical fluids, Nanotechnology, Scaling and industrialization, Computing and Simulation, Energy and Gas Reactivity. MATGAS's laboratories have last generation equipment. The laboratories are prepared with the highest safety and access control measures to ensure both the physical safety of researchers and operators and the strictest confidentiality regarding the experiments conducted. As part of a strategic decision, all new products and processes investigated in MATGAS include the Life Cycle Analysis, searching for the environmental benefit of the new products/processes. We are also members of the Catalan and Spanish network on Life Cycle Analysis and Sustainability, collaborating with a broad number of internationally recognized experts in the field.

Short profile of staff members with major contribution

Dr. Lourdes F. Vega (PhD in Physics, 1992). Since 2007 she is the R&D Director of Carburos Metálicos and MATGAS General Director. She is a senior scientist with an outstanding list of over 100 publications, she has been leading several research projects and directing 6 PhD theses and several other research works.

Dr. Oriol Ossó (PhD in Physics, 2004). He joined Carburos Metálicos in 2008 as a Project Coordinator in the area of Materials for Energy and is at present leading projects in the fields of Fuel Cells and CO_2 transformation by photocatalytic conversion. He is author of 26 scientific papers published in recognized international journals.

Eng. Joaquim Torres (Chemical Engineer, 1992) In 1995 he joined the R&D Department of Carburos Metálicos, and since 2005 he is a MATGAS Project Supervisor. He has been leading research in the area of supercritical CO_2 applications (with emphasis in the engineering aspects and materials for CO_2 management), high pressure gases, electrochemical processes and gasification of biomass. In addition to these activities, he has acted as a consultant for companies in the use of CO_2, being also the coordinator of safety in MATGAS.

Eng. Raul Solanas (Industrial Engineer, 1996). He has experience in the area of supercritical CO_2 since 2000. At present he is the technician of the Supercritical Fluids laboratory in MATGAS, being a permanent researcher from CSIC. He accumulates more than 15 years of experience working in different projects related to supercritical CO_2.

Partner No:	13
Name of legal entity	MIDDLE EAST TECHNICAL UNIVERSITY

Short Name:	METU-PAL

Description of legal entity

Petroleum Research Center (PAL) was established in 1991. Routine fuel quality control analyses are performed in the laboratories of the center for gasoline, diesel, biodiesel, fuel oil, LPG and natural gas. PAL laboratories are accredited according to ISO 17025. The analytical equipment as well as core tomography and core displacement test systems are used for academic as well as contracted research. The center is also conducting researches related to oil/ gas and geothermal reservoir evaluations. Several case studies were conducted for fields in Turkey on natural gas storage and Kızıldere geothermal and for oil fields in Azerbaijan and Kazakhstan. Recently PAL has led a national research project jointly with Turkish Petroleum Corporation about the assessment of the availability of Turkey's geologic CO_2 storage sites. The center has been involved in the European 7th Framework project named as Pan-European Coordination Action on CO_2 Geological Storage. Well cement integrity under CO_2 storage, geochemical and geomechanical effects, multiphase flow modelling, CO_2 natural analogues and monitoring and site characterization are among the research areas of the center.

Short profile of staff members with major contribution

Dr. Ender Okandan has a BSc degree from METU and MSc and PhD with a minor in Chemical Engineering from Stanford University all on Petroleum Engineering. She is an academic member of the Petroleum and Natural Gas Engineering Department and specialises in oil/gas and geothermal reservoir engineering and enhanced oil recovery. Presently she is supervising graduate research on well integrity, effect of CO_2 on different cement compositions, and supervised a PhD work on cap rock integrity. She acted as the first chairperson of the department and was the director of PAL after establishing it in 1994. She was the leader of the CO_2 storage capacity project in Turkey. She is also the country coordinator of EU FP 7 project, CGS Europe 256725.

Dr. Ilhan Topkaya is a senior expert at METU-PAL. She has more than thirty five years of experience in reservoir engineering and oil and gas production. Before joining METU-PAL, she was the Production Group Manager of Turkish Petroleum Corporation (TPAO) between the years 1998-2005. The on-going projects during this period were "Bati Raman CO_2 Injection Project", "Silivri Natural Gas Injection Project" and "Bati Kozluca CO_2 Injection Project". She is also a Part-Time Instructor at the Petroleum and Natural Gas Engineering Department of METU.

Dr. Mahmut Parlaktuna is a Professor and senior expert at Petroleum Research Center - PAL. His expertise is on petroleum, natural gas and geothermal reservoir engineering as well as natural gas hydrates. He was project coordinator or researcher on numerous projects concerning reservoir engineering. Recently, he participated in a CCS project aiming as an EOR application in Turkey.

Dr. Çağlar Sınayuç is an assistant professor in METU Petroleum and Natural Gas Engineering Department. Before joining the department he worked for Imperial College London for more than 3 years. He has contributed to the short term modelling studies performed for EU FP 6 CO2ReMoVe Project. He is specialized in CO_2 flow modelling, geomechanical effects of CO_2 injection and enhanced CBM recovery.

Dr. Nilgün Güleç is professor since 2000 at the METU Geological Engineering Department. She is specialized in the field of geochemistry and isotope geology as applied to magmatic rocks, crustal fluids and mineralization. One of her research area is the chemical characterization of Turkish geothermal fields that comprise natural analogue sites for geological storage of CO_2. In collaboration with colleagues from Scripps Institution of Oceanography (USA) and GeoForschungZentrum (Germany), she has been acting as the coordinator of several research projects concerned with isotope and gas geochemistry of geothermal fields in Turkey.

Partner No:	14
Name of legal entity	NATURAL ENVIRONMENT RESEARCH COUNCIL/BRITISH GEOLOGICAL SURVEY
Short Name:	BGS

Description of legal entity

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and a

component body of the Natural Environment Research Council (NERC), one of the UK's seven Research Councils. The BGS is the United Kingdom's premier centre for earth science information and expertise, employing around 750 staff and operating a series of state-of-the-art research laboratories with an international reputation for long-term, process-based research in support of model development and performance assessment particularly related to CO2 sequestration and radioactive waste disposal. BGS coordinated the ground-breaking Joule 2 project in the mid-1990s and has subsequently taken a leading role in CCS research via a number of characterization, storage capacity estimation, performance assessment and site monitoring projects. BGS also provides advice to the UK Government in developing the UK legislative framework for CO_2 storage. BGS is a member of the ECCSEL consortium and already operates a series of state-of-the-art laboratories that have specific focus on the provision of long-term process-based knowledge in support of CO_2 sequestration and radioactive waste disposal. These laboratories form the core of BGS's 'centre of excellence' for physical properties and processes.
Short profile of staff members with major contribution
Shaun Reeder is Head of Science Facilities with responsibility for the management of all BGS's laboratories (analytical geochemistry; mineralogy, petrology and biostratigraphy; physical properties; and fluid processes research) and science facilities (marine, drilling, geophysics, hydrogeology and image analysis). **Dr Jon F Harrington** is a senior research scientist with specialist expertise in the transport and mechanical properties of low permeability materials and extensive experience in research-quality testing. He is Facility Leader for the Fluid Processes Research laboratories and project manager for numerous scientific studies. **Dr Helen Reeves** is an engineering geologist with 11 years' post graduate experience. She is currently Head of Science for the Land Use & Development programme, and an expert in rock mechanical properties testing. **Simon J Kemp** is a mineralogist with over 22 years' experience of mineralogical investigations and an international reputation in clay mineralogy and X-ray diffraction (XRD) analysis. He is Facility Leader for the Mineralogy, Petrology and Biostratigraphy laboratories. **Dr Michael H Stephenson** has extensive experience of research in petroleum geology and biostratigraphy. He is Head of Science for Energy at the BGS with responsibility for managing a large program of research into carbon capture and storage, clean coal, renewables, oil and gas and advanced seismic techniques. **Dr Nick J Riley MBE** is co-ordinator of the European Research Network of Excellence on Geological CO_2 storage and President of its legal entity (the CO2GeoNet Association). He is Head of Science Policy Europe & Grants at the BGS, with responsibility for developing and initiating BGS's scientific collaboration in Europe.

Partner No:	15
Name of legal entity	PANSTWOWY INSTYTUT GEOLOGICZNY - PANSTWOWY INSTYTUT BADAWCZY
Short Name:	PGI-NRI
Description of legal entity	
Polish Geological Institute – National Research Institute, founded in 1919, manages multi-disciplinary research on the geological structure of Poland in order to use the knowledge for purposes of domestic economy and environmental protection. Besides research in all fields of modern geology, the Institute fulfils the role of a geological and hydrogeological survey of Poland, securing economic stability to the country in areas of both mineral (including hydrocarbons, conventional and unconventional) and groundwater resources management, environmental monitoring, CCS and geothermal. PGI-NRI is leading, since 2008, National Programme "Assessment of formations and structures suitable for safe CO_2 geological storage including monitoring plans". The programme is to provide information necessary for future permits on exploration of CO_2 storage sites all over the country and characterize selected storage sites using archive data and laboratory analyzes. PGI has provided expertise to the first Polish demo project Bełchatów and other CCS projects which are being planned as well. It is also involved in planned pilot CO_2 injection (sandstone Jurassic aquifer) supported by all major power companies operating in Poland. The research infrastructure will be constructed within PGI facility (wells, monitoring infrastructure). By now research injection permit has been obtained (27 kt CO_2) and contract negotiations completed.	
Short profile of staff members with major contribution	

Adam Wójcicki, Ph.D., Geophysicist, involved in CCS activities supported by the EU FP6 since 2004 (CASTOR, EU GeoCapacity, CO2NetEast) and domestic projects (e.g. WebGIS CCS atlas of Poland). Since 2008 working at PGI-NRI integrating national projects and activities on CO2 geological storage lead by PGI-NRI. It includes coordination of the national programme „Assessment of formations and structures for safe CO2 geological storage, including monitoring plans". Providing expertise and studies to stakeholders interested/involved in CCS activities in Poland, including the Polish pilot injection project and demos. Involved in CCS networking activities supported by the EU FP7 (CGS Europe, ECCSEL PP). Member of ENeRG network, involved in activities of CO2NET, cooperating with CO2GeoNet network since 2008.

Marek Jarosiński is Associate Professor of PGI-NRI, his principal expertise is within tectonics and geodynamics. Supervising PGI-NRI involvement in CCS demo project Bełchatów (where also SLB participates) and other PGI-NRI projects. Head of the Department of Geological Mapping where all CCS, hydrocarbon and geothermal projects are carried out.

Ewa Szynkaruk is managing project on PGI-NRI involvement in the demo CCS project Bełchatów, storage part. The project has included supervising and elaboration of results of field works (seismic and gravity surveys, two exploration wells) and constructing models of structures - potential storage sites, together with risk analyses and elaborating monitoring plans. Cooperating with SLB and domestic subcontractors.

Anna Feldman-Olszewska is a sedimentologist, her principal expertise is in evaluation of Jurassic sandstone aquifers for the purposes of CO_2 storage including studies and analyses on rock samples. Participang in the National Programme and PGI-NRI project supporting Bełchatów demo project.

Monika Konieczyńska is Head of Environmental Protection Division in PGI. Coordinating PGI-NRI involvement in the pilot injection project within the field of surface monitoring.

Wojciech Wołkowicz is Environmental Geologist, his expertise includes studies on CO_2 natural analogues and (by now) baseline surveys on CO_2 content within soil air and groundwater. Key monitoring specialist in the pilot project.

Partner No:	16
Name of legal entity	SINTEF ENERGI AS
Short Name:	SINTEF ER

Description of legal entity

SINTEF Energy Research (a legal entity affiliated to SINTEF) is a contract research institute focusing on power generation, energy conversion technologies, and energy distribution and end-use. In total SINTEF ER employs about 220 people. SINTEF ER has developed a considerable level of expertise pertaining to CCS, mainly relating to capture techniques in power cycles, gas handling and pre-treatment, and CO_2 transport. In collaboration with NTNU, SINTEF ER has more than 30 years of experience in numerical simulation of combustion processes and experimental capabilities (advanced laser diagnostics for combustion measurements). Of special relevance are a novel high pressure oxy-combustion facility (HIPROX) and a 150kW CLC cold pilot to be complemented by a hot pilot. Experience has in particular been built on oxy-combustion and hydrogen combustion in CO_2 capture processes through the Norwegian research program BIGCO2, and the EU projects ENCAP, DYNAMIS, ECCO and DECARBit – all led or coordinated by SINTEF ER. In addition, SINTEF ER possesses world-leading expertise in refrigeration and cryogenics, including modelling and simulation capabilities covering components, working media, and systems. The institute is, e.g., responsible for advanced cryogenic air separation units in DECARBit. SINTEF ER was also in lead of the WP2 Capture Technologies in the Sino-European COACH project (2006-2009), much devoted to pre-combustion concepts, notably poly-generation in a Chinese context.

SINTEF ER is furthermore the Coordinator of the national strategic R&D project BIGCLC, in which the enabling of large-scale CLC at pressurised conditions is being addressed, in addition to scrutinization of membranes, sorbents and various techniques. SINTEF ER also coordinates the Norwegian national R&D project BIGCO2 and the International CCS Research Centre BIGCCS. The BIGCCS Centre probably forms the largest single R&D project in the world addressing the CCS chain from CO_2 capture to underground storage.

Short profile of staff members with major contribution

Dr. Nils Røkke is President of Climate Change Technologies within SINTEF and Director of BIGCCS, the International CCS Research Centre at NTNU and SINTEF. He has also been Co-ordinator of the EU FP6 DYNAMIS and the EU FP7 DECARBit project, and Project Manager for the ENCAP EU FP6 project led by Vattenfall. He is Chairman of major CCS projects (e.g. the BIGCO2 project and the Enabling Remote Gas project), member of the EU ZEP Advisory Council, member of WG1 in ZEP, and is leading the ZEP Long Term R&D plan within capture. Dr. Røkke was Chairman for the GHGT-8 in Trondheim 2006, Chairman of the European CCS conference in February 2009, and Chair of both TCCS-5 (2009) and TCCS-6 (2011) in Trondheim (founded the series in 2002).

Dr. Marie Bysveen is the Combustion Group Team Leader and has 20 years of experience in combustion research, management of R&D projects and process engineering. She has been working on fuel technology, especially on the use of hydrogen and natural gas in combustion engines. Dr. Bysveen is the manager of the largest R&D project in Europe on Chemical Looping Combustion, known as BIGCLC, and she is the present Coordinator of the EU FP7 DECARBit project.

Dr. Mario Ditaranto has a PhD from 1998 in pure oxy-fuel combustion at CORIA-University of Rouen. Since then he has been working as a combustion specialist at SINTEF ER, mostly on experimental aspects of oxy-fuel and hydrogen combustion, but also on NO_x reduction methods for industrial applications (two patents). He is the project manager of the combustion activities in the Norwegian R&D projects BIGCO2 and in the BIGCCS Centre.

Dr Jens Hetland is a senior research scientist who has also industrial experience in oil & gas processing and manufacturing. He was leading an action on coal-based CO_2 capture technologies in China (the Sino-European COACH project) and has been appointed an international expert to the Asian Development Bank and the Chinese Government – the National Development and Reform Committee (NDRC) in providing recommendations for the first large-scale CCS demonstration in China (IGCC-CCS) 2009-2010. He is a member of the Editorial Board of Elsevier Journal of Applied Energy

Partner No:	17
Name of legal entity	SINTEF PETROLEUMSFORSKNING AS
Short Name:	SINTEF PR

Description of legal entity

SINTEF Petroleum Research (SINTEF PR; a legal entity owned by Stiftelsen SINTEF) is an R & D institute focusing on developing new knowledge and technology for exploration and production of petroleum resources, both nationally and internationally. Particular specialties are advanced drilling and integrated operations, petroleum related rock physics/mechanics, CO_2 storage and field development studies, as well as multiphase flow assurance through its world class industrial scale multiphase flow laboratory. SINTEF PR has been working with underground storage of CO_2 in relevance to the climate change issue since 1986. The projects have included all aspects of the storage scheme including enhanced oil recovery, transport infrastructure integration, economy and climate modelling. Since 1993 SINTEF PR has been participating in EU projects, starting with the “Underground storage of CO_2” in the Joule II programme, and including finished and ongoing projects such as SACS, SACS2, CO_2Store, ULCOS, CASTOR, CO_2GeoNet, CO_2ReMoVe and ECCO. SINTEF PR is today an active partner for Gassnova, Gassco and the Norwegian Petroleum Directorate in the work for establishing safe storage for CO_2 from the Mongstad and Kårstø plants, having delivered three reservoir studies on this topic.

Short profile of staff members with major contribution

Jan Åge Stensen Long experience in petroleum engineering both from industry and academia, with emphasis on methods for increased oil recovery. Currently one of the task leaders in the BIGCCS subproject on geological storage of CO_2.

Erik Lindeberg Long experience in petroleum engineering and all aspects of geological storage of CO_2. Central in the development of the field of research in Europe.

Alv-Arne Grimstad Experience from several large projects on geological storage of CO_2. Task leader for the storage part of BIGCO2.

Partner No:	18
Name of legal entity	STIFTELSEN SINTEF
Short Name:	SINTEF

Description of legal entity

Stiftelsen SINTEF is within the SINTEF Group; one of the largest research groups in Europe. Stiftelsen SINTEF has more than 1200 employees with international top-level expertise in science and technology and the annual turnover of 1600 million NOK (~ 200 M€) originating from industrial research contracts as well as European and National research projects. SINTEF is an independent and non-commercial corporation. The profit from our contract research is invested in new research, scientific equipment and competence.

In the present project, the Materials and Chemistry (MC) division of SINTEF will be involved. SINTEF MC has around 420 employees, with about 90% being scientists and technicians. The Material and Chemistry division has extensive activities in the fields CO_2 capture and transport and experience from several national and European R&D programs within FP5, FP6 and FP7 as coordinator and core partner.

Short profile of staff members with major contribution

Dr. Richard Blom is Research Manager at SINTEF MC, and has been working in the field of catalysis and sorption for the last 20 years. The last 10 years his main interest has been to develop materials and processes for CO_2 separation technologies. He has long term experience as project leader and coordinator for CCS related projects and has published more than 70 scientific publications

Dr. Rune Bredesen is Research Director at SINTEF MC, and has over 30 years of experience in materials research, and for the last 20 years his main activity has been directed to energy technology. He is member of the Editorial Board of Chemical Engineering Journal and has been the Coordinator of European Projects. He is managing the Capture project of the International CCS Research Centre BIGCCS. Bredesen is a member of several international scientific committees and has about 60 publications in international journals or scientific books.

Dr. Cato Dørum is Senior scientist at SINTEF MC, and has 10 years of experience in FE-based material and fracture modeling, and experimental mechanics. He is participating in several projects dealing with development of methodologies for prediction of initiation and propagation of fracture. He has a key role in several projects related to CO_2 transport at SINTEF Materials and Chemistry.

Dr. Partow Pakdel Henriksen is Research Manager at SINTEF Materials and Chemistry for the past 4 years, working mainly with material development for energy and environmental technologies. She has been working with CO_2 capture technologies (Membranes, adsorption and absorption) in the past 11 years. Prior to SINTEF, she has worked 10 years at ABB Environmental / ALSTOM Norway in the area of Air Pollution control for Power plants and various industries in air pollution technologies. She is the leader of CO_2 strategy group at SINTEF Materials and Chemistry.

Dr. Thor Mejdell is Senior research scientist, involved in the field of chemical engineering for more than 25 years. He has a PhD at NTNU from 1990 within process control and modelling, and has worked with CO_2 post combustion capture since 2003. He has coordinated the department's activities in the Castor, Dynamis and Ulcos projects from the EU 6'th framework program and the Cesar project in the 7'th framework program. He has also been heavily involved in the SOLVit project and is presently responsible for pilot plant activities at the new facility at Tiller.

Partner No:	19
Name of legal entity	THE UNIVERSITY OF EDINBURGH
Short Name:	UEDIN

Description of legal entity

The University of Edinburgh is one of the largest and most successful universities in the UK with an international reputation as a centre of academic excellence. Its international character is reflected in its student population, which comprises students from over 120 different countries worldwide. Diverse and deep quality can also be found in its truly international staff and in its joint research and other links with overseas universities, institutes, companies and governments. The University is the leading research university in Scotland and is amongst the top five in the United Kingdom. Following the announcement of the results of the 2008 Research Assessment Exercise some 63% of the University's research activity is in the highest categories (4* and 3*), of which one third is recognised as "world-leading". More than 90% of the institution's academic staff saw their research assessed across 39 subject areas. The results place the University in the top 5 in the UK by volume of 4* "world-leading" research.

The College of Science & Engineering

The College is in the front rank of UK University science and engineering groupings for research quality and research income. It is one of the largest science & engineering groupings in the UK, with over 1,800 staff and over 7,000 students. In the most recent (2008) UK Research Assessment Exercise the College of Science & Engineering continues to be a top performer, 96% of the research was classified as rated 4*. 42% of the world-leading scientists and engineers in Scotland are at the University of Edinburgh, and all seven of the Schools within the College have performed far above the UK average in their disciplines. The College is home to the UK's largest academic group in Carbon Capture and Storage in a single University, as a result of strategic investments in staff and infrastructure.

Short profile of staff members with major contribution

Prof Stefano Brandani - Chair of Chemical Engineering, Director of Research for the School of Engineering. Recipient of a Philip Leverhulme Prize and a Royal Society-Wolfson Research Merit Award. He was an expert reviewer for the IPCC Special Report on Carbon Dioxide Capture and Storage (2005).

Prof Andrew Curtis - TOTAL Chair of Geophysics. Research interests in mathematics and a previous career in applied geophysics research at Schlumberger global corporation. He leads Edinburgh Seismic Research (www.geos.ed.ac.uk/seismic/) which is the UK's largest grouping of research geophysicists for exploration and monitoring.

Prof Jon Gibbins - Chair of Power Plant Engineering and Carbon Capture. He is the Principal Investigator the UK CCS Community Network (www.ukccsc.co.uk) and is a member of UK Department of Energy and Climate Change Science Advisory Group.

Prof. R. Stuart Haszeldine - World's first Professor of Carbon Capture and Storage, appointed at the University of Edinburgh. Research Director of the UK's largest university CCS research group www.sccs.org.uk. Member DECC Science Advisory Group, DECC CCS Development Forum, and adviser to UK and Scottish Ministers. Recipient of the Scottish Science Prize (1999), and the William Smith Medal of the Geological Society (2011), for global excellence in applied geology. In 2003 he was elected a Fellow of the Royal Society of Edinburgh.

Dr Hyungwoong Ahn - Science and Innovation Award (S&IA) Lecturer in Carbon Capture.

Dr Hannah Chalmers - Lecturer in Power Plant Engineering for CO_2 Capture.

Dr Maria-Chiara Ferrari - S&IA Lecturer in Membranes for Carbon Capture.

Dr Stuart Gilfillan - NERC personal postdoctoral Fellow. Operates the only UK facility for noble gas/CO_2 gas isotope analysis applied to CCS.

Dr Mathieu Lucquiaud - Research Fellow in Power Plant Engineering for CO_2 Capture

Dr. habil. Christopher Ian McDermott. His work includes the investigation of heterogeneities on caprock integrity and reservoir storage capacity.

Dr Mark Naylor - Personal Fellow in GeoScience (Royal Society of Edinburgh and The Scottish Government). Expertise in analytical analysis of CO_2 storage security.

Dr Mark Wilkinson - Lecturer in CCS geology and Course Director for the world's first MSc in CCS.

Prof Anton Ziolkowski - PGS Chair of Petroleum GeoScience.

Partner No:	20
Name of legal entity	THE UNIVERSITY OF NOTTINGHAM
Short Name:	UNOTT

Description of legal entity

Higher Education Institute. The recent results of the national Research Assessment Exercise 2008 confirms the status of the University of Nottingham as a world-class institution carrying out research of international quality, and places us in the UK's top five universities for engineering.

In the field of carbon abatement from fossil energy, the direction of Nottingham's research is shaped primarily around how conventional fossil energy sources will be best exploited in the future in line with stricter environmental controls and the move towards near zero-emission power plants. Recent EPSRC, TSB/BERR and EU projects are addressing novel adsorbents for CO_2 capture and the control of other pollutants, fundamentals of oxyfuel combustion, understanding the effects of impurities on CO_2 phase behaviour and high temperature materials. A number of mineral carbonation projects, both in-situ and ex-situ, are also being carried out. The research is highly collaborative and involves extensive co-operation with key industries regarding exploitation, together with internationally leading research centres.

Short profile of staff members with major contribution

Prof. Maroto-Valer has established an international research reputation at the interface between energy and the environment. Her team is developing novel chemical and engineering solutions to meet the worldwide strive for cost-effective and environmentally-friendly energy, with particular emphasis on carbon dioxide capture, transport, storage and utilization. She has over 250 publications, including editor of 3 books, and 2 patents and holds leading positions in professional societies and several editorial boards. She is the Chief Scientific Officer of the National Centre for Carbon Capture and Storage, a joint partnership between UNOTT and BGS. At UNOTT she is Director of the Centre for Innovation in Carbon Capture and Storage (CICCS) and Head of the Energy and Sustainability Research Division at the Faculty of Engineering.

Dr Barry Lomax is interested in plant responses to CO_2. He runs the ASGARD (Artificial Soil Gassing and Response Detection) facility which is a specialist field facility designed to simulate a CO_2 leak so that ecosystem responses to CO_2 can be assessed under controlled conditions. CO_2 can be injected into the soil at a depth of 60cm and measurements of parameters such as gas concentrations and fluxes, isotopic signatures, soil moisture, root growth, and photosynthesis can be made.

Dr Giorgio Caramanna is a geologist, specialising in Monitoring techniques and lab experiments for the detection of CO_2 leakages from Carbon Geological Storage sites both on inshore and offshore (sub-seabed) environments. Giorgio utilises his skills as a scientific diver to study natural analogues for sub-seabed leakage.

Dr Sarah Mackintosh is a programme manager running the science programme at the National Centre for Carbon Capture and Storage. She is also the UK representative for ENeRG and a member of a number of CCS task forces.

Partner No:	21
Name of legal entity	TECHNISCHE UNIVERSITAET WIEN
Short Name:	TUV

Description of legal entity

Vienna University of Technology, Institute of Chemical Engineering (TUV). The Research Division "Chemical Process Engineering and Energy Technology" is one of the largest at the Institute. Main fields of activity of the division (about 50 scientific employees) are Zero Emission Technologies, Gasification and Gas Cleaning, Synthetic Biofuels, Reaction Engineering & Combustion, and Fluidized Bed Systems & Refinery Technology. During the last decade, several energy technology processes have been developed - starting from the idea via laboratory and pilot plants up to full scale demonstration units. The tools applied are of experimental and modelling nature. The group's special experience is with hot laboratory/pilot units in a scale of 100 kW and also with cold flow models of fluidized bed systems. During the recent years the research group

Pag. 820

has been involved in several European research projects in the field of fluidized bed systems for advanced fuel conversion technologies: GRACE (FP6), CCCC (RFCS), CLC GAS POWER (FP6), CACHET (FP6), RENEW (FP6), FLEXGAS (RFCS), BioSNG (FP6), AER GAS II (FP6), BiGPower (FP6), UNIQUE (FP7), INNOCUOUS (FP7), FECUNDUS (RFCS).

Short profile of staff members with major contribution

Prof. Hermann Hofbauer has got a large experience in the fields of fluidized bed technology and thermal fuel conversion. During the last 20 years he was involved in many international and national research projects. He is head of the Institute of Chemical Engineering with more than 150 scientific employees and head of the research division "Chemical Process Engineering and Energy Technology". Since 1982 more than 200 scientific papers have been published by him as author or co-author.

Tobias Pröll is responsible for the Research Group on Zero Emission Technologies since the division of Prof. Hermann Hofbauers former Research Group on Future Energy Technologies in 2010. Thus, Tobias Pröll is responsible for the chemical looping pilot plant as well as for the oxyfuel combustion pilot plant. He has got an education in Chemical Engineering from Vienna University of Technology and carried out his diploma thesis in the field of modelling and simulation of gas-liquid absorption processes. During his PhD he contributed essentially to the successful demonstration of dual fluidized bed biomass gasification by accompanying modelling and simulation work. Since 2006 he is responsible for chemical looping combustion and reforming research where the institute has become one of the leading institutions with the largest pilot plant in operation (www.chemical-looping.at).

Christoph Pfeifer is responsible for the Research Group on Gasification and Gas Cleaning. Thus, Christoph Pfeifer is responsible for the development of gasification technologies and the coordination of the pilot plants for gasification (pressurized bubbling fluidized bed gasifier, dual fluidized bed steam gasifier) as well as cold flow modelling of fluidized bed systems for gasification. Moreover, the group deals with catalytic gas cleaning and is therefore operating a 100Nm³/h slip stream tar reformer at the 8MW combined heat a power plant in Güssing based on the dual fluidized bed gasification technology.

Partner No:	22
Name of legal entity	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA
Short Name:	UniRoma1

Description of legal entity

With 21 faculties and over 4500 teaching and research staff, Università di Roma "La Sapienza" is an internationally recognised centre of excellent for education and cutting edge research. The group representing the university in this proposal has specialised in near-surface gas and water geochemistry since 1980, using it as a tool in such topics as basic geology (tectonics, fault mapping, volcanic processes), resource exploration (geothermal, oil and gas, mineral), pollution mapping (garbage dumps, gasoline spills), and waste disposal (nuclear, CO_2). Since 1989 this group has been involved in a total of 17 EC-funded research projects (including 3 as Project Leader), as well as numerous contracts with industry (ENEL, ENEA, ENI, Schumberger, PTRC, Carbosulcis, etc.). All of these have had a significant gas geochemistry component, with projects in the last 10 years concentrating on geological carbon dioxide capture and storage (CCS) (e.g. Nascent, Weyburn, CO2GeoNet, CO2ReMoVe, MovECBM, RISCS, SiteChar, CGS Europe, ECO2). Within these projects UniRoma1 has established itself as a world leader in the use of natural, leaking-CO_2 test sites to understand gas migration, to test monitoring technologies, and to study ecosystem impacts; has worked extensively on industrial sites to define baseline trends (Porto Tolle, Sulcis, etc.) and safety monitoring (Weyburn); and has conducted research into public perception and scientific knowledge dissemination. UniRoma1 is also an active participate in ZEP and the Italian CO_2 Club.

Short profile of staff members with major contribution

Salvatore Lombardi, as Head of the Fluid Chemistry Laboratory, has spent more than 30 years researching many aspects of gas and water reactions / distribution / migration in various geological environments. In nine EC-funded projects on CO_2 geological storage he has addressed his research towards the improvement of near-surface geochemical methods and the development of low cost geochemical monitoring stations for both terrestrial and marine environments.

Sabina Bigi has a PhD in structural geology and has been a Researcher within the Department of Earth Sciences since 1996. She specializes in regional structural geology, focussing recently on fault and fracture control of gas migration as related to CCS.

Samuela Vercelli has a Master and a Specialisation degree in Clinical Psychology and conducts research into the communication and dissemination of scientific knowledge. She is Vice-Chair of the Executive Committee of CO2GeoNet - Network of Excellence on the Geological Storage of CO_2. She is currently engaged in the development of a holistic approach for CCS communication.

Stan Beaubien has a M.Sc. in geochemistry applied to groundwater and surface water systems. In the field of CO_2 geological storage he has concentrated on the study of natural analogues to better understand gas migration processes as well as chemical and biological impacts of leaking gases.

Aldo Annunziatellis has a Master degree in geology and is completing the final year of his PhD at the Department of Earth Sciences. Since joining the group in 2000 he has specialised in GIS and the development of electronic geochemical devices such as flux measuring instruments and monitoring stations.

Stefano Graziani has a Master degree in Electronic Engineering and has been involved over the last 5 years in the design, development, testing, and deployment of continuous monitoring stations that can be deployed in unsaturated soil, groundwater, and marine systems.

Giancarlo Ciotoli has a Master and a PhD in geology from the University of Rome. He has been associated with the Fluid Geochemistry Lab since 1990, where he has focused on the study of deep gas migration to the biosphere. Recent areas of study include statistical multivariate analysis and innovative geostatistical methods in conjunction with GIS-type software for better interpreting gas geochemistry and geological data sets.

Partner No:	23
Name of legal entity	UNIVERSITAET STUTTGART
Short Name:	USTUTT

Description of legal entity

The Institute of Combustion and Power Plant Technology (IFK) in the Universität Stuttgart (USTUTT) has been dealing with conventional energy issues for more than 50 years and has gained considerable experience concerning the thermal utilisation of solid fuels such as coals, biomasses and solid recovered fuels. The research is focused on:

- the development of mathematical models for industrial combustion systems;
- the development of environmentally compatible firing and power station systems for different fuels;
- the development and use of intrusive and non-intrusive measuring techniques to characterise the combustion process and the analysis of fuels to characterise the combustion behaviour.

USTUTT has unique experimental facilities, due to its ability to use the infrastructure of the nearby power station. For all commercially available combustion and gasification systems, experimental facilities are available with capacities ranging from 15 kW up to 500 kW. USTUTT also has facilities for fuel pretreatment, fuel analysis and for the examination of products of combustion and corrosion, and measurement equipment adapted to different process variables and methods.

Previous experience: USTUTT is currently investigating a wide variety of processes for CO_2 free power production and works in close co-operation with industrial partners, research institutes and other universities. Major R&D and Demo-projects where IFK is or was acting as co-ordinator or partner are ENCAP, CASTOR, C3-capture, Oxy-burner, OxyCorr, Oxymode, RECOFUEL, UPSWING, BIOFLAM etc. An early project was the combined EU-APAS programme (COAL-CT92-0002) which was co-ordinated by the IFK. In the JOULE II and the JOULE III programme as well as in the subsequent FP5 and FP6 energy programmes the IFK co-ordinates and participates in several projects, concerning biomass combustion and gasification, biomass/coal co-combustion and zero-emission coal processes. Several national and regional projects complete this work.

Short profile of staff members with major contribution

Dipl.-Ing. Jörg Maier graduated in 1994 from Technical University of Stuttgart and joined the Institute as a scientific assistant. Since 1999 he has been appointed Head of the Department of Power Plant Technology at

IFK. His main activity and expertise is in the areas covered by combustion characteristics of solid fossil and solid recovered fuels, development and testing of primary measures and advanced conversion technologies (pressurised conversion), reduction and prediction of operational problems such as slagging, fouling and corrosion and the co-combustion and incineration of solid recovered fuels and wastes. Apart from his work in different multi-partner projects, his participation as convener in standardisation bodies such as CEN 343 and in other working groups, seminars and the dissemination of R&D is another important aspect of his activities.

Prof: Dr. techn Günter Scheffknecht graduated from the Technical University Vienna, Austria, in Mechanical Engineering in 1982. After his graduation he became an assistant at the Institute of "Technische Wärmelehre" (Thermodynamics) at the Technical University Vienna. Main research topics were the utilisation and storage of low temperature heat. In 1989 he became head of the Research and Technology activities at EVT. In 1996 Prof. Scheffknecht was in charge for Process Engineering and Research and Technology. Later on he was also responsible in the same field for the French boiler activities within the ALSTOM group. In 2004 Prof. Scheffknecht was assigned Director of the Institute of Combustion and Power Plant Technology (IFK) at the University of Stuttgart, Germany.

Partner No:	24
Name of legal entity	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO
Short Name:	TNO

Description of legal entity

TNO is the largest fully independent Research, Development and Consultancy organization in the Netherlands, with a staff of over 4,200 and a total annual turnover of close to 700 million Euros. TNO's primary tasks are to assist and support trade and industry, including SME's, governments and others in innovation and solving problems by rendering services and transferring knowledge and expertise. TNO participates in many EU programs aiming at technological development. TNO is organized in seven thematic core groups. Researchers from three of these core groups have been involved in CCS for nearly 20 years now. The core group Industrial Innovation has been pioneering in CO_2 capture and clean combustion technologies and materials studies for transport. While the core group Energy has been involved in areas such underground CO_2 storage, decision support systems, HSE studies. The core group Built Environment has been has been covering the climate effect of energy transition by means of in-situ and remote, earth observation techniques. TNO is coordinating the Dutch CATO-2 CCS study that started 2 years ago and will last for a minimal other 2 years, involving over 90 million Euros in research investments both from government and industry. The Geological Survey of The Netherlands, part of TNO Energy is involved in the prequalification study of some 12 CCS pilot plants both on- and off-shore The Netherlands, in aquifers and in depleted oil and gas fields.

Short profile of staff members with major contribution

Dr Sven van der Gijp is currently manager of the group Separation Technology of TNO Industrial Innovation, Delft, the Netherlands. This research group focuses on CO_2 capture and sour gas treatment. Van der Gijp is executive board member of two European projects in the field of CO_2 capture, CESAR and DECARBIT. In addition, he is member of the general assembly of the Dutch platform on CCS, CATO-2. Van der Gijp has a MSc in catalysis and a PhD in Material Science.

Dr Earl Goetheer is specialized in organic chemistry and process engineering and has more than 11 years of experience in chemical engineering since. He is technology manager in the field of carbon dioxide capture from flue gasses. Throughout his career he has been involved in several large international EU-projects. He published more than 20 titles in scientific journals, reports, books and proceedings. Next to that he holds more than 15 patents on separation technology.

Peter van Os is Project Manager at TNO Science & Industry with a technical background in Embedded System Development. 20 years of experience as a Hard- and Software engineer, System Engineer and Project Manager for projects in the field of industrial inspection and robotics. Currently: Project Coordinator of the EU FP7 project CESAR.

2.3 Consortium as a whole

2.3.1 Consortium capabilities

The Consortium represents the core of CCS research in Europe. The 24 partners of ECRI have prior experience from previous EU-projects – partly in joint undertakings. All partners have prior experience as project performers in large integrated EU projects, and some have acted as coordinator of large international research ventures, whereby the scientific/technological anchorage and the professional management of the project are ensured. ECRI's Coordinator NTNU, has prior experience from being the coordinator of the ENGAS Research Infrastructure project[7]. Furthermore, the human resources made available to the project cover the full range of proficiencies and multi-disciplinary skills in the fields of science and technology pertaining to thermal energy conversion, gas separation and cleaning, materials, geological storage and monitoring – including HSE (health, safety and environment) – all relating to experimental studies pertaining to the CCS chain.

The Consortium comprises 24 research institutes, 10 universities, and one national research agency. 18 partners are from EU member states (Poland, France, UK, Germany, Italy, Spain, The Netherlands and Greece) and 6 partners belong to associated countries (Norway, Switzerland and Turkey).

The scientific profile of the consortium, and the high number of partners and the manly research facilities, imply a rather comprehensive research environment dedicated to the most pressing research directions within CCS.

No.	Short Name	Country
1	NTNU	Norway
2	ENEA	Italy
3	BBU	Romania
4	BRGM	France
5	CERTH	Greece
6	DUT	Netherlands
7	ETH Zurich	Switzerland
8	IFRF	Italy
9	CIUDEN	Spain
10	IFPEN	France
11	OGS	Italy
12	MATGAS	Spain
13	METU-PAL	Turkey
14	BGS	UK
15	PGI-NRI	Poland
16	SINTEF ER	Norway
17	SINTEF-PR	Norway
18	SINTEF	Norway
19	UEDIN	UK
20	UNOTT	UK
21	TUV	Austria
22	UniRoma1	Italy
23	USTUTT	Germany
24	TNO	Netherlands

Figure 23.1: Territorial distribution of the participants in the ECRI consortium

2.3.2 Involvement of Stakeholders

External Advisors will comprise R&D-providers and industrial players that support the development of CCS in Europe. The advisors will be drawn upon on an ad hoc basis to provide their view on research priorities and relevance of new research topics to be raised by the project.

[7] The EU funded project ENGAS offered access to researchers through an integrated complex of 14 outstanding laboratories focusing on trans-boundary research within the field of environmental gas management. The project was coordinated by NTNU.

A Peer Review Board will be set to select projects to be carried out in facilities affiliated to ECRI. This Board will comprise experts from partners and/or external parties. In addition industrial strakeholders will be invited to participate in the Special Interest Group meetings (activities in WP5 Best Practices & Innovation along the CCS Chain).

2.3.3 Scientific and territorial complementarities

The consortium covers the scientific, technological and engineering areas relevant to the CCS chain. The consortium deemed complementary also in terms of country of origin. Access to country-specific information is considered essential to pursue the objectives of ECRI in terms of financial schemes and legal issues. It is anticipated that a European dimension is obtained, as 13 countries are represented in the Consortium (see Figure).

2.4 Resources to be committed

First it should be stated that the existing resource based of the consortium is substantial and robust. For instance the combined annual operating costs for BRISK installations is around 12 000 000 €, and the total replacement costs for these installations well exceeds 47 000 000 €. Additional support through the I3 instrument thus represents only a fraction of the resources available in normal operation.

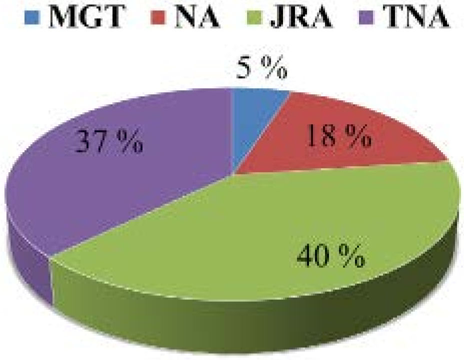


Figure 2.4.1 Budget allocation per activity (MGT: Managment , NA: Networking Activities, TNA:Transational Access Activities

The overall project budget has been allocated for different activities according to the recommended spans suggested by the Commission for I3 instruments. In terms of TA activities, care has been taken to ensure a reasonable distribution between the individual infrastructures. Reasonable budget requests have been made for management and other activities that may not be necessarily at the core of scientific investigations. Provisions for covering travel expenses for external users accessing transnational access has been considered. A standard rate will of (ca. 1000€) will applied for each user-visit, covering airfare, lodging, meal allowance, and local transportation (average duration of visit is around 20 calendar-days;. With an estimated 220 user-visits a total of 450000 Euro has been budgeted, allocated to each partner offering TA.
Travel costs of consortium members (general assemblies, open workshops, short courses, other NA and JRA activities) along with travel costs for external members of the User Selection Panel and Advisory Board are included in the various work packages. A management level description of recources is appended in Table 2.4.1

Subcontracting

Subcontracting is not planned for ECRI.

Table 2.4.1 Management level description of Recourses (indirect costs are excluded)

No	Short name	Person months	Personnel costs	Other direct costs (travel, consum-ables, etc.)	TA costs
1	NTNU*	63.0	663 600	588 000	300 500
2	ENEA	23.0	113 250	44 000	190 000
3	BBU	49.0	88 440	16 650	0
4	BRGM	9.0	62 250	40 000	90 000
5	CERTH	32.5	104 550	29 000	54 900
6	DUT	0.5	3 000	4 400	60 000
7	ETH	16.0	102 000	8 000	80 000
8	IFRF	27.5	146 500	55 000	114 000
9	CIUDEN	36.5	160 900	94 500	200 000
10	IFPEN	22.0	219 600	32 000	300 000
11	OGS	31.0	152 500	66 000	230 000
12	MATGAS	34.0	153 000	20 000	140 000
13	METU-PAL	1.0	3 500	6 600	51 600
14	BGS	32.0	170 368	60 000	250 000
15	PGI	1.5	6 000	10 000	50 000
16	SINTEF ER	17.5	232 750	29 300	230 000
17	SINTEF PR	14.0	182 750	33 000	101 800
18	SINTEF	22.0	238 000	54 000	335 000
19	UEDIN	41.5	233 300	144 000	220 000
20	UNOTT	36.5	187 290	51 000	40 000
21	TUV	41.0	163 098	32 000	154 000
22	UniRoma1	22.0	99 100	73 500	62 500
23	USTUTT	39.0	181 890	28 000	271 400
24	TNO	12.0	105 600	19 500	205 200
SUM		624.0	3 773 236	1 538 450	3 730 900

*28 PM allocated over 4 years for management to NTNU (Coordinator of ECRI) ,

* 385 k€ for travel and accommodation cost for TA users (Budger will be managed by NTNU)

Table 2.4.2: Summary of staff effort

Part. No	Short name	WP1-MGT	WP2-NA1	WP3-NA2	WP4-NA3	WP5-NA4	WP6-NA5	WP7-JRA1	WP8-JRA2	WP9-JRA3	Total
1	NTNU	28	11	2	2	3	1	0	16	0	**63**
2	ENEA	0	0,5	0	1	3	0	18	0	0	**22,5**
3	BBU	0	0,5	0	0	0	0	36	12	0	**48,5**
4	BRGM	0	0,5	0	0	2,5	0	0	0	6	**9**
5	CERTH	0	0,5	0	1	0,5	0	8,5	0	22	**32,5**
6	DUT	0	0,5	0	0	0	0	0	0	0	**0,5**
7	ETH Zurich	0	0,5	0	0	1,5	0	0	14	0	**16**
8	IFRF	0	0,5	2	0	8	0	18	0	0	**28,5**
9	CIUDEN	0	1	0	0	2	0	0	0	33	**36**
10	IFPEN	0	2	0	0	3	2	0	0	15	**22**
11	OGS	0	2	0	1	2	0	0	0	33	**38**
12	MATGAS	0	1	0	0	7	0	8	18	0	**34**
13	METU-PAL	0	0,5	0	0	0,5	0	0	0	0	**1**
14	BGS	0	1	0	0	1	0	0	0	30	**32**
15	PGI-NRI	0	0,5	0	0	1	0	0	0	0	**1,5**
16	SINTEF ER	0	0,5	0	0	0.5	5	11,5	0	12	**29**
17	SINTEF-PR	0	0,5	0	0	1,5	0	0	0	0	**2**
18	SINTEF	0	1	0	0	1,5	0	7,5	0	0	**10**
19	UEDIN	0	1	8	0	1,5	0	0	12	12,5	**35**
20	UNOTT	0	0,5	2	15	0,5	0	0	22	19,5	**59,5**
21	TUV	0	0,5	0	0	0,5	0	32	0	0	**33**
22	UniRoma1	0	0,5	2	0	2,5	0	0	0	18	**23**
23	USTUTT	0	1	0	0	2	0	36	0	0	**39**
24	TNO	0	0,5	0	0	0,5	2	0	9	0	**12**
	Total	**28**	**28,5**	**16**	**20**	**45,5**	**10**	**175,5**	**103**	**201**	**627,5**

Table 2.4.3 Total costs of project and distribution to the single activities and partners

No	Organisation Short Name	Organisation country	Estimated budget (whole duration of the project)							Total receipts	Requested EU Contribution
			RTD	Demon-stration	Coordination	Support	Management	Other	Total		
1	NTNU	NO	333 760	0	885 600	300 500	488 000	0	2 007 860	0	1 828 480
2	ENEA	IT	190 614	0	57 504	190 000	0	0	438 118	0	373 354
3	BBU	RO	160 704	0	5 580	0	0	0	166 284	0	125 504
4	BRGM	FR	119 000	0	45 500	90 000	0	0	254 500	0	206 268
5	CERTH/ISFTA	EL	194 645	0	33 000	54 900	0	0	282 545	0	226 564
6	DUT	NL	0	0	10 192	60 000	0	0	70 192	0	67 918
7	ETH Zurich	CH	140 000	0	31 200	80 000	0	0	251 200	0	212 820
8	IFRF	IT	172 800	0	93 000	114 000	0	0	379 800	0	326 525
9	CIUDEN	ES	250 320	0	56 160	200 000	0	0	506 480	0	437 816
10	IFPEN	FR	320 150	0	118 110	300 000	0	0	738 260	0	611 375
11	OGS	IT	267 100	0	53 575	230 000	0	0	550 675	0	471 520
12	MATGAS	ES	174 000	0	55 200	140 000	0	0	369 200	0	319 720
13	METU-PAL	TR	0	0	12 020	51 600	0	0	63 620	0	62 407
14	BGS	UK	430 412	0	26 361	250 000	11 000	0	717 773	0	599 482
15	PGI-NRI	PL	0	0	19 200	50 000	0	0	69 200	0	67 120
16	SINTEF ER	NO	299 431	0	153 288	230 000	0	0	682 719	0	550 659
17	SINTEF-PR	NO	299 850	0	47 085	101 800	0	0	448 735	0	359 613
18	SINTEF	NO	730 050	0	44 650	335 000	0	0	1 109 700	0	706 308
19	UEDIN	UK	362 395	0	124 556	220 000	0	0	706 951	0	597 512
20	UNOTT	UK	168 660	0	124 128	40 000	0	0	332 788	0	326 698
21	TUV	AT	226 944	0	7 174	154 000	0	0	388 118	0	330 604
22	UniRoma1	IT	199 360	0	57 600	62 500	0	0	319 460	0	263 380
23	USTUTT	DE	299 584	0	27 180	271 400	0	0	598 164	0	520 324
24	TNO	NL	205 080	0	67 860	205 200	0	0	478 140	0	392 073
		Total	5 544 859	0	2 155 723	3 730 900	499 000	0	11 930 482	0	9 984 044

3. Impact

3.1 Expected impact listed in the Work Programme

In response to the Work Programme, ECRI will contribute directly to the **technological development capacity in Europe** and also to the **scientific performance and attractiveness** of the European Research Area. ECRI will contribute to the *Innovation Union* commitment to increase the **potential for innovation**.

Moreover, the Work Programme states as follows:

> *"The aim of Integrating Activities is to bring together and integrate, on a European scale, key research infrastructures, in order to promote their coordinated use and development. This will ensure that European researchers have a wider and more efficient access to the high performing research infrastructures they require to conduct their research, irrespective of the location of the infrastructures."*

In compliance with the above, the objective of ECRI is to establish and strengthen a European coalition of high-ranking R&D providers and research environments, jointly committed to push the scientific and technological frontiers of CCS research (capture and storage of carbon dioxide) beyond the state-of-the-art. In this undertaking, ECRI will combine three categories of integrating activities in a synergistic manner. One of these categories is offering transnational access to researchers – free of charge – to conduct scientific work within the **best CCS research facilities in Europe.** The intention is to enhance the topical research, as needed by the European CCS community. Thus, ECRI will have an immediate impact on European CCS research in terms of **quantity** and **quality**.

The Work Programme furthermore lists the following expected impacts (under its section 1.1.1 *Integrating Activities*), from which the bullet points in italic (below) are extracted:

3.1.1 Structuring impact on ERA

- *"Integrating Activities are expected to have a structuring impact on the ERA and on the way research infrastructures operate, evolve and interact with similar facilities and with their users."*

In particular three challenges are seen to have a structuring impact, as they need to be closely addressed in order to scale up CCS research in Europe. These challenges are **cost, coordination** and the **cross-fertilisation** of ideas.

As the project aims to **help researchers access the best CCS research facilities** (free of charge), the resulting integrating activities will have an impact on the interaction with other (similar) facilities and with their users. This follows from the need for any proposed **research topics to be peer reviewed**, prioritised and selected according to a subset of criteria, as required to ensure topical relevance, quality and complementarity. This will have a structuring impact on the ways in which the research infrastructures operate.

ECRI will also have a structuring impact on the European Research Area in the way that various facilities affiliated with ECRI will be operated, especially with regard to its **governance structure**. ECRI will also **interact with similar initiatives** (i.a. the upcoming ECCSEL project and the new CCS-PNS project) – as appropriate – and with their users.

3.1.2 On synergy, complementary capabilities and innovation potential

- *"Operators of infrastructures will develop synergies and complementary capabilities in such a way as to offer an improved access to researchers and to develop their innovation potential."*

In ECRI, emphasis will be placed on activities at the **forefront of the technological development**, thus enabling industry to strengthen its knowledge base and its technological know-how. Synergy and complementary capabilities will be created in various ways. Of particular interest and relevance are specific **knowledge products** to be developed on the basis of activities relating to transnational access.

Operators of research facilities affiliated with ECRI are desirous of furthering synergies and complementary capabilities in a way that will offer improved access to researchers and to develop their innovation potential. Likewise, a coordinated approach between operators, users and public authorities will give rise to **optimising**

development and fostering increased use. In addition, close interaction among a large number of researchers – active in and around a number of research facilities – will enable cross-disciplinary fertilisation and a wider **sharing of knowledge** and technologies across topical fields, and **between academia and industry**.

3.1.3 On optimising use, and sustainable operation of research infrastructures

- *"Likewise, a more co-ordinated approach between infrastructure operators, users and public authorities will enable to optimise the development, use and sustainable operation of the identified research infrastructures."*

ECRI responds to the Work Programme in terms of **involvement and engagement** of stakeholders. ECRI also responds to Commitment n. 4, as referred to in the Work Programme, i.e. *Opening of Member State operated RIs to the full European user community*. This will enable researchers to make **decisive contributions** to the grand societal challenges in energy supply and climate change via actions. This undertaking requires a **new approach to achieve future goals** in a **cost-effective** manner.

A coordinated approach to increase research within Europe will be met via cross-institutional and transnational access to laboratories and facilities that must **interact within and between countries**. ECRI will foster **commitment to common research priorities** between researchers, industry and EU demonstration projects.

A key task of ECRI will be the **facilitation of knowledge sharing** between members, from members to stakeholders, and to funding bodies such as (inter alia) the European Commission, project proponents, and industry.

Optimising the development, use and sustainable operation will be partly obtained by **avoiding duplication of efforts** and/or poor utilisation of resources. This will be ensured by adjusting research priorities according to industrial needs and EC strategy.

3.1.4 On cross-disciplinary fertilisation and knowledge sharing

- *"In addition, a closer interaction between a large number of researchers active in and around a number of infrastructures will facilitate cross-disciplinary fertilisation and a wider sharing of knowledge and technologies across fields and between academia and industry."*

A main purpose of ECRI is to **facilitate interaction between researchers** from different organisations in order to create new **synergies and motivation**. Throughout the project period ECRI will **offer**

- **access** to world-class laboratory facilities by prominent researchers and reputable industrial players
- **profound CCS expertise**, enhancing thematic discussions on activities within ECRI
- extensive **analytical skills**, allowing and delivering new knowledge that will have the maximum beneficial impact on the field.

In this way the project will have a significant role to play in fostering **cooperation between partners, between stakeholders, and within the European (and global) CCS society**.

Research across the CCS chain will be promoted in order to integrate work that is currently organised in **capture/ transport/storage silos**. Research efforts within specific discipline areas may be pooled in order to overcome institutional barriers that separate researchers within these disciplines.

Furthermore, by drawing upon expertise from within the consortium, analytical approaches can be used to **add value to raw data, knowledge and experience** arising from projects. In this manner ECRI will yield **best practices from lessons learnt**, which will have a huge impact on the European (and global) CCS society. Eventually, this may help accelerating the deployment of CCS in Europe and worldwide.

3.1.5 On innovation of related research infrastructures

- *"Integrating Activities should also contribute to increase the potential for innovation of the related research infrastructures, in particular by reinforcing the partnership with industry, through e.g. transfer of knowledge and other dissemination activities, activities to foster the use of research infrastructures by industrial researchers, involvement of industrial associations in consortia or in advisory bodies."*

At the present critical stage in technology development, the partners believe that it is through the providing of **innovative information** and through the sharing of **advanced laboratories** that issues of techno-economic viability can be quickly addressed and solutions for commercial deployment be devised. This kind of **derisking of the commercial CCS development** – still at laboratory scale – will increase the public confidence in CCS. This may also have an important impact on the **perception of the European Research Area**.

ECRI will make efforts to increase the potential for innovation, in particular by reinforcing links with innovative companies. The focus on innovation is reflected in the description of the objectives of the proposed actions, and is further envisaged in the work packages – particulary in WP NA5 (Task NA5.3 Managing innovation – creating synergy).

ECRI contributes to the innovation objectives in two different ways:

1. by **integrating activities within world-class CCS research facilities** aimed at offering transnational access and conducting joint research, thus enabling researchers to generate substantial knowledge which can lead to **new innovative solutions**, such as more efficient products, processes and services relating to CCS, and thereby help to **address societal challenges** – especially the issues of **climate change** and **security of energy supply**. Innovation is reflected in the stated objective of ECRI and the scope of the specific work packages, as well as in the expected impact statements.
2. by **increasing the potential for innovation** within the research infrastructures associated with ECRI, in particular by **reinforcing links with companies** that drive innovation. This includes activities and partnership with industry, such as **transfer of knowledge** and other dissemination activities. ECRI will also carry out activities involving industrial researchers, and will include industrial players in **reference group**s and for **peer review**.

3.1.6 On innovation reflected in the objectives of ECRI

- *The focus on innovation should be reflected in the description of the objectives of the proposed actions.*

In prioritising research activities to be carried out in ECRI, two main directions are emphasised, i) the **academic research** (generic/fundamental) and ii) **innovation** (i.e. applied, operational, pre-normative research). Projects belonging to the latter direction will be ranked according to their potentiality and capability for **reducing the overall energy penalty** and for **lowering the levelised cost** of the CCS chain, and also for **ramping up the speed** and capacity needed **for CCS to become material**. These aspects are all research topics that call for innovation with **emphasis placed on energy penalty and cost**.

3.1.7 On innovation and education

For ECRI to reside within the knowledge triangle (Figure 6), it is necessary to place **emphasis on education and innovation**. Hence, ECRI will make research facilities and services systematically **available for higher education and training**. This will have a significant **impact on the next generation of engineers and researchers** specialising in topics related to CCS. As these persons will subsequently make use of their experience and skills, they will contribute to enhance the European knowledge base – scientifically and also technologically. They will contribute to the ability of developing industry and to **bringing forward CCS for successful utilisation** by society.

In this manner, the added value created via ECRI may become quite substantial.

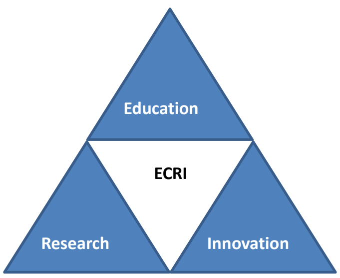


Figure 6: The knowledge triangle[8]

[8] Source: A vision for strengthening world-class research infrastructures in the ERA, Report of the Expert Group on Research Infrastructures. 2010

3.1.8 Socio-economic impact

The project addresses socio-economic issues in various ways, such as the needs and perception of knowledge, scientific and technological development, education and training. In this context, **collaboration** appears to be quite essential, especially **within the consortium, and transnationally on a large scale within Europe**. In the course of the project, collaboration may be extended to **international actions outside Europe** – especially in consideration of Australia, China and USA, aimed at creating synergy – partly in the generation of specific knowledge, and partly in broaching CCS closer to end-users.

In this endeavour, the project will pave the ground for activities that will contribute to employ graduates (at MSc and PhD level) trained in ECRI-affiliated facilities, and students specialising in CCS. Secondly, the project will provide **knowledge and innovation** to be **commercialised by industries**, which will in turn **create job opportunities**.

The **impact of knowledge** can be measured by the number of publications of **scientific papers** in impact factor journals and other periodicals, as well as the value granted to external researchers through the open access policy of ECRI. Likewise, the **impact of development** can be recognised via the **number of national and international patents**, and also by the number of **technologies developed and transferred** (including prototypes, methodologies and designs). Finally, the **impact of knowledge transfer** and collaborations is identifiable via the **number of collaborative projects**, the volume of **research contracts,** competitive funding and/or international grants.

3.2 Strategic impact

3.2.1 Impact of EU policy on CCS

In meeting the upcoming urgency and need for technological development and improvement within CCS, it becomes obvious that **moving the frontier** in technology from the state-of-the-art **is far beyond the capacity of a single nation**. Therefore, the principal aim of the Work Programme – through the current call (*INFRA-2012-1.1.18*, Integrating Activities on CCS, to which ECRI responds), and a parallel call (*INFRA-2012-2.2.3*, a new CCS Research Infrastructure) aimed at establishing the European Carbon Dioxide and Storage Laboratory, ECCSEL, – is to **ensure that the policy goals** of the European Union **can be achieved,** as concerns the safe and swift commercial deployment of CCS within Europe by 2020 and beyond.

Through its mission, ECRI will **support industrial initiatives of implementing CCS** pursuant to the **European roadmap** and the **SET-Plan**. From a SET-Plan perspective, ECRI will promote efficiency within the European Research Area (ERA) and it will link to the European Energy Research Alliance (EERA). The new *CCS Integrating Activities* (i.e. this proposal) jointly with the new *CCS Research Infrastructure* (i.e. a new ECCSEL-RI proposal) and the *CCS Demo Sectretariat* (CCS PNS) may have a reciprocal impact on knowledge and capacity building in the interaction between research and the commercial deployment of CCS.

The European and international impact of accelerating the development of CCS for commercial use complies to the **dedication of significant and specific CCS legislation** (i.e. the CCS Directive and amendments to other Directives), the granting of significant funds to CCS commercial demonstration (EERP and NER300) and numerous CCS research projects, as well as the inclusion of CCS within the European emissions trading system (EU ETS). ECRI is considered to have a **key role** to play in **initiating this acceleration**. The most obvious reason is that granting access to a **pool of test facilities** on a **time-sharing basis** will **enhance the intensity and value of experimental research**.

Seen as a **toolbox for joint programming** within the EERA CCS Joint Programme, ECRI may boost innovation through joint and extended use of the new research laboratory infrastructure, and also respond to the industrial needs via ZEP and other European CCS initiatives.

3.2.2 Impact on the European approach

The idea of ECRI is to **enable excellent researchers** from all regions of Europe (and, where appropriate, from third countries) to **undertake research** that requires the **most advanced equipment and facilities**. The partners are open to discussing **actions with** other nations if it can be justified that this will add value to the results (synergy).

The project will imply a European approach, rather than a local or national approach, as ECRI is based on a **pan-European collection of CCS research laboratories** and test sites, and it will direct significant investments into new advanced research laboratories devoted to CCS. ECRI will therefore benefit from having a pre-existing collection of internal CCS expertise.

On a medium-to-long term basis ECRI will have additional impact on

- **European competition**, by its contribution to the acceleration of CCS towards industrial exploration and deployment
- **innovation**, by forming a breeding ground 7 invention, exploration and pre-commercial testing of CCS techniques and technologies
- the **regulatory framework**, pertaining to safety and environmental aspects of CCS and also the working environment (i.e. HSE issues)
- **mobility and joint programming** of European CCS resources

Moreover, via its consortium, ECRI will be capable of collecting relevant **information on institutional research projects world-wide** – and on the majority of all CCS-focused networks and groups. ECRI will also be well positioned to **assess strategic impacts on or of CCS in a societal context**.

3.2.3 Impact on the issue of climate change

The United Nations ranks ***climate change* as the most severe issue of our time**. Nonetheless, in some nations the issue of *security of energy supply* appears to represent an even more severe concern. Since energy demand is believed to grow in the foreseeable future, these issues can hardly be combined unless a larger part of the **global energy is provided with less greenhouse gas emissions**.

CCS is seen as a key technology in tackling climate change. The IEA anticipates that CCS will contribute 19% of the emissions reductions required world-wide by 2050 (Figure 7). The IEA further anticipates that the level should be as high as 24% within OECD Europe.[9] (It should be noted, however, that in OECD Europe this does not solely apply to the power sector, as **50% of the reductions must be achieved within industry**.)

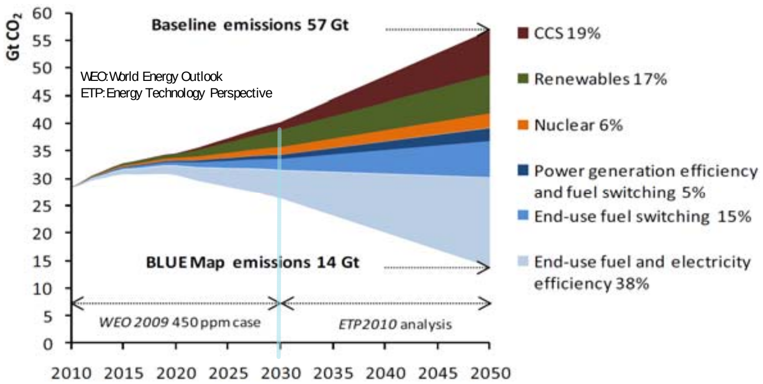


Figure 7: IEA scenario for abatement of world energy-related CO_2 emissions (Source: IEA 2010, Energy Outlook)

IEA analyses also indicate that without CCS, the overall cost of reducing emissions to 2005 levels by 2050 will increase significantly.

Against the challenge of this back-drop the integrating activities of ECRI will have a significant impact on the pace of development of second generation CCS technology.

[9] IEA Technology Perspectives, 2010, page 333

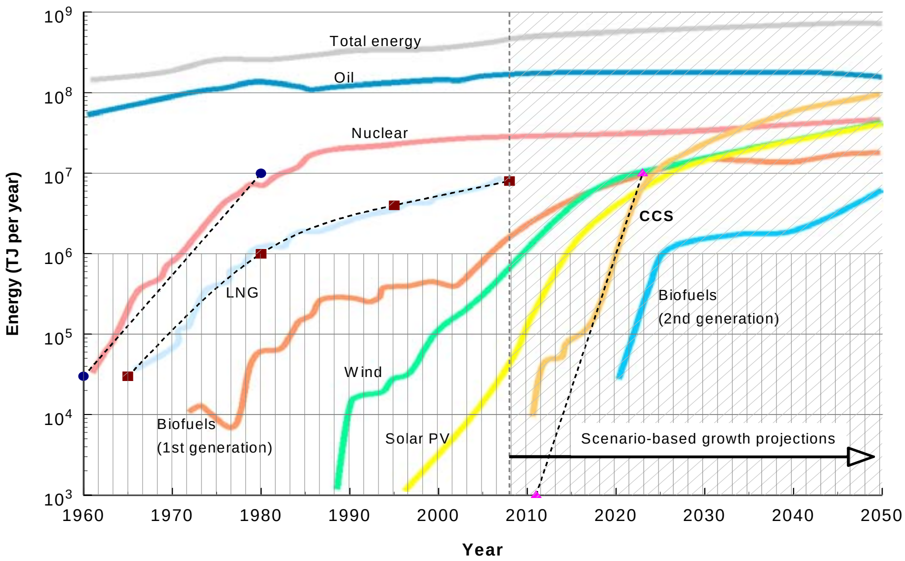


Figure 8: Timeline for broaching new energy technology into society

In order for ECRI to have the expected impact in Europe, **concepts for mitigating the CO_2 emission in industrial processes** must become an essential **part of the project**.

History suggests that at least three decades are needed from a successful energy technology becomes available (when delivering 1000 TJpa) until it is material (when reaching 1% of the global energy mix) [10]. In contrast, to meet the 450 ppm scenario of the IEA[11] **CCS must be developed and deployed within just one decade**. This represents an unprecedented challenge that calls for the highest political leverage to **mobilise the required capacities and financial resources**[12].

ECRI responds to the expressed needs for further technological development to **ensure that CCS can be deployed at a large scale in Europe** and elsewhere, to cut the global emissions of greenhouse gases by **50-80% by 2050**.

According to climate modelling, this tremendous reduction is necessary to limit global warming by 2°C - as pronounced by the UN and the IEA (made up by the Blue Map scenario of Figure 5 – and the CCS trajectory of Figure 6). Although this reduction can be regarded as nothing but an unprecedented challenge, ECRI **responds directly to the core of this issue**.

3.2.4 Impact - external factors

Discussions with research groups in Convergence Regions will lead to a broadening of the partnership and the research infrastructure managed by ECRI. Furthermore, in terms of other national and international activities, the Consortium is uniquely placed to **interpret, understand and engage** with all **CCS groups** involved in experimental research actions.

The outcome of the project will rely heavily on the **participation, openness, and trust** of the partners and stakeholders. Potential obstacles will be further analysed as part of risk assessment.

[10] Kramer, G.J.; Haigh, M.: ”No quick switch to low-carbon energy”. Nature, Vol 462, 3 December 2009

[11] Blue Map, consistent with the 2°C target by 2050

3.3 Dissemination and/or exploitation of project results, and management of intellectual property

The **outcome of the project** will be the result of three integrating activities (NA, TA, and JRA) and stem from three main topical areas (i.e. energy conversion, CO_2 separation, and CO_2 storage). Hence, a matrix will be formed for the reporting of topical research on a typological basis. As all topics addressed will be carried out under the condition that the results shall be public, this matrix will be regularly updated, and made available on the web-site of the project. It will include pointers to abstract and summary of these reports.

Furthermore, the full reports will be made available to European players within the CCS community on request. In this way the addressee of a report will be registered, thus enabling ECRI partners to follow up the report in terms of subsequent commercial use.

ECRI partners will also be actively involved in publicising results at scientific conferences, and in international journals or periodicals with peer review. Dissemination will also take place directly in workshops with industries or in meetings with stakeholders.

Industries will be invited to take part in specific research events, either by becoming part of specific TA projects to make use of the research facilities directly or indirectly, or they may participate in workshops organised by ECRI.

Intellectual property will be handled as background information belonging to the partner that is entitled to such intellectual property rights.

4. Ethical Issues

In pursuing the objectives of ECRI, no fundamental rights are contravened. The undertakings of the project consist mainly of technical, strategic and organisational work which will not involve any human subjects, personal data or animals. The work will be performed in Austria, Norway, France, Germany, Greece, Netherlands, Poland, Romania, Spain, Switzerland, Turkey,. United Kingdom. The focus is on setting up a European research infrastructure within CO_2 capture and storage. The technologies to be addressed by ECRI will not be used for any kind of military purpose or terrorism.

Nonetheless, ethics will be included as a continuous topic to ensure that ethical challenges are discussed and that the required guidance is provided. The project shall be conducted based on the basic values: honesty, generosity, courage and solidarity and in accordance with applicable laws and regulations. This is the responsibility of the Executive Board, the Project Management and the individuals that constitute the project organisation at all levels.

Obviously, efforts to reduce the level of greenhouse gas (GHG) emissions may have a direct positive impact on environment and society. In particular, ECRI conforms to the Green Paper[13]: *A European Strategy for Sustainable, Competitive and Secure Energy* issued by the Commission in 2006. CO_2 capture and storage can be one of the main avenues to achieve the reduction targets for the medium to long-term reduction of GHG emissions. Furthermore, the technology has the potential for improving the competitive edge of the European industry. CCS also responds to the issue of security of energy supply, based on own – or alternative – fossil resources.

However, some related ethical issues may arise basically owing to a growing concern of depletion of fossil fuel reserves and limited knowledge as concerns consequences of underground storage of captured CO_2. As international regulations become stricter pursuant to the climatic change issue and large efforts are put into investigating the basis for these concerns, capture concepts are prone to attract more interest and new solutions are explored for low-carbonaceous power generation. Today, even environmentalists and several NGOs promote CO_2 capture and storage as a better choice than any alternative for large-scale power generation. Still, ECRI acknowledges that an uncertainty exists. This uncertainty represents an opportunity to inform about technical progress made within the frames of political decisions to grant the achievement of safe CO_2 storage.

[13] http://europa.eu/documents/comm/green_papers/pdf/com2006_105_en.pdf

Ethical issues table

	Research on Human Embryo/ Foetus	YES	Page
	Does the proposed research involve human Embryos?		
	Does the proposed research involve human Foetal Tissues/ Cells?		
	Does the proposed research involve human Embryonic Stem Cells (hESCs)?		
	Does the proposed research on human Embryonic Stem Cells involve cells in culture?		
	Does the proposed research on Human Embryonic Stem Cells involve the derivation of cells from Embryos?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

	Research on Humans	YES	Page
	Does the proposed research involve children?		
	Does the proposed research involve patients?		
	Does the proposed research involve persons not able to give consent?		
	Does the proposed research involve adult healthy volunteers?		
	Does the proposed research involve Human genetic material?		
	Does the proposed research involve Human biological samples?		
	Does the proposed research involve Human data collection?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

	Privacy	YES	Page
	Does the proposed research involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?		
	Does the proposed research involve tracking the location or observation of people?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

	Research on Animals	YES	Page
	Does the proposed research involve research on animals?		
	Are those animals transgenic small laboratory animals?		
	Are those animals transgenic farm animals?		
	Are those animals non-human primates?		
	Are those animals cloned farm animals?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

	Research Involving non-EU Countries (ICPC Countries)	YES	Page
	Is any material used in the research (e.g. personal data, animal and/or human tissue samples, genetic material, live animals, etc) : a) Collected and processed in any of the ICPC countries?		
	b) Exported to any other country (including ICPC and EU Member States)?		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

	Dual Use	YES	Page
	Research having direct military use		
	Research having the potential for terrorist abuse		
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	x	

Pag. 839

5. Consideration of gender aspects

Per se, capture and storage of CO_2 is insensitive to gender in the sense that each individual may have its own concern as to climate change and to the impact climate change may have on future energy systems and societal development.

ECRI is devoted to networking, transnational access and related services as well as joint research activities. Hence, the project will deal essentially with the providing and facilitation of specific knowledge about the needs of European CCS research. Under this commitment, the project does not – per se – deal with the gender issue on scientific terms. However, women still represent a low percentage (roughly 15%) of industrial researchers within the European Union. Industrial and technological research within energy and electrical engineering exhibits the lowest participation of women (next to civil engineering). Therefore, ECRI is desirous of seeking the involvement of women within European CCS research projects (the stakeholder) and within the ECRI cluster made up by dispersed research facilities to promote gender equality. In this undertaking, the project, its consortium and the participants' organisations are all committed to promote gender equality and provide equal opportunities between men and women.

Within the project, several female representatives will be actively involved. The presence of female WP-leaders provides an important stimulus towards the increased participation of women. It is envisaged that active participation of female researchers and leaders will be promoted in order to ensure that the teams within the research facilities remain balanced and efficient.

It is furthermore proposed that at least 50% of the Executive Committee (ExCo) meetings and 30% of the WP-meetings will be scheduled as teleconferences or Internet meetings in order to reduce travelling, as this would help to reconcile work and private life. Also, use of a gender-neutral language is stated as a general rule in all documents prepared and disseminated by ECRI.

Moreover, in consideration of information intended for the public outreach to be made available by ECRI, it will be kept in mind that the perception of technology, environment and risk issues in a societal (and geopolitical) context is prone to vary by gender – as evidenced by recent European perception studies on CCS. This experience calls for special attention when establishing communication strategies about CO_2 capture, transport and storage. Essential to creating awareness towards CCS is the providing of relevant and objective knowledge via public information, targeting the attitudes and concerns that occur between the genders.

6. Appendix I (Transnational Access Cost Sheets)

Pag. 841

Appendix I

Calculation of Unit Costs

for Transnational Access

Pag. 841

Calculation of the Unit Cost for Transnational Access

Participant number	1	**Organisation short name**		NTNU	
Short name of Infrastructure	**Membrane Lab**	**Installation number**	**1.1**	**Short name of Installation**	**MEMB-FAB**
Name of Installation	**Membrane fabrication**			**Unit of access**	**weeks**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		120000
	Maintenance of facilities during the project period (48 months)		18000
	Consumables (gases, chemicals, etc)		80000
	Software licences (LabView, GC, etc)		10 000.00
	Analysis costs		
	Total A		**228 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)		300 000.00
	Technical staff (PM cost 30 k€)		300 000.00
	Analytical costs		
	Total B		**600 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 57960**	57 960.00
D. Total estimated access eligible costs = A+B+C			885 960.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			180
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**4922**
H. Quantity of access offered under the project (over the whole duration of the project)			9
I. **Access Cost charged to the project [3][4] = G x H**			**44 298.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**1**	**Organisation short name**	**NTNU**		
Short name of Infrastructure	**Membrane Lab**	**Installation number**	**1.2**	**Short name of Installation**	**MEMB-PERM**
Name of Installation	**Membrane permeation test**			**Unit of access**	**weeks**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		120000
	Maintenance of facilities during the project period (48 months)		21200
	Consumables (gases, chemicals, etc)		90000
	Software licences (LabView, GC, etc)		10 000.00
	Analysis costs		
	Total A		**241 200.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)		300 000.00
	Technical staff (PM cost 30 k€)		300 000.00
	Analytical costs		
	Total B		**600 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **58884**	58 884.00
D. Total estimated access eligible costs = A+B+C			900 084.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			180
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**5000.47**
H. Quantity of access offered under the project (over the whole duration of the project)			9
I. **Access Cost charged to the project** [3][4] **= G x H**			**45 004.23**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 844

Calculation of the Unit Cost for Transnational Access

Participant number	**1**	**Organisation short name**	**NTNU**		
Short name of Infrastructure	**Absorption Lab**	**Installation number**	**1.3**	**Short name of Installation**	**ABSKIN**
Name of Installation	**Kinetic Lab**			**Unit of access**	**weeks**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		30000
	Maintenance of facilities during the project period (48 months)		
	Consumables (gases, chemicals, etc)		9000
	Software licences (LabView, GC, etc)		
	Analysis costs		
	Total A		**39 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)		100 000.00
	Technical staff (PM cost 30 k€)		240 000.00
	Analytical costs		10 000.00
	Total B		**350 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**27230**	27 230.00
D. Total estimated access eligible costs = A+B+C			416 230.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			180
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2312.39**
H. Quantity of access offered under the project (over the whole duration of the project)			30
I. **Access Cost charged to the project [3][4] = G x H**			**69 371.70**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 844

Pag. 845

Calculation of the Unit Cost for Transnational Access

Participant number	**1**	**Organisation short name**	**NTNU**		
Short name of Infrastructure	**Absorption Lab**	**Installation number**	**1.4**	**Short name of Installation**	**ABSDEG**
Name of Installation	**degradation**			**Unit of access**	**weeks**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		30000
	Maintenance of facilities during the project period (48 months)		
	Consumables (gases, chemicals, etc)		9000
	Software licences (LabView, GC, etc)		
	Analysis costs		
	Total A		**39 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)		65 000.00
	Technical staff (PM cost 30 k€)		120 000.00
	Analytical costs		50 400.00
	Total B		**235 400.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**19208**	19 208.00
D. Total estimated access eligible costs = A+B+C			293 608.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			180
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1631.16**
H. Quantity of access offered under the project (over the whole duration of the project)			30
I. **Access Cost charged to the project [3][4] = G x H**			**48 934.80**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 845

Calculation of the Unit Cost for Transnational Access

Participant number	**1**	**Organisation short name**		**NTNU**	
Short name of Infrastructure	**Absorption Lab**	**Installation number**	**1.5**	**Short name of Installation**	**ABSEQ**
Name of Installation	**VLE laboratory**			**Unit of access**	**weeks**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		30000
	Maintenance of facilities during the project period (48 months)		
	Consumables (gases, chemicals, etc)		9000
	Software licences (LabView, GC, etc)		
	Analysis costs		
	Total A		**39 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)		100 000.00
	Technical staff (PM cost 30 k€)		240 000.00
	Total B		**340 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**26530**	26 530.00
D. Total estimated access eligible costs = A+B+C			405 530.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			180
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2252.94**
H. Quantity of access offered under the project (over the whole duration of the project)			30
I. **Access Cost charged to the project [3][4] = G x H**			**67 588.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**2**	**Organisation short name**		**ENEA**	
Short name of Infrastructure	**ZECOMIX**	**Installation number**	**2.1**	**Short name of Installation**	
Name of Installation	**Zero Emission COal MIXed technology**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)	0.00
	Maintenance of facilities during the project period (48 months)	60 000.00
	Consumables (gases, chemicals, etc)	74 000.00
	Software licences (LabView, GC, etc)	40 000.00
	Total A	**174 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 8,25 k€)	83	684 750.00
	Technical staff (PM cost 4,5 k€)	114	513 000.00
	Total B		**1 197 750.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**96022.5**	89 000.00
D. Total estimated access eligible costs = A+B+C			1 460 750.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1825.94**
H. Quantity of access offered under the project (over the whole duration of the project)			60
I. **Access Cost charged to the project** [3][4] **= G x H**			**109 556.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	2	**Organisation short name**		ENEA	
Short name of Infrastructure	ENEA CCS PLATFORMS	**Installation number**	02.feb	**Short name of Installation**	SOTA CCS
Name of Installation	COHYGEN-PILOT + SOTALABS			**Unit of access**	days

A. **Estimated direct eligible costs of providing access within the project life-time excluding personnel costs**	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		0.00
	Maintenance of facilities during the project period (48 months)		88 000.00
	Consumables (gases, chemicals, etc)		100 000.00
	Software licences (LabView, GC, etc)		25 000.00
	Total A		**213 000.00**
	of which subcontracting (A')		
B. **Estimated personnel direct eligible costs needed to provide access within the project life-time**	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 9 k€)	100	900 000.00
	Technical staff (PM cost 5 k€)	148	740 000.00
	Total B		**1 640 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		max 129710	105 000.00
D. Total estimated access eligible costs = A+B+C			1 958 000.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			810
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2417.28**
H. Quantity of access offered under the project (over the whole duration of the project)			33
I. **Access Cost charged to the project [3][4] = G x H**			**79 770.24**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**4**	**Organisation short name**		**BRGM**	
Short name of Infrastructure	**Technology Platform**	**Installation number**	**4.1**	**Short name of Installation**	**Montmiral**
Name of Installation	**Technological plateform Montmiral**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	consumables and electricity for pumps	100 000.00
	travel and accomodation of technician and scientist	100 000.00
	Total A	**200 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher)	16	78 720.00
	Technical staff	30	221 400.00
	Total B		**300 120.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1] **max 35008.4**	35 008.40
D. Total estimated access eligible costs = A+B+C	535 128.40
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time	263
F. Fraction of the Unit cost to be charged to the project [2]	100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)	**2038.12**
H. Quantity of access offered under the project (over the whole duration of the project)	44
I. **Access Cost charged to the project [3][4] = G x H**	**89 677.28**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	5	**Organisation short name**		CERTH/ISFTA	
Short name of Infrastructure	**Storage**	**Installation number**	**5.1**	**Short name of Installation**	
Name of Installation				**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)		12 000.00
	Consumables (gases, chemicals, etc)		20 000.00
	Software licences (Eclipse, Gatecycle, gProms, TOUGHREACT)		28 000.00
	Total A		**60 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher)	12	60 000.00
	Technical staff	40	140 000.00
	Total B		**200 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **18200**	18 200.00
D. Total estimated access eligible costs = A+B+C			278 200.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			490
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**567.76**
H. Quantity of access offered under the project (over the whole duration of the project)			70
I. **Access Cost charged to the project [3][4] = G x H**			**39 743.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**5**	**Organisation short name**		**CERTH**	
Short name of Infrastructure		**Installation number**	**5.2**	**Short name of Installation**	
Name of Installation				**Unit of access**	**days**

		Person-Months	Eligible Costs (€)
A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)		30 000.00
	Consumables (gases, chemicals, etc)		24 000.00
	utilities		6 000.00
	Total A		**60 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher)	12	70 000.00
	Technical staff	40	60 000.00
	Total B		**130 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 13300**	13 300.00
D. Total estimated access eligible costs = A+B+C			203 300.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			490
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**414.9**
H. Quantity of access offered under the project (over the whole duration of the project)			36
I. **Access Cost charged to the project [3][4] = G x H**			**14 936.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 852

Calculation of the Unit Cost for Transnational Access

Participant number	**6**	**Organisation short name**		**DUT**			
Short name of Infrastructure	**Thermolab**	**Installation number**	**6.1**	**Short name of Installation**	**Laboratory for thermodynamic experiments**		
Name of Installation	**Laboratory for thermodynamic experiments**			**Unit of access**	**days**		

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		30 000.00
	Maintenance of facilities during the project period (48 months)		200 000.00
	Consumables (gas , steam)		100 000.00
	Software licences (LabView, GC, etc)		1 000.00
	Total A		**331 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 80 k€)	6	480 000.00
	Technical staff (PM cost 30 k€)	10	300 000.00
	Total B		**780 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**77770**	77 770.00
D. Total estimated access eligible costs = A+B+C			1 188 770.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			750
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1585.03**
H. Quantity of access offered under the project (over the whole duration of the project)			38
I. **Access Cost charged to the project [3][4] = G x H**			**60 231.14**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 852

Pag. 853

Calculation of the Unit Cost for Transnational Access

Participant number	**7**	**Organisation short name**	**ETHZ**		
Short name of Infrastructure	**GS Lab**	**Installation number**	**7.1**	**Short name of Installation**	**2 PSA**
Name of Installation	**Gas Separation lab**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Consumables (gases, chemicals, etc)	120 000.00
	Maintenance of facilities	17 000.00
	Energy	40 000.00
	Cleaning	31 000.00
	Total A	**208 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 45 k€)	8.4	378 000.00
	Technical staff (PM cost 36 k€)	3	108 000.00
	Total B		**486 000.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max 48580**	48 580.00
D. Total estimated access eligible costs = A+B+C		742 580.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time		1 000
F. Fraction of the Unit cost to be charged to the project [2]		100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)		**742.58**
H. Quantity of access offered under the project (over the whole duration of the project)		54
I. **Access Cost charged to the project [3][4] = G x H**		**40 099.32**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 853

Calculation of the Unit Cost for Transnational Access

Participant number	**7**	**Organisation short name**		**ETHZ**	
Short name of Infrastructure	**ADS EQ**	**Installation number**	**7.2**	**Short name of Installation**	**ADS EQ**
Name of Installation	**Adsortpion Equilibrium**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Consumables (gases, chemicals, etc)		93 000.00
	Maintenance of facilities		15 000.00
	Energy		32 000.00
	Total A		**140 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor)	12	250 000.00
	Technical staff (PM cost 36 k€)	1	36 000.00
	Total B		**286 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**29820**	29 820.00
D. Total estimated access eligible costs = A+B+C			455 820.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			1 000
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**455.82**
H. Quantity of access offered under the project (over the whole duration of the project)			44
I. **Access Cost charged to the project [3][4] = G x H**			**20 056.08**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 855

Calculation of the Unit Cost for Transnational Access

Participant number	**7**	**Organisation short**		**ETHZ**	
Short name of Infrastructure	**Mineralization**	**Installation number**	**7.3**	**Short name of Installation**	**FGM**
Name of Installation	**Flue Gas Mineralization Unit**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Consumables (gases, chemicals, etc)	70 000.00
	Maintenance of facilities	99 000.00
	Energy	32 000.00
	Total A	**201 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 45 k€)	4.8	170 000.00
	Technical staff (PM cost 36 k€)	2	69 000.00
	Total B		**239 000.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1] **max** **30800**	30 800.00
D. Total estimated access eligible costs = A+B+C	470 800.00
(i.e. both internal and external) within the project life-time	1 000
F. Fraction of the Unit cost to be charged to the project [2]	100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)	**470.8**
H. Quantity of access offered under the project (over the whole duration of the project)	43
I. **Access Cost charged to the project [3][4] = G x H**	**20 244.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

If not, insert 100%.

to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 855

Calculation of the Unit Cost for Transnational Access

Participant number	**8**	**Organisation short name**	**IFRF**		
Short name of Infrastructure	**L. E. A.**	**Installation number**	**8.1**	**Short name of Installation**	**IPFR**
Name of Installation	**Isothermal Plug Flow Reactor**			**Unit of access**	**week**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)		40 000.00
	Consumables (gases, chemicals, etc)		100 000.00
	Laboratory consumable for sample characterisation		100 000.00
	Total A		**240 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Operators, technicians, (4000 € /MM)	24	96 000.00
	Reseacher (7200 €/MM)	16	115 200.00
	Total B		**211 200.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**31584**	31 584.00
D. Total estimated access eligible costs = A+B+C			482 784.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			40
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**12069.6**
H. Quantity of access offered under the project (over the whole duration of the project)			2
I. **Access Cost charged to the project [3][4] = G x H**			**24 139.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**8**	**Organisation short name**		**IFRF**	
Short name of Infrastructure	**L. E. A.**	**Installation number**	**8.2**	**Short name of Installation**	**FOSPER**
Name of Installation	**Fornace Sperimentale**			**Unit of access**	**day**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance		120 000
	Utilities		100 000
	Fuel (coal or gas with max cost 1 €/kg)		240 000
	Oxygen		240 000
	Costs are related to oxy-combustion tests with innovative burners,		
	four weeks of test per year, four days available for test per week		
	Total A		**700 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Technical operator, investigator (4000 € /MM)	36	144 000.00
	Researcher (7200 €/MM)	12	48 000.00
	These costs include plant preparation, burner		
	installation and plant cleaning after the trials		
	In-flame measurements are included		
	Total B		**192 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **62440**	62 440.00
D. Total estimated access eligible costs = A+B+C			954 440.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			64
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**14913.13**
H. Quantity of access offered under the project (over the whole duration of the project)			7
I. **Access Cost charged to the project [3][4] = G x H**			**104 391.91**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**9**	**Organisation short**		**CIUDEN**	
Short name of Infrastructure	***es.CO2***	**Installation number**	**9.1**	**Short name of Installation**	**Transport Rig**
Name of Installation	**Transport Rig**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Installations space rental fees during the project period (48 months)		0.00
	Maintenance of facilities during the project period (48 months)		2 235 628.90
	Consumables (gases, material probes, energy, etc)		3 353 443.35
	Analysis and tests		32 000.00
	Certificate on financial statements and bank guarantee		2 000.00
	Protection of knowledge		1 000.00
	Total A		**5 624 072.25**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff and postgraduate staff	12	90 585.00
	Technical staff	36	172 935.00
	Manual Labour	39	112 407.75
	Total B		**375 927.75**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 420000**	420 000.00
D. Total estimated access eligible costs = A+B+C			6 420 000.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			600
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**10700**
H. Quantity of access offered under the project (over the whole duration of the project)			10
I. **Access Cost charged to the project [3][4] = G x H**			**107 000.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**9**	**Organisation short**		**CIUDEN**	
Short name of Infrastructure	***es.CO2***	**Installation number**	**9.2**	**Short name of Installation**	**CCS Lab**
Name of Installation	**CCSLAB**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Installations space rental fees during the project period (48 months)		0.00
	Maintenance of facilities during the project period (48 months)		680 000.00
	Consumables (gases, chemicals, etc)		560 000.00
	Software licences		90 000.00
	Total A		**1 330 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff and postgraduate staff	4.8	36 234.00
	Technical staff	52.8	253 638.00
	Manual Labour	52.8	152 182.80
	Total B		**442 054.80**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 124043.836**	124 043.84
D. Total estimated access eligible costs = A+B+C			1 896 098.64
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2370.12**
H. Quantity of access offered under the project (over the whole duration of the project)			20
I. **Access Cost charged to the project [3][4] = G x H**			**47 402.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**9**	**Organisation short**		**CIUDEN**	
Short name of Infrastructure	***es.CO2***	**Installation number**	**9.3**	**Short name of Installation**	**PISCO2**
Name of Installation	**PISCO2**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		0.00
	Maintenance of facilities during the project period (48 months)		320 000.00
	Consumables (gases, chemicals, etc)		580 000.00
	Software licences (LIMS)		32 000.00
	Tests & Analysis		320 000.00
	Total A		**1 252 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Technical staff	39	187 346.25
	Manual Labour	9.6	27 669.60
	Total B		**215 015.85**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 102691.1095**	102 691.11
D. Total estimated access eligible costs = A+B+C			1 569 706.96
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1962.13**
H. Quantity of access offered under the project (over the whole duration of the project)			23
I. **Access Cost charged to the project [3][4] = G x H**			**45 128.99**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**10**	**Organisation short name**		**IFPEN**	
Short name of Infrastructure	**TransProS**	**Installation number**	**10.1**	**Short name of Installation**	**TransProS**
Name of Installation	**Transport Properties for CO2 Storage**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory cost during the project period		1 045 051.00
	Total A		**1 045 051.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor)	42.56	520 968.00
	Technical staff	63.84	496 062.00
	Total B		**1 017 030.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 144345.67**	144 345.67
D. Total estimated access eligible costs = A+B+C			2 206 426.67
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			640
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**3447.54**
H. Quantity of access offered under the project (over the whole duration of the project)			37
I. **Access Cost charged to the project [3][4] = G x H**			**127 558.98**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**10**	**Organisation short name**		**IFPEN**	
Short name of Infrastructure	**CRC**	**Installation number**	**10.2**	**Short name of Installation**	**CRC**
Name of Installation	**Caprock Characterization**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory cost during the project period		1 043 487.00
	Total A		**1 043 487.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor)	63.84	781 453.00
	Technical staff	42.56	330 708.00
	Total B		**1 112 161.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 150895.36**	150 895.36
D. Total estimated access eligible costs = A+B+C			2 306 543.36
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			720
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**3203.53**
H. Quantity of access offered under the project (over the whole duration of the project)			40
I. **Access Cost charged to the project [3][4] = G x H**			**128 141.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**10**	**Organisation short name**		**IFPEN**	
Short name of Infrastructure	**U544**	**Installation number**	**10.3**	**Short name of Installation**	
Name of Installation	**mini-pilot absorption plant**			**Unit of access**	

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		677 528.00
	Total A		**677 528.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor)	15.48	189 488.00
	Technical staff (operation)	41.6	323 249.00
	Total B		**512 737.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 83318.55**	83 318.55
D. Total estimated access eligible costs = A+B+C			1 273 583.55
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			1 120
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1137.13**
H. Quantity of access offered under the project (over the whole duration of the project)			39
I. **Access Cost charged to the project [3][4] = G x H**			**44 348.07**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**11**	**Organisation short**		**OGS**	
Short name of Infrastructure		**Installation number**	**11.1**	**Short name of Installation**	**aircraft**
Name of Installation	**Aircraft and remote sensing instruments (CO2 detection over large areas)**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Consumables for a total of 160 days (4 flight hours/day) during 48 months		118 400.00
	Pilot extra charge for total of 160 days (4 flight hours/day) during 48 months		28 800.00
	Aircraft management and parking during the project period (48 months)		160 000.00
	Ordinary maintenance of the aircraft during the project period (48 months)		60 000.00
	Out of ordinary maintenance of the aircraft during the project period (48 months)		120 000.00
	Software licences		20 000.00
	Total A		**507 200.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (1 researcher)	48	240 000.00
	Technical staff (2 technitians)	96	320 000.00
	Total B		**560 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	max	74704	74 704.00
D. Total estimated access eligible costs = A+B+C			1 141 904.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			160
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**7136.9**
H. Quantity of access offered under the project (over the whole duration of the project)			8
I. **Access Cost charged to the project [3][4] = G x H**			**57 095.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	11	**Organisation short**		OGS	
Short name of Infrastructure		**Installation number**	11.2	**Short name of Installation**	**Geophysical equipment**
Name of Installation	**Equipment for the geophysical imaging of the subsurface (CO2 pathways to the surface)**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Multichannel high resolution Seismis		240 000.00
	GPR surveys		32 000.00
	ERT surveys		28 000.00
	Gradiometer surveys		24 000.00
	the above costs are comprehensive of spare parts replacement, usual maintenence, instruments repairing, and general consumables, over a period of 48 months, for a crew working in the field for 6 months/year		
	Fuel costs for vibroseis and other cars		9 000.00
	Travel, living and lodging expenses for the crew members in Italy, and allowances for field work		158 400.00
	Total A		**491 400.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (2 researchers)	96	480 000.00
	Technical staff (5 technitians)	240	800 000.00
	Total B		**1 280 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**123998**	123 998.00
D. Total estimated access eligible costs = A+B+C			1 895 398.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			528
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**3589.77**
H. Quantity of access offered under the project (over the whole duration of the project)			20
I. **Access Cost charged to the project [3][4] = G x H**			**71 795.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 866

Calculation of the Unit Cost for Transnational Access

Participant number	**11**	**Organisation short**		**OGS**	
Short name of Infrastructure		**Installation number**	**11.3**	**Short name of Installation**	**BiO marine laboratories**
Name of Installation	**Equipment for studying CO2 leakage at sea, and its impacts on marine biosphere**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)	20 000.00
	Consumables (gases, chemicals, etc)	40 000.00
	Utilities	10 000.00
	Consumables and utilities are considered through statistic values for a full	
	use of the biological laboratory equipment during 5.5 months/year	
	Total A	**70 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (2 researchers)	96	480 000.00
	Technical staff (2 technitians)	96	320 000.00
	Total B		**800 000.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**60900**	60 900.00
D. Total estimated access eligible costs = A+B+C			930 900.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			660
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1410.45**
H. Quantity of access offered under the project (over the whole duration of the project)			40
I. **Access Cost charged to the project** [3][4] **= G x H**			**56 418.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 866

Calculation of the Unit Cost for Transnational Access

Participant number	**11**	**Organisation short**		**OGS**	
Short name of Infrastructure		**Installation number**	**11.4**	**Short name of Installation**	**DeepLab Sea Floor Landers**
Name of Installation	**Equipment for charactering and monitoring offshore natural laboratories (oceanographic parameters)**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance of facilities deployed off-shore for a total of 6 months/year, during the project period (48 months) with replacement of the damaged or off-duty ones		76 800.00
	years		71 500.00
	Support ship (12 operative days /year + stand-by meteo)		144 000.00
	Consumables and working time in the Calibration Centre during 4 years		48 000.00
	Total A		**340 300.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (1 expeienced Engineer)	48	240 000.00
	Technical staff (2 technitians part-time 50%)	48	160 000.00
	Total B		**400 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1] **max** **51821**			51 821.00
D. Total estimated access eligible costs = A+B+C			792 121.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			720
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1100.17**
H. Quantity of access offered under the project (over the whole duration of the project)			40
I. **Access Cost charged to the project [3][4] = G x H**			**44 006.80**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**12**	**Organisation short name**		**MATGAS**	
Short name of Infrastructure	**GS Lab**	**Installation number**	**12.1**	**Short name of Installation**	**Gas separation lab**
Name of Installation	**Separation and conditioning of CO2, absorption - adsorption**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Consumables (gases, chemicals, etc)		93 000.00
	Maintenance of facilities		15 000.00
	Energy		75 000.00
	Cleaning		32 000.00
	Total A		**215 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 45 k€)	8.4	378 000.00
	Technical staff (PM cost 36 k€)	0	0.00
	Total B		**378 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**41510**	41 510.00
D. Total estimated access eligible costs = A+B+C			634 510.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			1 000
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**634.51**
H. Quantity of access offered under the project (over the whole duration of the project)			135
I. Access Cost charged to the project [3][4] = G x H			**85 658.85**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**12**	**Organisation short name**	**MATGAS**		
Short name of Infrastructure	**HP Lab**	**Installation number**	**12.2**	**Short name of Installation**	**High Pressure Lab**
Name of Installation	**Thermophysical properties and Integrity, Transport**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Consumables (gases, chemicals, etc)		93 000.00
	Maintenance of facilities		15 000.00
	Energy		32 000.00
	Cleaning		16 000.00
	Total A		**156 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 45 k€)	4.8	216 000.00
	Technical staff (PM cost 36 k€)	0	0.00
	Total B		**216 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 26040**	26 040.00
D. Total estimated access eligible costs = A+B+C			398 040.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			1 000
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**398.04**
H. Quantity of access offered under the project (over the whole duration of the project)			135
I. **Access Cost charged to the project [3][4] = G x H**			**53 735.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**13**	**Organisation short name**		**METU-PAL**	
Short name of Infrastructure	**PVT LAB**	**Installation number**	**13.1**	**Short name of Installation**	**PVT LAB**
Name of Installation	**PVT Analysis Laboratory**			**Unit of access**	**days**

A. **Estimated direct eligible costs of providing access within the project life-time excluding personnel costs**	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		20 000.00
	Maintenance of facilities during the project period (48 months)		12 000.00
	Consumables (gases, chemicals, etc)		6 500.00
	Software licences (LabView, GC, etc)		6 000.00
	Spare Parts (column, liner, filter, etc)		16 000.00
	Certified standard gas and fluids		25 000.00
	Total A		**85 500.00**
	of which subcontracting (A')		
B. **Estimated personnel direct eligible costs needed to provide access within the project life-time**	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 60 k€)	2	120 000.00
	Technical staff (PM cost 30 k€)	2	60 000.00
	Total B		**180 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**18585**	18 585.00
D. Total estimated access eligible costs = A+B+C			284 085.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			220
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1291.3**
H. Quantity of access offered under the project (over the whole duration of the project)			40
I. **Access Cost charged to the project [3][4] = G x H**			**51 652.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**14**	**Organisation short name**	**BGS**		
Short name of Infrastructure	**BGS NP3L**	**Installation number**	**14.1**	**Short name of Installation**	**n/a**
Name of Installation	**National Physical Properties and Processes Laboratories**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance and calibration of facilities during the project period (48 months)		40 000.00
	Software licences		20 000.00
	Consumables (reaction vessels, valves, gases, chemicals, etc)		460 000.00
	Total A		**520 000.00**
	of which subcontracting (A')		***0.00***
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Senior researcher (PM cost 7.4 k€)	48	356 160.00
	Scientific staff (PM cost 5.6 k€)	112	629 216.00
	Technical and analytical staff (PM cost 3.5 k€)	48	167 904.00
	Total B		**1 153 280.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 117129.6**	117 129.60
D. Total estimated access eligible costs = A+B+C			1 790 409.60
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			3 100
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**577.55**
H. Quantity of access offered under the project (over the whole duration of the project)			433
I. **Access Cost charged to the project [3][4] = G x H**			**250 079.15**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 872

Calculation of the Unit Cost for Transnational Access

Participant number	**15**	**Organisation short name**		**PGI-NRI**	
Short name of Infrastructure	**Injection field lab**	**Installation number**	**15.1**	**Short name of Installation**	**Pilot Injection installation**
Name of Installation	**Installation of pilot CO2 injection into Jurassic aquifer**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)	10 000.00
	Maintenance of facilities during the project period (48 months)	24 000.00
	Consumables (gases, chemicals, etc)	30 000.00
	Software licences	2 000.00
	Total A	**66 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (PM cost 23,8 k€)	5	119 000.00
	Technical staff (PM cost 13,6 k€)	8	108 800.00
	Total B		**227 800.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**20566**	20 566.00
D. Total estimated access eligible costs = A+B+C			314 366.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			250
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1257.46**
H. Quantity of access offered under the project (over the whole duration of the project)			40
I. Access Cost charged to the project [3][4] = G x H			**50 298.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 872

Calculation of the Unit Cost for Transnational Access

Participant number	**16**	**Organisation short name**		**SINTEF ER**	
Short name of Infrastructure	**CLC-CFM**	**Installation number**	**16.1**	**Short name of Installation**	**CLC_CFM**
Name of Installation	**Chemical Looping Combustion - Cold Flow Model**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		15 000.00
	Maintenance of facilities during the project period (48 months)		21 000.00
	Consumables (particles/powder, filters)		12 000.00
	Total A		**48 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (25000 €/PM)	3	75 000.00
	Technical staff (16000 €/PM)	4	64 000.00
	Total B		**139 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **13090**	13 090.00
D. Total estimated access eligible costs = A+B+C			200 090.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			80
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2501.13**
H. Quantity of access offered under the project (over the whole duration of the project)			15
I. **Access Cost charged to the project [3][4] = G x H**			**37 516.95**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

<table>
<tr><td>Participant number</td><td>16</td><td colspan="2">Organisation short name</td><td colspan="2">SINTEF ER</td></tr>
<tr><td>Short name of Infrastructure</td><td>SCOM Lab</td><td>Installation number</td><td>16.2</td><td>Short name of Installation</td><td>SCOM Lab</td></tr>
<tr><td>Name of Installation</td><td colspan="3">SINTEF Combustion Lab</td><td>Unit of access</td><td>days</td></tr>
</table>

<table>
<tr><td rowspan="13">A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs</td><td colspan="2">Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .</td><td>Eligible Costs (€)</td></tr>
<tr><td colspan="2">Laboratory space rental fees during the project period (48 months)</td><td>15 000.00</td></tr>
<tr><td colspan="2">Maintenance of facilities during the project period (48 months)</td><td>47 500.00</td></tr>
<tr><td colspan="2">Consumables (gases, chemicals, etc)</td><td>200 000.00</td></tr>
<tr><td colspan="2">Software licences (LabView, GC, etc)</td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">Total A</td><td>262 500.00</td></tr>
<tr><td colspan="2">of which subcontracting (A')</td><td></td></tr>
<tr><td rowspan="11">B. Estimated personnel direct eligible costs needed to provide access within the project life-time</td><td>Category of staff</td><td>Person-Months</td><td>Personnel Costs (€)</td></tr>
<tr><td>Scientific staff (25000 €/PM)</td><td>6</td><td>150 000.00</td></tr>
<tr><td>Technical staff (16000 €/PM)</td><td>14</td><td>224 000.00</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total B</td><td>374 000.00</td></tr>
<tr><td colspan="3">C. Indirect eligible costs < = 7% x ([A-A']+B) [1] max 44555</td><td>44 555.00</td></tr>
<tr><td colspan="3">D. Total estimated access eligible costs = A+B+C</td><td>681 055.00</td></tr>
<tr><td colspan="3">E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time</td><td>250</td></tr>
<tr><td colspan="3">F. Fraction of the Unit cost to be charged to the project [2]</td><td>100.0%</td></tr>
<tr><td colspan="3">G. Estimated Unit cost charged to the project = F x (D/E)</td><td>2724.22</td></tr>
<tr><td colspan="3">H. Quantity of access offered under the project (over the whole duration of the project)</td><td>40</td></tr>
<tr><td colspan="3">I. Access Cost charged to the project [3][4] = G x H</td><td>108 968.80</td></tr>
</table>

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**16**	**Organisation short name**		**SINTEF ER**	
Short name of Infrastructure	**HIPROX**	**Installation number**	**16.3**	**Short name of Installation**	**HIPROX**
Name of Installation	**High Pressure Oxy-Fuel Combustion Facility**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (TA only available 2 years)		30 000.00
	Maintenance of facilities during the project period (TA only available 2 years)		50 000.00
	Consumables (gases, chemicals, etc)		66 000.00
	Software licences (LabView, GC, etc)		
	Total A		**146 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (25000 €/PM)	9	225 000.00
	Technical staff (16000 €/PM)	13	208 000.00
	Total B		**433 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 40530**	40 530.00
D. Total estimated access eligible costs = A+B+C			619 530.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			70
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**8850.43**
H. Quantity of access offered under the project (over the whole duration of the project)			10
I. **Access Cost charged to the project** [3][4] **= G x H**			**84 079.09**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**17**	**Organisation short name**		**SPR**		
Short name of Infrastructure	**Reservoir laboratory**	**Installation number**	**17.1**	**Short name of Installation**	**Core-SCAL**	
Name of Installation	**Core flood laboratory**			**Unit of access**	**days**	

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		125 000.00
	Maintenance of facilities during the project period (48 months)		40 000.00
	Consumables (gases, chemicals, etc)		40 000.00
	Software licences (LabView, GC, etc)		2 000.00
	Total A		**207 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher) (PM cost 27 k€)	4	108 000.00
	Technical staff (PM cost 20 k€)	16	320 000.00
	Total B		**428 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **44450**	44 450.00
D. Total estimated access eligible costs = A+B+C			679 450.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**849.31**
H. Quantity of access offered under the project (over the whole duration of the project)			60
I. **Access Cost charged to the project [3][4] = G x H**			**50 958.60**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 877

Calculation of the Unit Cost for Transnational Access

Participant number	**17**	**Organisation short name**	**NTNU**	
Short name of Infrastructure	**Reservoir laboratory**	**Installation number**	**17.2**	**Short name of Installation**	**Fluid-pVT**
Name of Installation	**Fluid (PVT) laboratory**		**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		125 000.00
	Maintenance of facilities during the project period (48 months)		20 000.00
	Consumables (gases, chemicals, materials, etc)		20 000.00
	Software licences (LabView, GC, etc)		2 000.00
	Total A		**167 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher) (PM cost 27 k€)	4	108 000.00
	Technical staff (PM cost 20 k€)	16	320 000.00
	Total B		**428 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 41650**	41 650.00
D. Total estimated access eligible costs = A+B+C			636 650.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			750
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**848.87**
H. Quantity of access offered under the project (over the whole duration of the project)			60
I. **Access Cost charged to the project [3][4] = G x H**			**50 932.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 877

Calculation of the Unit Cost for Transnational Access

Participant number	**18**	**Organisation short**		**SINTEF**	
Short name of Infrastructure	**SINTEF MC-CCS**	**Installation number**	**18.1**	**Short name of Installation**	**SINTEF SMLab**
Name of Installation	**characterization and evaluation**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		43 000.00
	Maintenance of facilities during the project period (48 months)		300 000.00
	Consumables (gases, chemicals, etc)		160 000.00
	Total A		**503 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Senior Researcher) (PM cost 26 k€)	35	910 000.00
	Technical staff (PM cost 18 k€)	30	540 000.00
	Total B		**1 450 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 136710**	136 710.00
D. Total estimated access eligible costs = A+B+C			2 089 710.00
(i.e. both internal and external) within the project life-time			1 000
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2089.71**
H. Quantity of access offered under the project (over the whole duration of the project)			48
I. **Access Cost charged to the project [3][4] = G x H**			**100 306.08**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 879

Participant number	**18**	**Organisation short**		**SINTEF**	
Short name of Infrastructure	**SINTEF MC-CCS**	**Installation number**	**18.2**	**Short name of Installation**	**SINTEF AbsLab**
Name of Installation	**Lab scale absorption pilot plant**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)		220 000
	Consumables (gases, chemicals, etc)		50 000
	Software licences		5 000
	Total A		**275 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Senior Researcher) (PM cost 26 k€)	13	338 000.00
	Technical staff (PM cost 18 k€)	36	648 000.00
	Total B		**986 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	max 88270		88 270.00
D. Total estimated access eligible costs = A+B+C			1 349 270.00
(i.e. both internal and external) within the project life-time			600
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2248.78**
H. Quantity of access offered under the project (over the whole duration of the project)			49
I. **Access Cost charged to the project [3][4] = G x H**			**110 190.22**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 879

 Pag. 880

Calculation of the Unit Cost for Transnational Access

Participant number	**19**	**Organisation short**		**UEDIN**	
Short name of Infrastructure	**COFR**	**Installation number**	**19.1**	**Short name of Installation**	**CO2 Flow Rig**
Name of Installation	**CO2 Flow Rig**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Core Preparation	15 600.00
	Standard cell membranes,replacement pipes, CO2 use etc.	10 400.00
	Miscellaneous	5 200.00
	Total A	**31 200.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Lab Manager (5404 PM)	2	10 808.00
	Technical staff (3870)	8	30 960.00
	Research staff(6687 PM)	8	53 496.00
	Total B		**95 264.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1] **max** **8852.48**	8 852.48
D. Total estimated access eligible costs = A+B+C	135 316.48
(i.e. both internal and external) within the project life-time	800
F. Fraction of the Unit cost to be charged to the project [2]	100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)	**169.15**
H. Quantity of access offered under the project (over the whole duration of the project)	90
I. **Access Cost charged to the project [3][4] = G x H**	**15 223.50**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

If not, insert 100%.

to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

 Pag. 880

Calculation of the Unit Cost for Transnational Access

Participant number	19	**Organisation short**		UEDIN	
Short name of Infrastructure	GREAT	**Installation number**	19.2	**Short name of Installation**	GREAT
Name of Installation	Analogue Technology			**Unit of access**	days

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Core Collection and Preparation		40 000.00
	Standard cell membranes,replacement pipes, CO2 use etc.		40 000.00
	Miscellaneous lab supplies		8 000.00
	Lab space rent		4 000.00
	Total A		**92 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Lab Manager (5404 PM)	2	10 808.00
	Senior Technical staff (3870 PM)	8	30 960.00
	Research staff(3870 PM)	8	30 960.00
	Senior research staff (6687 PM)	8	53 496.00
	Total B		**126 224.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**15275.68**	15 275.68
D. Total estimated access eligible costs = A+B+C			233 499.68
(i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**291.87**
H. Quantity of access offered under the project (over the whole duration of the project)			100
I. **Access Cost charged to the project [3][4] = G x H**			**46 407.33**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 882

Calculation of the Unit Cost for Transnational Access

Participant number	**19**	**Organisation short**		**UEDIN**	
Short name of Infrastructure	**COFP**	**Installation number**	**19.3**	**Short name of Installation**	**CO2 porescale**
Name of Installation	**CO2 porescale**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs		Eligible Costs (€)
	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Micro Channel and Pore Preparation	80 000.00
	pore wettability measurement, chemicals, minerals, replacement pipes, CO2 use etc.	64 000.00
	Miscellaneous	40 000.00
	Total A	**184 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	Category of staff	Person-Months	Personnel Costs (€)
	Technical staff (3870)	8	30 960.00
	Research staff(6687 PM)	16	106 992.00
	Total B		**137 952.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**22536.64**	22 536.64
D. Total estimated access eligible costs = A+B+C			344 488.64
(i.e. both internal and external) within the project life-time			800
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**430.61**
H. Quantity of access offered under the project (over the whole duration of the project)			100
I. **Access Cost charged to the project** [3][4] **= G x H**			**68 466.99**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 882

Pag. 883

Calculation of the Unit Cost for Transnational Access

Participant number	**19**	**Organisation short**	**UEDIN**	
Short name of Infrastructure	**FoAM**	**Installation number**	**19.4**	**Short name of Installation**	**FoAM**
Name of Installation	**Membranes**		**Unit of access**	**week (5 days)**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months) (50 m2)		20 800.00
	Maintenance of facilities during the project period (48 months)		24 000.00
	Consumables (gases, chemicals, etc)		79 500.00
	Software licences (LabView, GC, etc)		2 000.00
	Total A		**126 300.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Hyunwoong Ahn 25%, Maria-Chiara Ferrari 25%)		274 000.00
	Post grad students (2 students 100%)		376 000.00
	Technical staff (Steven Gourlay 10%, Bill Leslie 10%)		49 000.00
	Total B		**699 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**57771**	57 771.00
D. Total estimated access eligible costs = A+B+C			883 071.00
(i.e. both internal and external) within the project life-time			200
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**4415.36**
H. Quantity of access offered under the project (over the whole duration of the project)			15
I. **Access Cost charged to the project** [3][4] **= G x H**			**176 172.86**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Pag. 883

Calculation of the Unit Cost for Transnational Access

Participant number	**19**	**Organisation short**		**UEDIN**	
Short name of Infrastructure	**AMP**	**Installation number**	**19.5**	**Short name of Installation**	**Process Lab**
Name of Installation	**processes**			**Unit of access**	**week (5 days)**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months) (50 m2)		20 800.00
	Maintenance of facilities during the project period (48 months)		14 000.00
	Consumables (gases, chemicals, etc)		127 000.00
	Software licences (LabView, GC, etc)		2 000.00
	Total A		**163 800.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Hyunwoong Ahn 25%, Maria-Chiara Ferrari 25%, Daniel Friedrich 100%)		444 000.00
	Post grad students (1 student 100%)		188 000.00
	Technical staff (Steven Gourlay 10%, Bill Leslie 10%)		49 000.00
	Total B		**681 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1] **max** **59136**			59 136.00
D. Total estimated access eligible costs = A+B+C			903 936.00
(i.e. both internal and external) within the project life-time			200
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**4519.68**
H. Quantity of access offered under the project (over the whole duration of the project)			15
I. **Access Cost charged to the project** [3][4] **= G x H**			**180 787.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
If not, insert 100%.
to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**20**	**Organisation short name**		**UNOTT**		
Short name of Infrastructure	**MMVCO2**	**Installation number**	**20.1**	**Short name of Installation**	**MMV1**	
Name of Installation	**MMV CO2 RIGS**			**Unit of access**		

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	facility charges over 4 years		1 335 840.00
	Total A		**1 335 840.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Principle investigator	4.5 days	2 712.00
	Co investigator	3 days	1 132.00
	Researcher	46 days	13 087.00
	Administrator	10.5 days	3 580.00
	Total B		**20 511.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**94944.57**	5 309.00
D. Total estimated access eligible costs = A+B+C			1 361 660.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			880
F. Fraction of the Unit cost to be charged to the project [2]			47.3%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**731.12**
H. Quantity of access offered under the project (over the whole duration of the project)			30
I. Access Cost charged to the project [3][4] = G x H			**21 933.60**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**22**	**Organisation short name**		**TUV**	
Short name of Infrastructure	**Technikum Vienna**	**Installation number**	**22.1**	**Short name of Installation**	**CLPP150**
Name of Installation	**100-150kW Chemical Looping Pilot Plant**			**Unit of access**	**test campaign**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Maintenance of facilities during the project period (48 months)	35 000.00
	Consumables (oxygen carrier, gases, chemicals, etc)	160 000.00
	Total A	**195 000.00**
	of which subcontracting (A')	***0.00***

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Senior researcher (84 240€/year)	48	336 960.00
	Junior researcher (47 736€/year)	192	763 776.00
	Total B		**1 100 736.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**90701.52**	90 701.52
D. Total estimated access eligible costs = A+B+C			1 386 437.52
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			18
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**77024.31**
H. Quantity of access offered under the project (over the whole duration of the project)			2
I. Access Cost charged to the project [3][4] = G x H			**154 048.62**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**22**	**Organisation short name**		**UniRoma1**		
Short name of Infrastructure	**Natural field laboratories**	**Installation number**	**22.1**	**Short name of Installation**	**Natural field laboratories**	
Name of Installation	**Terrestrial and marine natural field laboratories – access and support**			**Unit of access**	**days**	

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Laboratory space rental fees during the project period (48 months)		10 000.00
	Maintenance of facilities during the project period (48 months)		40 000.00
	Consumables (gases, chemicals, etc)		10 000.00
	Storage facilities at field sites during the project period (48 months)		30 000.00
	Access agreements for field sites during the project period (48 months)		10 000.00
	Vehicle / boat rental at field sites during the project period (48 months)		25 000.00
	Total A		**125 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Full Professor) (PM cost 16 k€)	4	64 000.00
	Scientific staff (senior Researcher) (PM cost 8 k€)	8	64 000.00
	Technical staff (PM cost 5 k€)	8	40 000.00
	Total B		**168 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max 20510**	20 510.00
D. Total estimated access eligible costs = A+B+C			313 510.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			350
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**895.74**
H. Quantity of access offered under the project (over the whole duration of the project)			70
I. Access Cost charged to the project [3][4] = G x H			**62 701.80**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**23**	**Organisation short name**	**USTUTT**		
Short name of Infrastructure	**KSVA**	**Installation number**	**23.1**	**Short name of Installation**	**KSVA**
Name of Installation	**Pilot scale 0.5 MWth combustion facility**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Eligible Costs (€)
Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	
Fuel pretreatment and handling (48 months)	185 000.00
Consumables (gases, chemicals, etc) (48 months)	325 000.00
Maintenance of the facility (48 months)	127 000.00
Total A	**637 000.00**
of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time — Category of staff	Person-Months	Personnel Costs (€)
Scientific staff (Researcher, Professor) (80 k€ per year)	288	1 920 000.00
Technical staff (50k€ per year)	216	900 000.00
Laboratory staff (40k€ per year)	120	400 000.00
Total B		**3 220 000.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max 269990**	269 990.00
D. Total estimated access eligible costs = A+B+C		4 126 990.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time		600
F. Fraction of the Unit cost to be charged to the project [2]		100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)		**6878.32**
H. Quantity of access offered under the project (over the whole duration of the project)		30
I. Access Cost charged to the project [3][4] = G x H		**206 349.60**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**23**	**Organisation short name**		**STUTT**	
Short name of Infrastructure	**BTS**	**Installation number**	**23.2**	**Short name of Installation**	**BTS**
Name of Installation	**Technical scale 20 kW electrically heated combustor**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)		38 000.00
	Consumables (gases, chemicals, etc) (48 months)		47 600.00
	Maintenance of the facility (48 months)		105 000.00
	Total A		**190 600.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	48	320 000.00
	Technical staff (50k€ per year)	48	200 000.00
	Laboratory staff (40k€ per year)	30	100 000.00
	Total B		**620 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**56742**	56 742.00
D. Total estimated access eligible costs = A+B+C			867 342.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			400
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**2168.36**
H. Quantity of access offered under the project (over the whole duration of the project)			30
I. **Access Cost charged to the project [3][4] = G x H**			**65 050.80**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**24**	**Organisation short name**	**TNO**		
Short name of Infrastructure	**TNO PILOT**	**Installation number**	**24.1**	**Short name of Installation**	**TNO PILOT**
Name of Installation	**TNO PILOT**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)		38 000.00
	Consumables (gases, chemicals, etc) (48 months)		320 000.00
	Maintenance of the facility (48 months)		210 000.00
	Total A		**568 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	48	320 000.00
	Technical staff (50k€ per year)	48	200 000.00
	Laboratory staff (40k€ per year)	30	100 000.00
	Total B		**620 000.00**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]		**max** **83160**	83 160.00
D. Total estimated access eligible costs = A+B+C			1 271 160.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			400
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**3177.9**
H. Quantity of access offered under the project (over the whole duration of the project)			20
I. Access Cost charged to the project [3][4] = G x H			**63 558.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**24**	**Organisation short name**	**TNO**		
Short name of Infrastructure	**Micro/Mini pland demonstrator**	**Installation number**	**24.2**	**Short name of Installation**	**Micro/Mini pland demonstrator**
Name of Installation	**Micro/Mini pland demonstrator**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .	**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)	38 000.00
	Consumables (gases, chemicals, etc) (48 months)	150 000.00
	Maintenance of the facility (48 months)	210 000.00
	Total A	**398 000.00**
	of which subcontracting (A')	

B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	48	320 000.00
	Technical staff (50k€ per year)	48	200 000.00
	Laboratory staff (40k€ per year)	30	100 000.00
	Total B		**620 000.00**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max 71260**	71 260.00
D. Total estimated access eligible costs = A+B+C		1 089 260.00
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time		400
F. Fraction of the Unit cost to be charged to the project [2]		100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)		**2723.15**
H. Quantity of access offered under the project (over the whole duration of the project)		20
I. Access Cost charged to the project [3][4] = G x H		**54 463.00**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**24**	**Organisation short name**		**TNO**	
Short name of Infrastructure	**Qscan Solvent**	**Installation number**	**24.3**	**Short name of Installation**	**Qscan Solvent**
Name of Installation	**Qscan Solvent**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)		38 000.00
	Consumables (gases, chemicals, etc) (48 months)		50 000.00
	Maintenance of the facility (48 months)		80 000.00
	Total A		**168 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	27	180 000.00
	Technical staff (50k€ per year)	28	116 666.67
	Laboratory staff (40k€ per year)	20	66 666.67
	Total B		**363 333.33**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**37193.33333**	37 193.33
D. Total estimated access eligible costs = A+B+C			568 526.67
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			400
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1421.32**
H. Quantity of access offered under the project (over the whole duration of the project)			20
I. **Access Cost charged to the project [3][4] = G x H**			**28 426.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**24**	**Organisation short name**		**TNO**	
Short name of Infrastructure	**CLC fixed Bed**	**Installation number**	**24.4**	**Short name of Installation**	**CLC fixed Bed**
Name of Installation	**CLC fixed Bed**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)		5 000.00
	Consumables (gases, chemicals, etc) (48 months)		5 000.00
	Maintenance of the facility (48 months)		5 000.00
	Total A		**15 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	17	113 333.33
	Technical staff (50k€ per year)	20	83 333.33
	Laboratory staff (40k€ per year)	15	50 000.00
	Total B		**246 666.67**

C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max 18316.66667**	18 316.67
D. Total estimated access eligible costs = A+B+C		279 983.33
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time		400
F. Fraction of the Unit cost to be charged to the project [2]		100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)		**699.96**
H. Quantity of access offered under the project (over the whole duration of the project)		45
I. **Access Cost charged to the project [3][4] = G x H**		**31 498.20**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.
[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.
[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)
[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms

Calculation of the Unit Cost for Transnational Access

Participant number	**24**	**Organisation short name**		**TNO**	
Short name of Infrastructure	**Hgh Pressure ABS/DES**	**Installation number**	**24.5**	**Short name of Installation**	**Hgh Pressure ABS/DES**
Name of Installation	**Hgh Pressure ABS/DES**			**Unit of access**	**days**

A. Estimated direct eligible costs of providing access within the project life-time excluding personnel costs	Describe the direct eligible costs for providing access to the installation over the project life-time (e.g. maintenance, utilities, consumable costs). All contributions to capital investments of the infrastructure are not eligible .		**Eligible Costs (€)**
	Fuel pretreatment and handling (48 months)		38 000.00
	Consumables (gases, chemicals, etc) (48 months)		50 000.00
	Maintenance of the facility (48 months)		80 000.00
	Total A		**168 000.00**
	of which subcontracting (A')		
B. Estimated personnel direct eligible costs needed to provide access within the project life-time	**Category of staff**	**Person-Months**	**Personnel Costs (€)**
	Scientific staff (Researcher, Professor) (80 k€ per year)	27	180 000.00
	Technical staff (50k€ per year)	28	116 666.67
	Laboratory staff (40k€ per year)	20	66 666.67
	Total B		**363 333.33**
C. Indirect eligible costs < = 7% x ([A-A']+B) [1]	**max**	**37193.33333**	37 193.33
D. Total estimated access eligible costs = A+B+C			568 526.67
E. Total estimated quantity of access provided to all normal users of the infrastructure (i.e. both internal and external) within the project life-time			400
F. Fraction of the Unit cost to be charged to the project [2]			100.0%
G. **Estimated Unit cost charged to the project** = F x (D/E)			**1421.32**
H. Quantity of access offered under the project (over the whole duration of the project)			20
I. **Access Cost charged to the project [3][4] = G x H**			**28 426.40**

[1] Indirect costs are limited to 7% of the direct costs minus subcontracts. If not relevant leave this field blank.

[2] If only a fraction of the unit cost is being charged, please indicate the value of this fraction (in %) in line G. If not, insert 100%.

[3] The Access cost charged to the project shall not exceed 20% of the costs of providing the total quantity of access to the installation over the duration of the project (as indicated in row D. Total estimated access eligible costs)

[4] In the case of a participant giving access to more than one infrastructure/installation, please report in the access line of the GPF A3.1 form the sum of all the amounts coming from the individual access cost calculation forms