Agenzia Nazionale per le Nuove Tecnologie,
l'Energia e lo Sviluppo Economico Sostenibile

Ministero dello Sviluppo Economico

RICERCA DI SISTEMA ELETTRICO

Documento CERSE-UNIPI RL 1067/2010

Web pages and present studies related to the information on nuclear wastes management

G. Forasassi, R. Lofrano, G. Pugliese

Report RdS/2010/149

WEB PAGES AND PRESENT STUDIES RELATED TO THE INFORMATION ON NUCLEAR WASTES MANAGEMENT

G. Forasassi, R. Lofrano, G. Pugliese

Settembre 2010

Report Ricerca di Sistema Elettrico
Accordo di Programma Ministero dello Sviluppo Economico – ENEA
Area: Produzione e fonti energetiche
Tema: Nuovo Nucleare da Fissione

Responsabile Tema: Stefano Monti, ENEA

CIRTEN
CONSORZIO INTERUNIVERSITARIO
PER LA RICERCA TECNOLOGICA NUCLEARE

UNIVERSITA' DI PISA

DIPARTIMENTO DI INGEGNERIA MECCANICA NUCLEARE E DELLA PRODUZIONE

Web pages and present studies related to the information on nuclear wastes management

AUTHORS

G. FORASASSI

R. LO FRANO

G. PUGLIESE

CIRTEN-UNIPI RL 1067/2010

PISA, LUGLIO 2010

Lavoro svolto in esecuzione della linea progettuale LP6 punto C- AdP ENEA MSE del 21/06/07
Tema 5.2.5.8 – "Nuovo Nucleare da Fissione".

CONTENT

1. Introduction

The European energy interested Institutions policy developed, in the last decade, several Green Papers and Strategic Energy Reviews to advance the agenda on sustainability, competitiveness and security of supply. The main goal of those European energy Institutions was/is to ensure safe, secure, sustainable and affordable energy supply. In this framework the challenges in the global energy scenarios, also in combating climate change at the global level, highlighted the need of new Energy Strategy objectives (Europe 2020 Strategy) to promote a "Resource-efficient Europe".

The European Strategic Energy Technology Plan (SET-Plan) incorporates the commitment to deliver the 20- 20-20 targets (the EU Commission's proposal will focus on wind, solar, bio energy, electricity grids, capture and storage of carbon and nuclear fission (generation IV reactors)) that might be achieved developing a suitable internal energy market (in Fig.1 it is shown the foreseen nuclear energy roadmaps for 2010 to highlight the important role of nuclear energy), based on regional and pan-European interconnections, promoting low carbon innovation and ensuring, in the same time, the objectives of competitiveness, sustainability and security of supply.

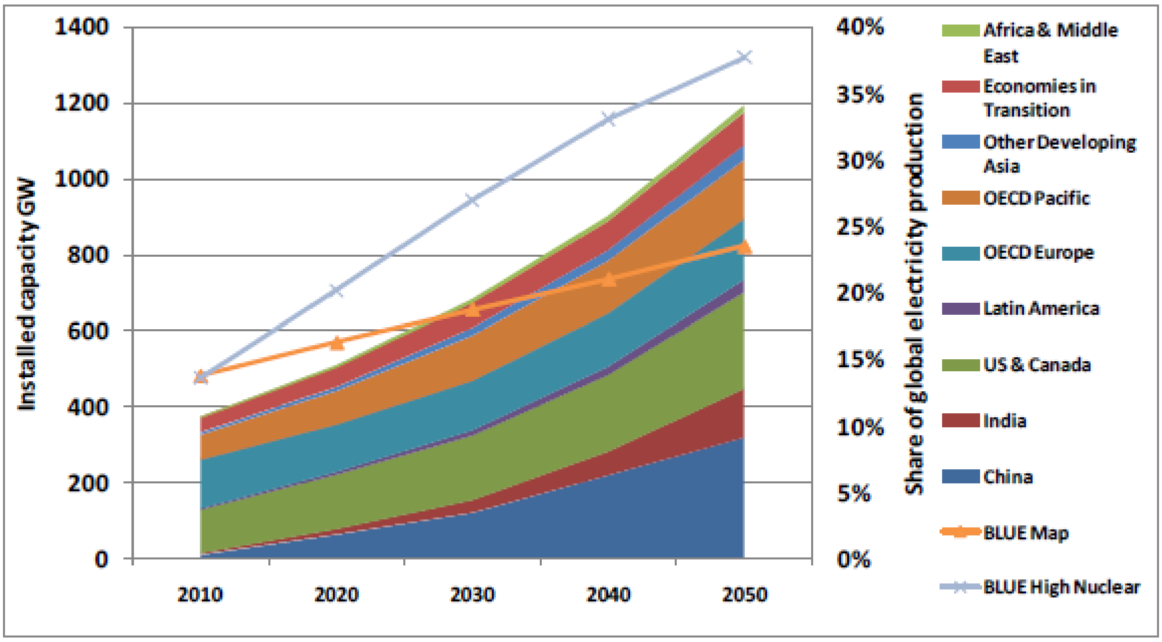


Fig. 1- Role of nuclear energy in a low-carbon strategy [1]

To achieve the EU's goals nuclear energy appears to offer a real alternative to other types of energy in the European Union. How to manage the radioactive waste is of course one of the main problems to be addressed in the nuclear energy including scenarios.

According to IAEA, a radioactive "waste" is considered any material that contains a concentration of radionuclides higher than the level of acceptable natural radioactivity and, therefore, susceptible to regulations. Because of the wide variety of nuclear applications, the amounts, types and even physical forms of radioactive wastes vary considerably: some wastes can remain radioactive for hundreds or thousands of years, while others may require storage for only a short decay period prior to conventional disposal.

Radioactive wastes and spent fuel are produced in many activities such as nuclear electricity generation, spent fuel reprocessing, radioisotope applications in medicine, industry, research, etc. Consequently a wide variety of radioactive wastes are generated, each one requiring a different management according to international standards of safety and security. The IAEA safety standards (organized in three categories of Safety Standards Series, as shown in Fig. 2) reflect an international consensus on what represents a high safety level for protecting people and environment from harmful effects of ionizing radiations [2]. These safety guides provide recommendations on how to comply with the safety requirements, and reflect best practices to achieve high levels of safety.

Various schemes have been set up in order to classify radioactive waste according to the physical, chemical and radiological properties that are of relevance to particular facilities or circumstances in which radioactive wastes are managed. These schemes have led to a variety of terminologies, which may differ from State to State and even between facilities in the same State.

In some instances, this has given rise to difficulties in establishing consistent and coherent national waste management policies and implementing strategies, and can lead to less than optimal levels of safety.

It also makes communication on waste management practices difficult at national as well as at international levels, particularly in the context of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [3].

The vast majority of Europeans would support European legislation regulating radioactive waste management: this position was developed by the recent survey by Eurobarometer survey instrument of the EU. Italian citizens, or at least 83% of the survey respondents, think that this aspect should be regulated at European level.

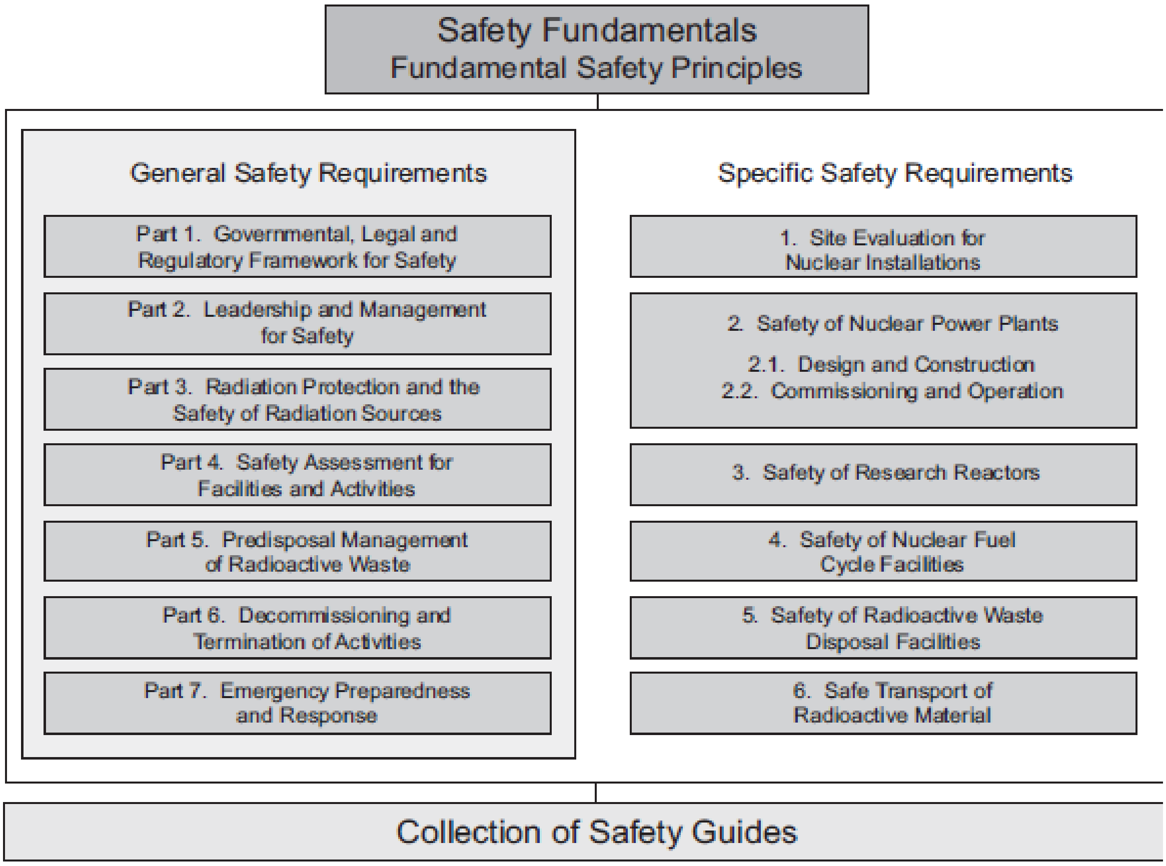


Fig. 2 - IAEA safety standards [2]

The concern for the radioactive waste risk is shared by the citizens of both countries that possess nuclear power installations, and those that do not produce nuclear energy: the risk is considered real by almost all people in Cyprus, Hungary, the Netherlands and Slovenia, but in any Country the concerned people greatly exceeds the majority: 59% in Austria, 60%in United Kingdom, 62% in Malta, etc..

2. Waste Management

All power plants have a finite “life” beyond which it is no longer economical to operate them. Generally speaking, operating/”old” Nuclear Power Plants (NPP's) were designed for a life of about 30 years, while more recent plants are designed for a 40 to 60 years operating life.

To date, about 70 commercial power reactors, over 250 research reactors and a number of fuel cycle facilities, have been retired from operation and some of these have been fully dismantled. Assuming on average about 25-years lifespan, almost 300 nuclear power plants would have to be decommissioned by the year 2010.

The operation, maintenance of nuclear facilities and their dismantling, once their operating life is over, generate radioactive waste that presents large variations; for instance:

- In activity level, between wastes originating from containment envelopes and wastes resulting from the reactor core itself;
- In bulk and weight between concrete rubble and huge metal components, such as reactor vessels;
- In gross waste volume, between concrete waste from containment envelopes and waste resulting from filtration systems.

The fundamental principles of the management of radioactive wastes are the protection of the population and workers and of the environment, taking also into account the impact of radioactive wastes on future generations.

The radioactive wastes must be classified considering several factors, such as operational or long term safety, the demands of process engineering, the availability of management or disposal facilities or the source of generation of the waste.

Therefore radioactive waste (RW) management operations might include collection, sorting, processing, packaging, transport, storage and disposal. Moreover the RW packages are stored in appropriate facilities at major nuclear sites before being shipped to a processing or disposal facility, where they might remain indefinitely.

RW produced by the peaceful uses of nuclear energy are characterized by different shapes and level of activity that can vary within large limits. Radiations are different (α, β, γ e n) with different energy content as well as half-lives. Due to such diversity the waste management is of meaningful importance to regulate nuclear facility decommissioning.

Radioactive Waste Management (RWM) incorporates all administrative, operational and safety-related activities that are involved in the collection, sorting, treatment, conditioning, and market preparation, temporary storage, transport and disposal, of all categories of radioactive wastes, including transportation. While RWM methods vary from country to country, the primary objective is to protect citizens and the environment from hazards arising from radioactive waste and effluents, both for the present and the future.

The disposal of high-level radioactive wastes is the most important issue when dealing with the sustainability of nuclear power.

The final destination of material from decommissioned plants raises a similar concern. Nuclear wastes are felt by the population, even if it is not the case, as an unsolvable or at least, unresolved environmental problem whose consequences will be borne by future generations.

2.1 Types of radioactive waste

Radioactive wastes (RW) are generally grouped into different classes based on measurable criteria recommended by the IAEA. As a general rule, wastes are classified on:

1. The activity level of wastes (below the “release threshold” the waste is no longer considered radioactive);
2. The half-life of the elements contained in the waste.

The combination of both criteria may be useful to determine the type of shielding to be provided, the duration of containment needed and the monitoring period required for the disposal facilities. In the following table I they are summarized the most relevant characteristics of RWs that are used by International Regulatory body for their classification.

Table I - Parameters used to classify RWs [2]

RW parameters	
Origin	
Criticality	
Radiological properties	Half-life of radionuclides Heat generation Intensity of penetrating radiation Activity concentration of radionuclides Surface contamination

Physical Properties	Dose factor of relevant radionuclides Decay products Physical state (solid, liquid, gaseous) Size and weight Compactibility Dispersibility Volatility Miscibility Free liquid content
Chemical properties	Chemical composition Solubility and chelating agents Potential chemical hazard Corrosion resistance/corrosiveness Organic content Combustibility and flammability Chemical reactivity and swelling potential Gas generation Sorption of radionuclides
Biological properties	Potential biological hazard Bio-accumulation
Other factors	Volume Amount arising per unit of time Physical distribution

Aside from these two main criteria, the French classification system (National Radioactive Materials and Waste Management Plan) is based on processing and disposal methods. Currently, in France 84% of the waste already packaged has an industrial disposal solution and is sent to a dedicated disposal center.

To facilitate communication and information exchange among Member States, IAEA instituted a revised waste classification system that group the wastes in six class, taking into account both qualitative and quantitative criteria and including activity levels and heat content. A conceptual illustration of the waste classification scheme is presented in Fig. 3.

The vertical axis represents the activity content whilst the horizontal axis represents the half-lives of the radionuclides contained in the waste [2-3].
The showed activity content can range from negligible to very high, that corresponds to very high concentration of radionuclides or very high specific activity: "*the higher the level of activity content, the greater the need to contain the waste and to isolate it from the biosphere*" [3].

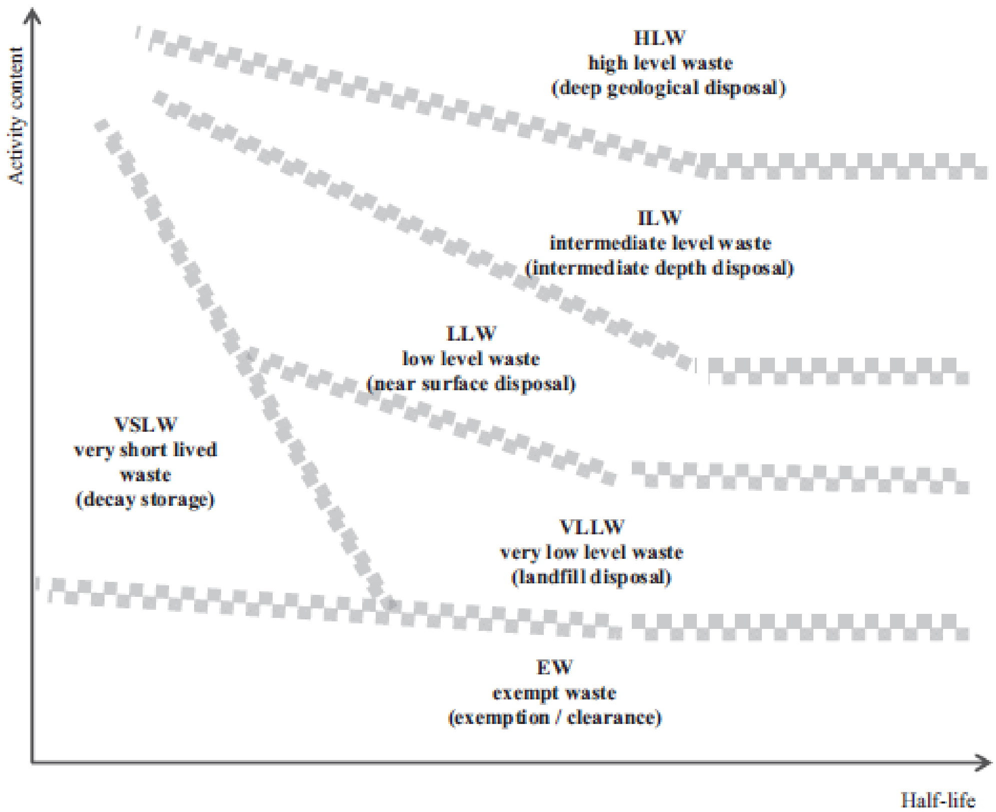


Fig. 3 - Conceptual radioactive waste classification [2]

The half-lives of radionuclides contained in the waste can vary from short (seconds) to very long time spans (millions of years). Therefore, a radionuclide with a half-life less than about 30 years is considered to be short lived.
The mentioned IAEA classification scheme also represented in the previous Fig. 2 is based on the following six class:

(1) Exempt waste (EW): wastes with low activity level cleared from regulatory control for radiation protection purposes.

(2) Very short lived waste (VSLW): waste containing primarily radionuclides with very short half-lives that can be temporary stored for decay over a period of few years and subsequently cleared from regulatory control according to arrangements approved by the regulatory body, for uncontrolled disposal, use or discharge.

(3) Very low level waste (VLLW): wastes, including soil and rubble with low levels of activity concentration, that may not be considered EW and without the need of a high level of containment and isolation; therefore, they are suitable for disposal in near surface landfill type facilities with limited regulatory control. Concentrations of longer lived radionuclides in VLLW are generally very limited.

(4) Low level waste (LLW): this type of wastes, characterized by a limited amounts of long lived radionuclides, have activity level above the clearance limits and require a robust isolation and containment for time periods up to few hundred years in suitable near surface facilities. LLW may include short lived radionuclides at higher levels of activity concentration and, also, long lived radionuclides, but only at relatively low levels of activity concentration.

(5) Intermediate level waste (ILW): due to its content, characterized particularly by long lived radionuclides, ILW requires an adequate containment, isolation and disposal at greater depths, taking care of the heat dissipation during its storage and disposal.
ILW may contain, in particular, alpha emitting radionuclides that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon.

(6) High level waste (HLW): *waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste.* Disposal in deep, stable geological formations, usually several hundred meters or more below the surface, is the generally recognized option for disposal of HLW.

It is important to note that in the IAEA GSG-1, 2010, is indicated that the management of decay heat should be considered if the thermal power of waste packages reaches several Watts per cubic meter.

An accurate methodology to manage RW (useful also in planning the disposal facility design) should be take into account:

- Quantitative and radiological inventories to be identified;
- Inventory work at every deconstruction step: electromechanical dismantling, cleanup of concretes, followed by dismantling and demolition, and specific treatment proposal;
- Technical and economic analyses;
- Waste-treatment specifications in partnership with waste producers;
- Packaging specifications in partnership with waste producers;
- Waste-acceptance criteria, waste-compliance control specifications;
- Development of suitable disposal facilities fulfilling regulatory requirements;
- Prospective economic studies;
- Consistency studies between forecast inventory and existing disposal solutions.

Moreover in the following Fig. 4 it is schematized the physical appearance of RW [4-5].

Physical appearance of radioactive waste produced by the nuclear industry

VLLW:	Scrap metal, rubble, miscellaneous debris, produced mainly by dismantling operations, mining residues, waste from some research activities, and the cleanup of formerly contaminated sites.
LLW:	Resins, filters, gloves, concrete-immobilized waste, produced by the operation of nuclear power plants, treatment plants and research laboratories. Technological or maintenance waste (gloves, shoe covers, vinyl suits, etc.) is distinguished from process waste resulting for example from the ventilation or scrubbing of circuits carrying primary coolant in nuclear power plants.
ILW:	Resins, solvents, concentrates, materials from steam generators; hulls, nozzles, cladding from the operation of power plants and used fuel treatment plants.
HLW:	Fission products and minor actinides from the treatment of used fuel.

Fig. 4 - RW physical appearance [5]

2.2 RW Treatment

Depending on their physical and radiological characteristics, maintenance and operational waste will require different RW management processes.

The nuclear waste produced by the electro-nuclear industry is very small if compared with other type of industrial wastes. Each year, nuclear power generation facilities worldwide produce about 200,000 m^3 of low and intermediate level radioactive waste, and about 10,000 m^3 of high level waste including used fuel designated as waste. In the OECD countries the amount of conditioned radioactive wastes are only 81,000 m^3 per year.

A typical 1000 MWe LWR will generate (directly and indirectly) 200-350 m^3 low and intermediate level waste per year, also discharging about 20 m^3 (27 tonnes) of used fuel per year, which corresponds to a 75 m^3 disposal volume following encapsulation if it is treated as waste. "Where that used fuel is reprocessed, only 3 m^3 of vitrified waste (glass) is produced, which is equivalent to a 28 m^3 disposal volume following placement in a disposal canister" [6-7].

Therefore the nuclear waste management is mainly linked to the spent nuclear fuel aspects, such as the treatment, recycling and re-fabrication, the waste reprocessing, conditioning, transportation and disposal. Before to analyze the storage and disposal, it is important to consider important RW management steps [6-7]:

1. The treatment;
2. The conditioning.

These two relevant processes allow to minimise RW volume and reduce its potential hazard by conditioning it into a stable solid form or containment to ensure that the waste can be safely handled during transportation, storage and final disposal. Moreover these two process allow to convert radioactive waste materials into a form that may be suitable for its subsequent management, such as transportation, storage and final disposal.

It is important to note that, treatment processes such as compaction (Fig. 5) and incineration allow to reduce only the RW volume. Moreover, the radioactivity of the waste will become more concentrated as the volume is reduced.

"Compaction is a mature, well-developed and reliable volume reduction technology that is used for processing mainly solid man-made low-level waste (LLW).

Some countries (Germany, UK and USA) also use the technology for the volume reduction of man-made intermediate- level/transuranic waste.

Compactors can range from low-force compaction systems (~5 tonnes or more) through to presses with a compaction force over 1000 tonnes, referred to as super compactors. Volume reduction factors are typically between 3 and 10, depending on the waste material being treated" [7].

Fig. 5 - RW Compactation [8]

Conditioning processes, such as cementation (Figs. 6) and vitrification are used to convert waste into a stable solid and insoluble form, thus preventing possible accidental dispersion to the surrounding environment.

(a)

(b)

Figs. 6 – RW cementation (a) and vitrification (b) [9-10]

Conditioning processes are dependent on the level of activity and the type (classification) of waste and may be schematized in the following steps:

a. Identifying a suitable matrix material, such as cement, bitumen, polymers etc., and packaging system according to the type of waste;

b. Immobilising the waste through mixing with the matrix material

c. Packaging the immobilised waste in a metallic or concrete boxes as an example.

3. European web pages

The basis of nuclear energy in Europe referred to 1957 and are related to the institution of the European Atomic Energy Community (Euratom), that allowed/allows to coordinate the Member States' research programmes for the peaceful use of nuclear energy, to pool knowledge, infrastructure and to ensures the security of atomic energy supply within the framework of a unique monitoring system, by establishing common safety standards. Furthermore an overview and presentation of the best practices used in the countries mostly interested in nuclear energy exploitation among the foreseen 13 EU countries are provided. In addition a nearly complete index of the web pages available in Internet on the RW management (including storage/disposal) is presented in the associated document CIRTEN-UNIROMA1 RL 1161-2010 [11]

3. 1 European Commission web pages

The European Commission organized and set up a web page (Fig. 7 and 8) to inform on nuclear energy [12] mainly focusing on:

1. Nuclear Safety Directive;
2. Nuclear Safety;
3. Nuclear Energy.

Fig. 7 – European Commission web page on nuclear safety

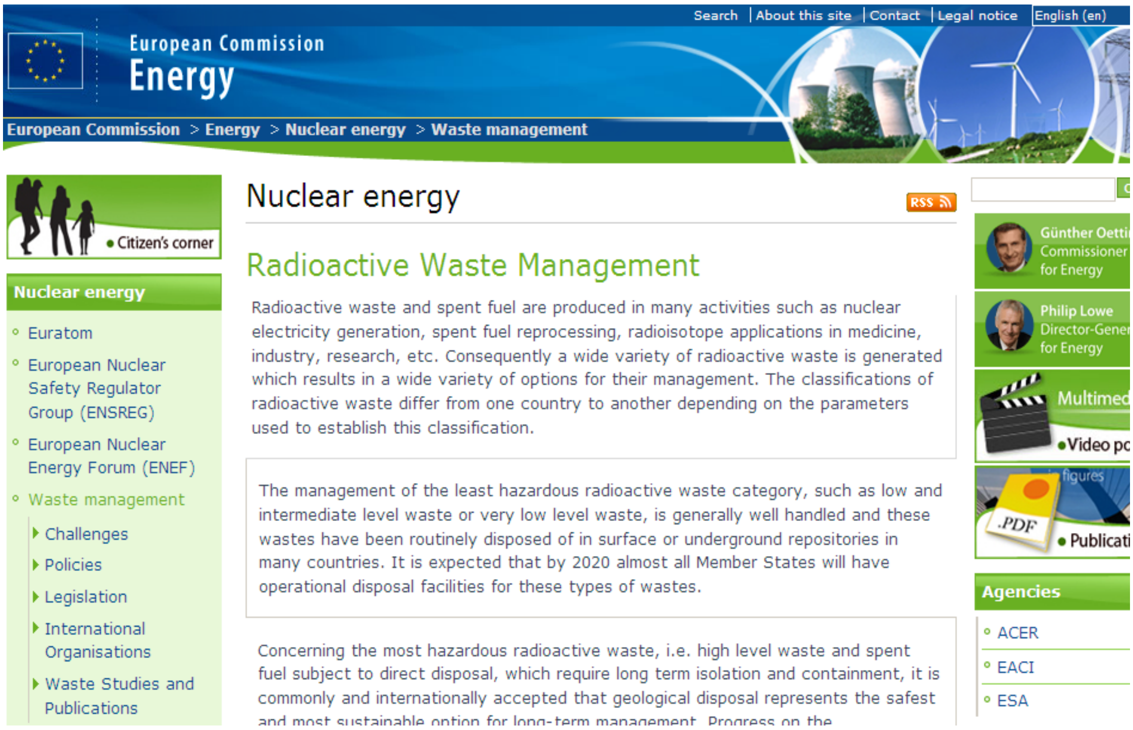


Fig. 8 – European Commission web page on RWM

3.1.1 Nuclear Safety Directive

the Nuclear Safety Directive that is aimed at maintaining and promoting the continuous improvement of nuclear safety and its regulation as well as ensuring that EU Member States shall provide for appropriate national arrangements to protect workers and population against the dangers arising from ionizing radiations from nuclear installations.

Objectives, definitions, scopes and national legislative obligations are defined in the document available at: http://register.consilium.europa.eu/pdf/en/09/st10/st10667.en09.pdf

3.1.2 Nuclear Safety

Nuclear Safety (previous Fig. 7) in particular is focused on the risk related to radioactive waste in countries with and without nuclear power plants.

The EU Commission has published on April 2010 a Eurobarometer survey, Europeans and Nuclear Safety Report available at http://ec.europa.eu/energy/nuclear/safety/safety_en.htm, highlighting that the majority of Europeans would find useful to have European legislation on radioactive waste management [13].

The results of the carried out survey revealed that the information on nuclear and safety is of meaningful importance particularly in relation to level of knowledge and satisfaction of Europeans in terms of feeling informed on nuclear safety, nuclear issues and received information.

The results highlighted that Europeans continue to be unfamiliar with safety issues related to nuclear power plants [14]: the situation was the same showed in the 2006 survey.

Moreover only the 25% of citizens feel 'very well' or 'fairly well' informed while the 49% 'not very well informed'; the remaining 25% assumed to be 'not informed at all' about the safety of nuclear power plants, as indicated in Fig.9.

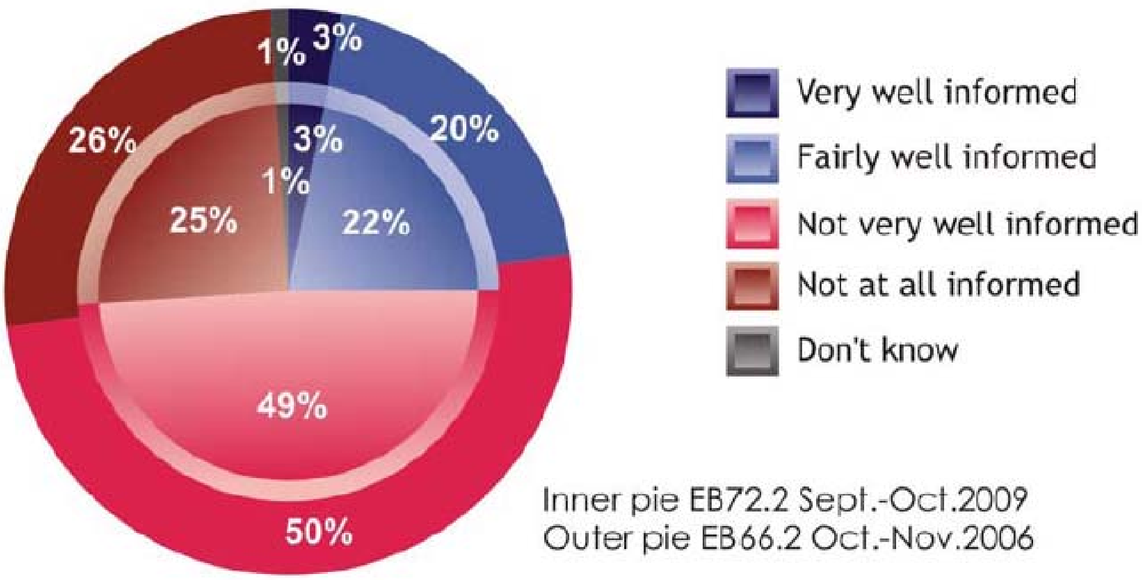


Fig. 9 –Level of feeling informed [14]

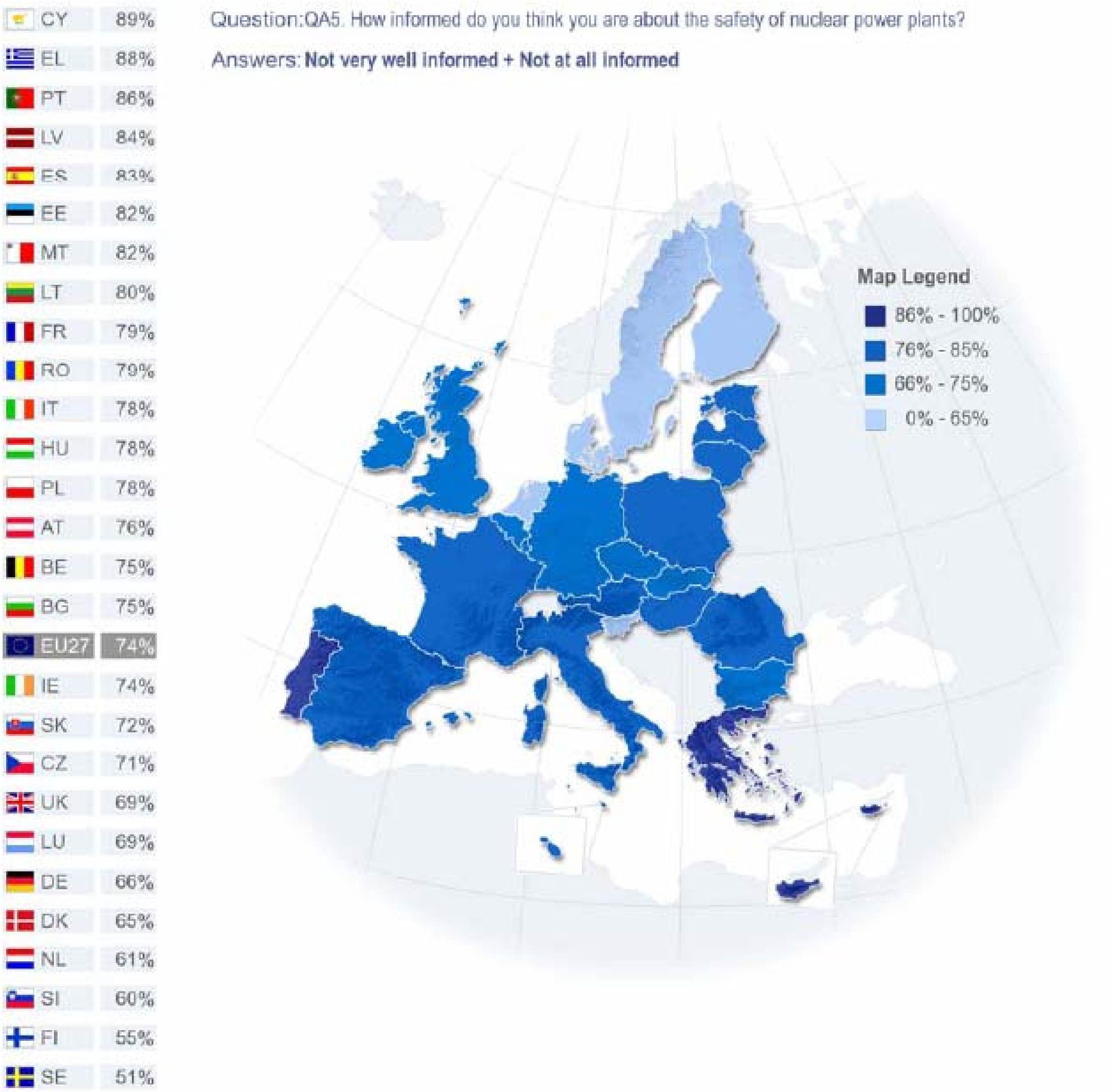
The majority of European people, in every country, feels uninformed about nuclear safety as represented in Fig. 10.

As indicated in the European Nuclear and Safety report, the relation between the feeling to be informed and the presence or absence of nuclear powers plants was less evident than in the past; where there is not operating NPPs the lack of information is higher, affecting almost the 90% of respondents in Cyprus (89%) or Greece (88%), as an example.

In any case in all Member States, the vast majority of respondents feel that the information the media offer is not sufficient.

However, in countries with active NPPs respondents have slightly more positive opinions than citizens in countries where domestic electricity is produced by other options.

Furthermore in every country the Eurobarometer revealed "*that schools do not offer enough information to children to give them the basic knowledge of energy and nuclear issues. Respondents in Greece (77%) are least likely to trust schools to educate children about energy choices, followed by respondents in the Netherlands (70%) and Hungary (68%)*".



(a)

QA5 How informed do you think you are about the safety of nuclear power plants?

	Very well informed	Fairly well informed	Not very well informed	Not at all informed	DK	Informed	Not informed
EU27	3%	22%	49%	25%	1%	25%	74%
Sex							
Male	3%	29%	48%	19%	1%	32%	67%
Female	2%	16%	50%	30%	2%	18%	80%
Education (End of)							
15-	2%	13%	46%	37%	2%	15%	83%
16-19	2%	21%	51%	25%	1%	23%	76%
20+	4%	31%	48%	16%	1%	35%	64%
Still studying	2%	25%	53%	19%	1%	27%	72%
Respondent occupation scale							
Self- employed	4%	25%	48%	22%	1%	29%	70%
Managers	4%	33%	50%	12%	1%	37%	62%
Other white collars	3%	23%	51%	21%	2%	26%	72%
Manual workers	1%	19%	53%	26%	1%	20%	79%
House persons	2%	13%	48%	35%	2%	15%	83%
Unemployed	2%	17%	48%	31%	2%	19%	79%
Retired	3%	23%	45%	28%	1%	26%	73%
Students	2%	25%	53%	19%	1%	27%	72%
Risks and advantages linked to nuclear power							
More advantages	4%	32%	48%	15%	1%	36%	63%
More risks	2%	18%	53%	26%	1%	20%	79%
Experience nuclear energy							
Experience	6%	38%	43%	13%	-	44%	56%
No experience	1%	18%	51%	28%	2%	19%	79%
Personal perception of nuclear energy							
Benefit	3%	33%	48%	15%	1%	36%	63%
Risk	2%	17%	52%	28%	1%	19%	80%

(b)

Figs. 10 – European level of feeling to be informed [13]

Finally it was highlighted that the mass media are the main source of information (with 72% for television and newspapers 40%) about nuclear issues.

Internet was indicated as the third most used source for information on nuclear energy (27%); while only the 7% of respondents mentioned schools and universities (around 15% of the sample is aged between 15 and 24).

The aspects of nuclear safety and security on which Europeans would be much more informed are the RW management, the main safety procedures of nuclear power plants, etc. (Fig. 11)

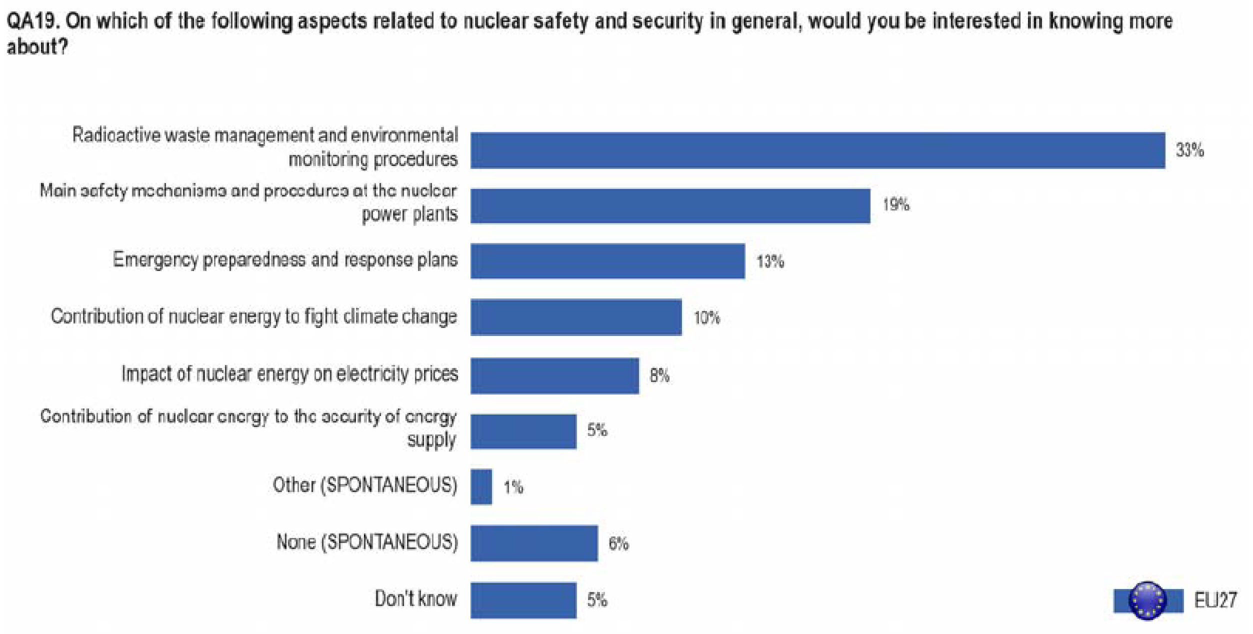


Fig. 11 – Aspects of nuclear safety and security [13]

3.1.3 Nuclear Energy

The basis for nuclear energy in Europe was laid in 1957 by the European Atomic Energy Community (Euratom) with the intent to activate cooperation in the field of research, protect people, monitor the peaceful use of nuclear energy and cooperate with other countries and international organizations. To attain these intents the European Commission set up web pages on Nuclear Energy (http://ec.europa.eu/energy/nuclear/index_en.htm) which contain broad information on the main nuclear issues and in particular on radioactive waste management. This web page (previously represented in Fig. 9) is organized in the following subsection:

1. European nuclear organization (Euratom, European Nuclear Safety Regulator Group (ENSREG), European Nuclear Energy Forum (ENEF));
2. Waste management
3. Radiation protection
4. Safety
5. Governance issues
6. Research
7. Links
8. Decommissioning

9. Transport

In addition the sub-section dedicated to the waste management is organized in order to support the national and European legislation as well as to inform on:

1. Radioactive Waste and Spent Fuel Data Collection and Reporting, Record Keeping and Knowledge Transfer in the EU;
2. Situation Concerning Uranium Mine and Mill Tailings in an Enlarged EU;
3. Attitudes towards radioactive waste.

A great attention is given to the question of radioactive waste management (particularly with reference to long lived wastes) due to the fears of citizens linked to nuclear energy and its safety aspects/issues.

Therefore a correct and clear information carried out through mass media, TV, newspapers, conferences etc. would influence the people approach, especially many of the opponents with their "Not in my backyard" opinion, and determine a change of their opinion.

Moreover the European Commission will propose European legislation on nuclear safety, security and RW management until the end of 2010 and, at present, is conducting a public consultation on such a legislative proposal.

While each Member State must choose whether or not to invest in nuclear energy, the nuclear safety and security framework applied everywhere in the EU is of common interest, therefore approaches for a possible EU legislative proposal on the management of spent fuel and radioactive waste are the topics investigated by means of a public consultation, launched during the period 31/03/2010 - 31/05/2010. The proposed questionnaire is available online on: http://ec.europa.eu/energy/nuclear/consultations/2010_05_31_fuel_waste_en.htm.

Finally, as already indicated, in order to examine the attitudes of European citizens towards nuclear energy and radioactive waste the Directorate-General for Energy and Transport launched also a Eurobarometer survey ("Research and Political Analysis" Unit), conducted in the 27 Member States of the European Union, concerning the role of the EU in managing radioactive waste, how informed citizens feel about radioactive waste and the involvement of citizens in decision-making.

The responses highlighted that: *"…to gain a deeper insight in the publics' opinion regarding radioactive waste, the following key variables have been used while analyzing the different questions:*

- *Respondents' support for nuclear energy production: QB2 Are you totally in favor, fairly in favour, fairly opposed or totally opposed to energy production by nuclear power stations?*

- *Their self-perceived level of information about radioactive waste: QB1 How well informed do you think you are about radioactive waste? Very well informed, fairly well informed, not very well informed or not at all informed…"* [14].

3.2 Nuclear Energy Agency web pages

The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD) aiming at maintaining and developing, through international co-operation, the scientific, technological and legal bases required for the safe, sustainable and economical use of nuclear energy for peaceful purposes.
To achieve these goals the NEA (http://www.nea.fr/nea/) organizes a forum for sharing information and experience, a centre of excellence to helps Member countries to pool and maintain their technical expertise and joints projects and information exchange programmes. The main areas of work are the following:

1. Nuclear safety and regulation
2. Nuclear energy development
3. Radioactive waste management
4. Radiological protection and public health
5. Nuclear law and liability
6. Nuclear science
7. The Data Bank
8. Information and communication

3.2.1 Nuclear regulation: law and liability

As for the nuclear law and liability aspects are concerned, the main goal in this area is related to the support or help given to national and international legal regimes, in the framework of the peaceful uses of nuclear energy, covering also law information and education aspects.
Moreover, within this framework, NEA established the International School of Nuclear Law (ISNL)(Fig.12) in 2001 and the University of Montpellier 1 with the support of the International Atomic Energy Agency with the purpose of providing a intensive course of education in international nuclear law to law students at doctoral or masters level and to young professionals in the nuclear sector who wish to develop their knowledge.

Fig. 12- NEA educational initiative

It may be useful to remark that ISNL examined/examines the main aspects of nuclear law, in particular nuclear safety, radiological protection, radioactive waste management, transport of nuclear materials, etc.

3.2.2 NEA approach to RW management

The key point to attain public acceptance is, also for NEA, how to value safety, noting that safety at any price without reference to potential health benefits may limit the development of nuclear power. While it seems that the question may be at least commonly understood for NPPs, nuclear waste management (Fig.13) and mainly RW disposal has yet to be fully drawn into the debate for the reason that progress on high-level disposal sites has been limited. Therefore nuclear safety debate might be focused on the following important issues:

- Public acceptance of nuclear power plants;
- Development of the back end of the nuclear fuel cycle;
- Assurance that civil nuclear technologies and fuel will not be used for military purposes.

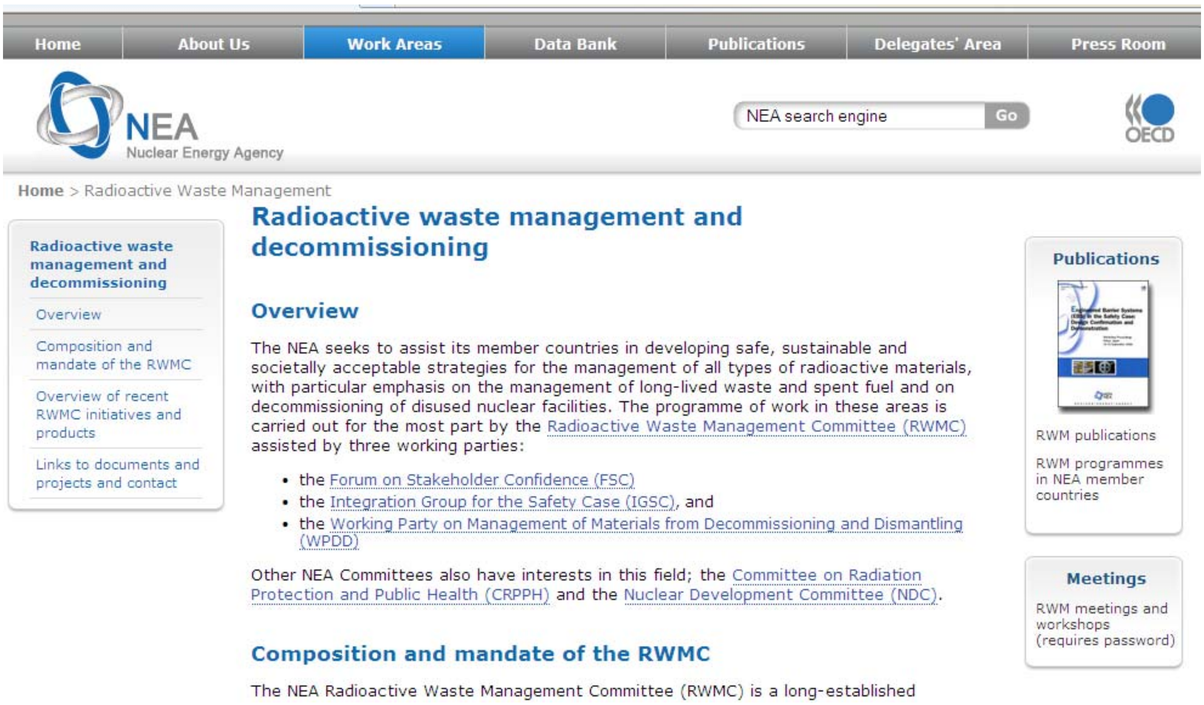


Fig. 13 - RW management and decommissioning

Public acceptance of nuclear power requires unavoidably the acceptance of all its related activities, such as fuel and waste transportation, disposal of intermediate and low-level radioactive waste and many other activities that characterizes the decommissioning of NPP.

These aspects are mandatory, how highlighted by the demonstrations against shipments of high-level waste and spent fuel in Germany in March 1997 and the recurring public attention on reprocessed fuel shipments from France to Japan clearly illustrate this.

In several countries, like United States, Germany, United Kingdom etc., the matter of high-level waste disposal found strong public opposition (due to the fear of nuclear weapons development) resulting in the suspension of plans for reprocessing of wastes.

Therefore "… *can nuclear waste of all kinds be stored or isolated safely until its radioactivity is no longer harmful to humans or the environment*?" [14] is the most important question to which nuclear technical community answers "yes".

The primary goal, that the RW management must achieve, is to ensure non-proliferation and the minimization of RW risks for the future generation.

NEA RWM collected public opinion on the geological disposal for long lived radioactive waste. The obtained answers highlighted that the consensus on the merits of geological disposal in deep and stable geological formations is subordinated to the capability to develop technical solution and appropriate engineered infrastructure allowing to minimise potential long-term radiological impacts on humans and the environment. However the currently strong public reaction against many projects to develop LLW disposal sites shows that the general point of view of citizens is indeed far from that one of the specialist. As for the spent fuel reprocessing, that in particular has always raised concerns about the management of the plutonium, public acceptance challenges will be conditioned by the assurance that it will not be used for military purposes. In the NEA web page (http://www.nea.fr/pub/policypapers/) there is also a section dedicated to the publication or press release where it is possible to find a selection of papers on various aspects of nuclear energy for peaceful purposes (Fig. 14).

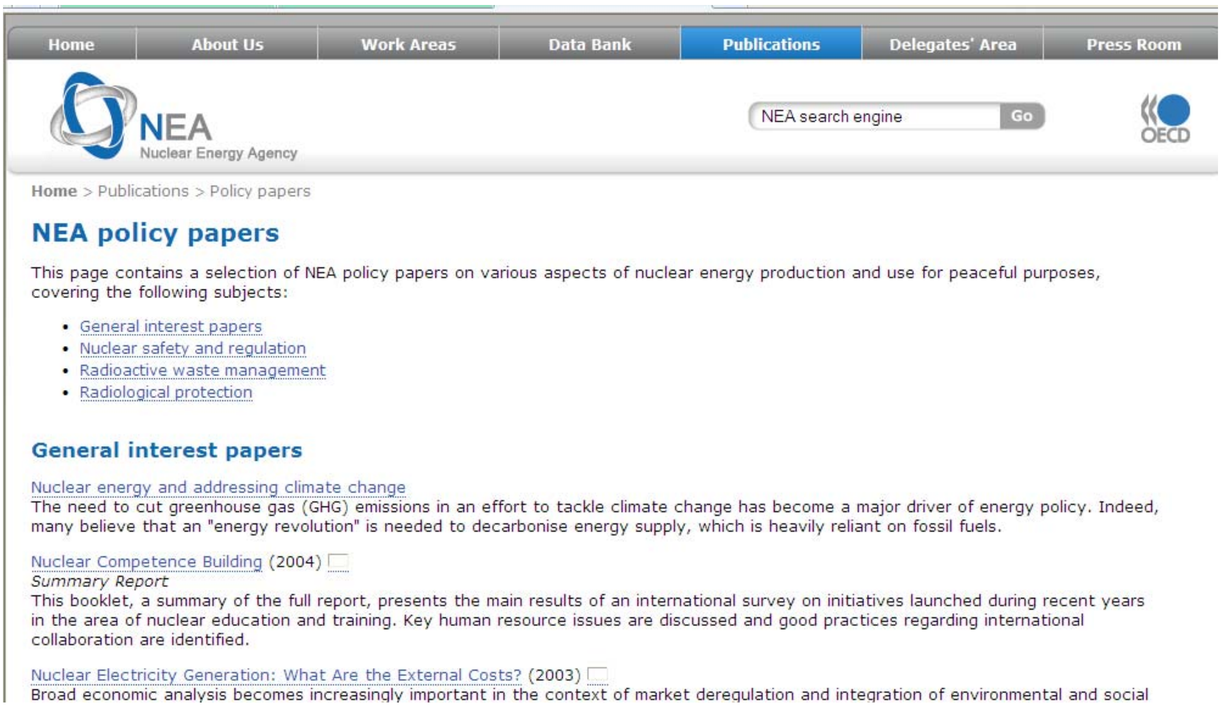


Fig. 14 - NEA web page dedicated to information

The mentioned policy papers area contains adjourned and interesting studies (until present date), among which the study, carried out during 2010, on public attitudes and acceptance of nuclear energy and the need for better information (http://www.nea.fr/ndd/reports/2010/nea6859-public-attitudes.pdf)[15]. In this study several observations arose, among which the following:

1. Most of people understand that his own Country is energy dependent and agree that the nuclear energy could help to be less dependent and ensure a lower and more stable energy prize.
2. People, who leaves in a country without NPP, thinks that the risks of nuclear energy outweighs its advantages.
3. almost 60% of people believe that NPP are/can be safely operated.
4. Even if people states to feel inadequate the own level of knowledge, they think that an increased knowledge on nuclear issues may lead to higher level of support.
5. "..*Scientist and environmental organization are most trusted to provide information*".

The report on public attitudes and acceptance of nuclear energy highlighted (Fig.15), as main conclusion, that the opposition to nuclear energy would reduce significantly if the matter of RW disposal was solved.

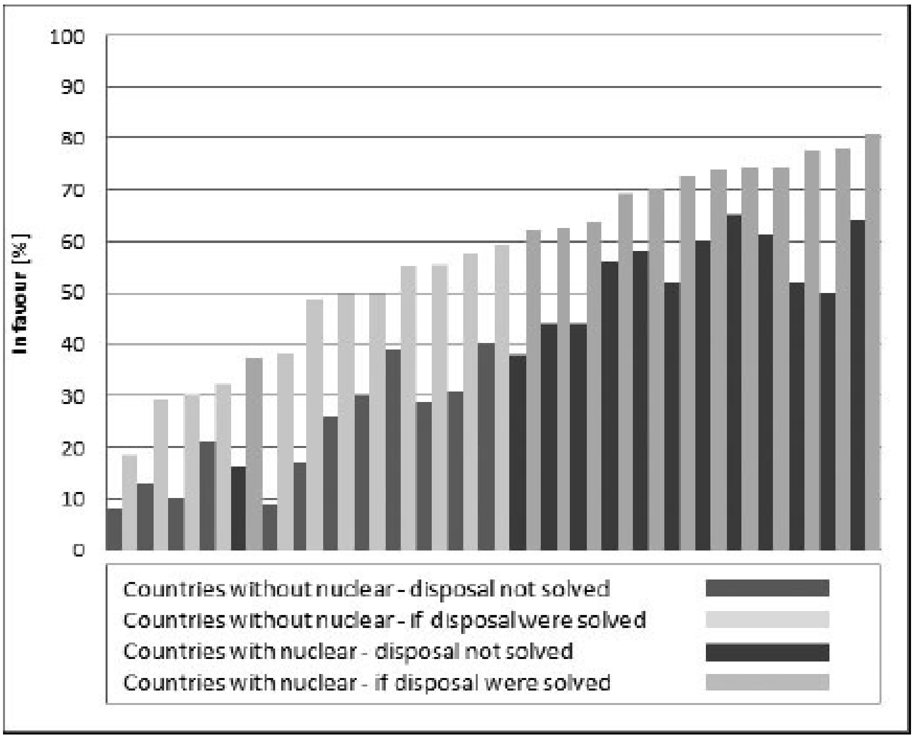


Fig. 15- Change in the acceptance of nuclear vs. solved waste disposal problem [14]

3.2.3 Information activities

OECD-NEA promotes and organizes conference, workshop, events and courses aiming at the information and dissemination of nuclear knowledge in order to create general consensus and acceptability of nuclear energy through also the International Energy Agency (Fig. 16)[16].

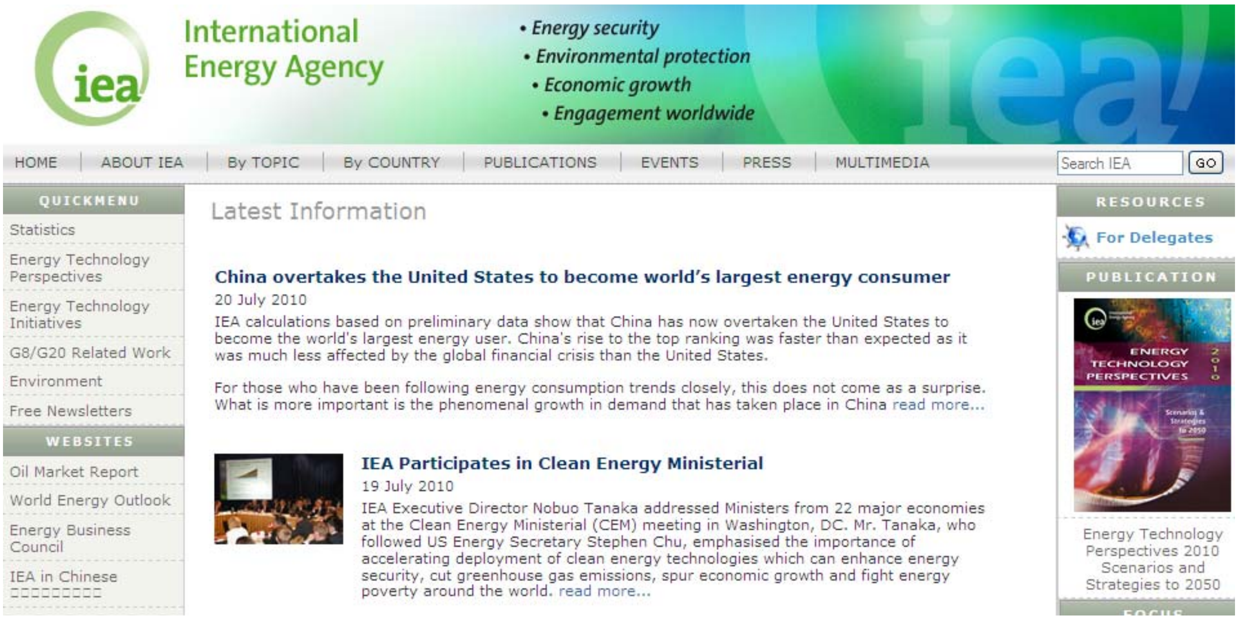


Fig. 16- International Energy Agency web page

One of the most important event during 2010 was the International Conference on Access to Civil Nuclear Energy (Fig.17) addressed to promote the peaceful and responsible use of nuclear power and enable the debate on how to develop a nuclear programme, also with international cooperation.

This conference represented a platform where Member Sates may share experience and lessons learned to improve access to nuclear power and to have the opportunity to identify what they must do to ensure the realization of nuclear energy's potential as a reliable, sustainable and environmentally friendly energy source (all these aspects are inherently linked).

Fig. 17- International Conference on Access to Civil Nuclear Energy home page

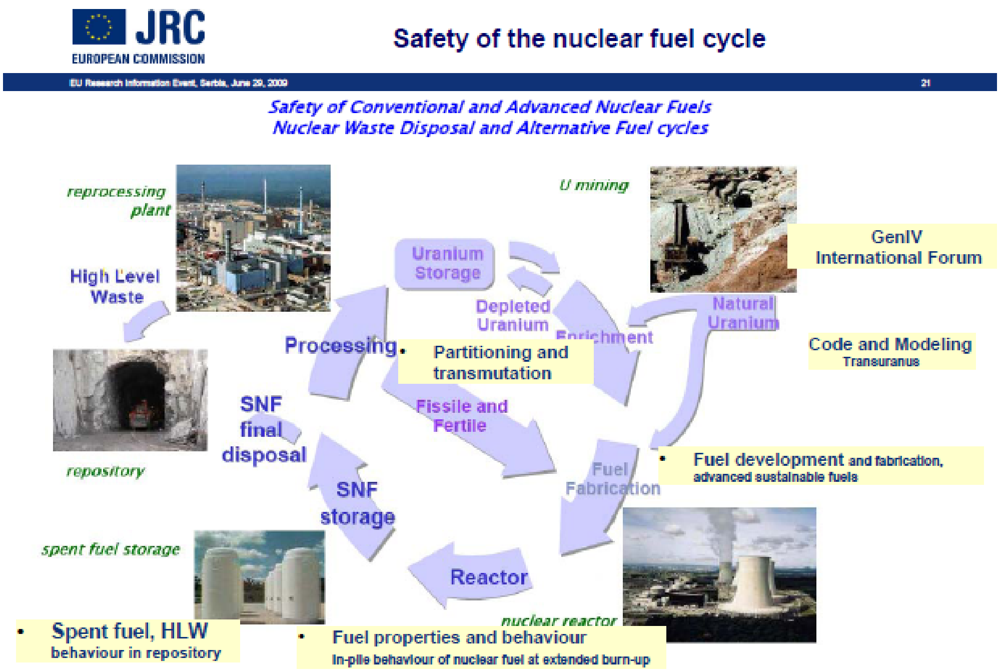
3.3 JRC's decommissioning and waste management programme

In 1999 the European Commission launched a Decommissioning and Waste Management (D&WM) Programme that include more than a hundred projects spanning from the realisation or refurbishment of facilities for waste management, decommissioning of nuclear facilities and management of radioactive waste and nuclear material.

The programme main objectives/legal background are related to the exchange, inter comparison and handling of environmental radioactivity information (Fig. 18 b) and in emergency (CD 87/600) conditions and to the analysis of the significance of the information collected.

JRC activities (Figs.18) mainly refer to the management of high level nuclear waste following the two major options chosen in the EU:

1. the geological disposal (the aim of which is to prevent the release of radionuclides to the biosphere over a very long time scale);
2. the partitioning and transmutation, which represents an alternative strategy that would considerably reduce the radio-toxicity of waste both in activity and in time.



(a)

(b)

Fig. 18 - Joint Research Center nuclear fuel cycle approach (a) and information activity (b)

Moreover JRC supports international programmes with special emphasis on the JEFF project (Joint Evaluated Fission and Fusion File) and promotes the development and dissemination of reliable knowledge and/or nuclear information in the area:

- o Analysis of Nuclear Traces in the Environment

- Radionuclide metrology for primary standardization and policy support
- Nuclear data for radioactive waste management and safety of new reactor developments
- Alpha-Immune Therapy
- Radioactivity Environmental Monitoring
- Knowledge management , education and training - nuclear fuel cycle
- Alternative Nuclear Fuel Cycle
- Nuclear Waste Disposal
- Fundamental and applied Actinides Research
- Basic research in nuclear physics and nuclear data standards

The last updated publication about RW management, available at the JRC site referred to 2009 and is "Geological disposal of radioactive waste: moving towards implementation"[17]. This report analyzes the state-of-the-art of technology and procedures that are necessary to implement the high-level RW management. Other last press releases are linked to the EU Eurobarometer 2010 survey, as shown in Fig. 19

Fig. 19 – JRC press releases web page

3.4 Nuclear Decommissioning Authority

The Nuclear Decommissioning Authority (NDA) (http://www.nda.gov.uk/) is involved in RW management within UK developing and implementing strategy for nuclear low level (LLW) and higher activity wastes (HAW). NDA RW management outlines the benefits deriving from the nuclear energy in terms of cost, cost saving when dealing of decommissioning and waste treatments (Fig.20) [18].

Decommissioning is usually associated with the clean-up and eventual demolition of redundant facilities but construction programmes play an equally important role, particularly in ensuring that radioactive waste is dealt with safely.

Fig. 20 – NDA waste management

NDA annual report allow people to be informed on radioactive waste activities and management in order to attain high level of public acceptance.

The RW management is organized according to the following scheme and radioactive sources Figs. 21.

In the document all the activities that produce LLW, which represents the largest proportion of the total wastes, are clearly indicated. ILW (which is more radioactive) is produced as a result of fuel reprocessing and the operation of nuclear power plants, while larger RW activities result from decommissioning and cleanup activities.

In the UK definition, the term HLW is restricted to the heat generating products of reprocessing, initially held in liquid form and then immobilised by vitrification.

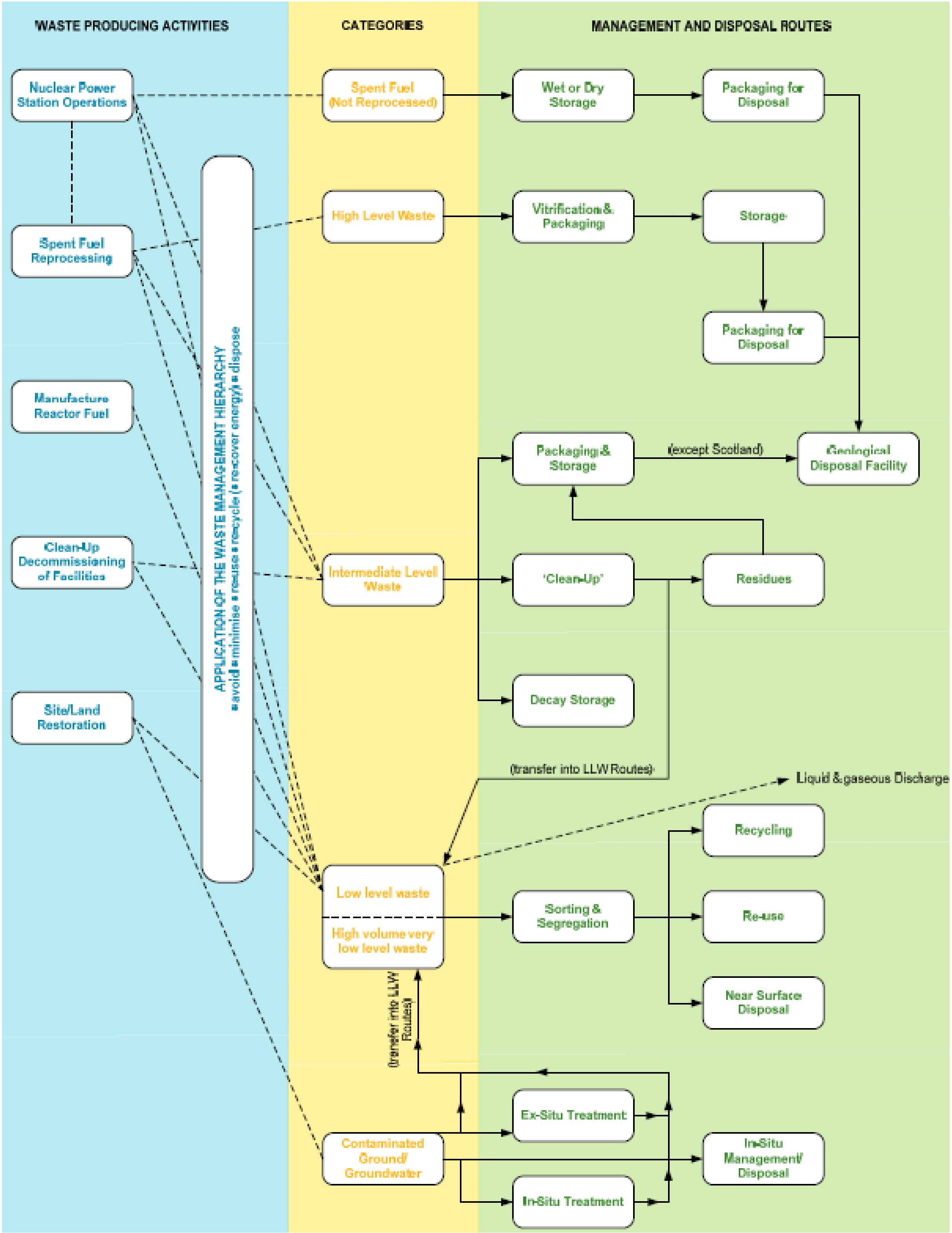


Fig. 21 – NDA RW management scheme

Activity/source	Inside NDA estate	Outside NDA estate	Wastes produced	Issues
Research, prototype and operational nuclear reactors*	✓	✓	• Operational waste (and stored operational waste, considered 'legacy' or 'historical') • Authorised discharges • Decommissioning waste • Spent fuel	• Treatment of process wastes (eg ion exchange resins) • Cleanup or treatment of various wastes held at reactor sites • Wastes from the decommissioning process – the reactor facilities and installations such as fuel ponds • Contaminated ground and groundwater
Uranium enrichment / manufacture of fuel for nuclear reactors	✓	✓	• Operational waste • Authorised discharges • Decommissioning waste	• Treatment of process wastes including residues • Wastes from the decommissioning process • Contaminated ground and groundwater
Reprocessing of used reactor fuel**	✓		• Operational waste (and stored operational waste, considered 'legacy' or 'historical') • Authorised discharges • Decommissioning waste	• Fuel cladding waste • Process wastes • Liquid high level waste • Wastes from the decommissioning process • Contaminated ground and groundwater
Manufacture of nuclear weapons		✓	• Operational waste • Authorised discharges • Decommissioning waste	Most wastes from defence sector consigned to NDA disposal facilities
Medical and research activities		✓	• Sealed sources • Low activity materials	Some wastes consigned to NDA disposal facilities
* including operation of nuclear powered submarines				
** fuel reprocessing represents a major source of HAW. Some waste arisings are owned by British Energy, some by overseas utilities, and others by NDA				

Fig. 22 – NDA RW classification

As it was already highlighted, waste management strategy should take into account mainly the following objectives:

- Risk reduction;
- Maintenance of security;
- Optimization of operations, value for money;
- Robustness/flexibility of waste management in the event of policy change or factors outside our control;

o Availability of capability and skills base.

3.5 ANDRA : French National Agency for radioactive waste management

ANDRA (http://www.andra.fr/international/index.html) (Fig.23) is the public French national agency in charge to ensure the sustainable management of radioactive materials and waste.
The RWs produced in France (as in other countries) vary considerably by their activity levels, half-lives, volumes and contents (fission products, sludge, etc.).
The classification of French RW is a function of their management: on one hand, the distinction between very short lived waste, short-lived waste and long-lived waste, and on the other hand the distinction between very low, low, intermediate or high-level waste. In addition the radiological risk is evaluated on the basis of two main parameters: the activity level and the half-life.

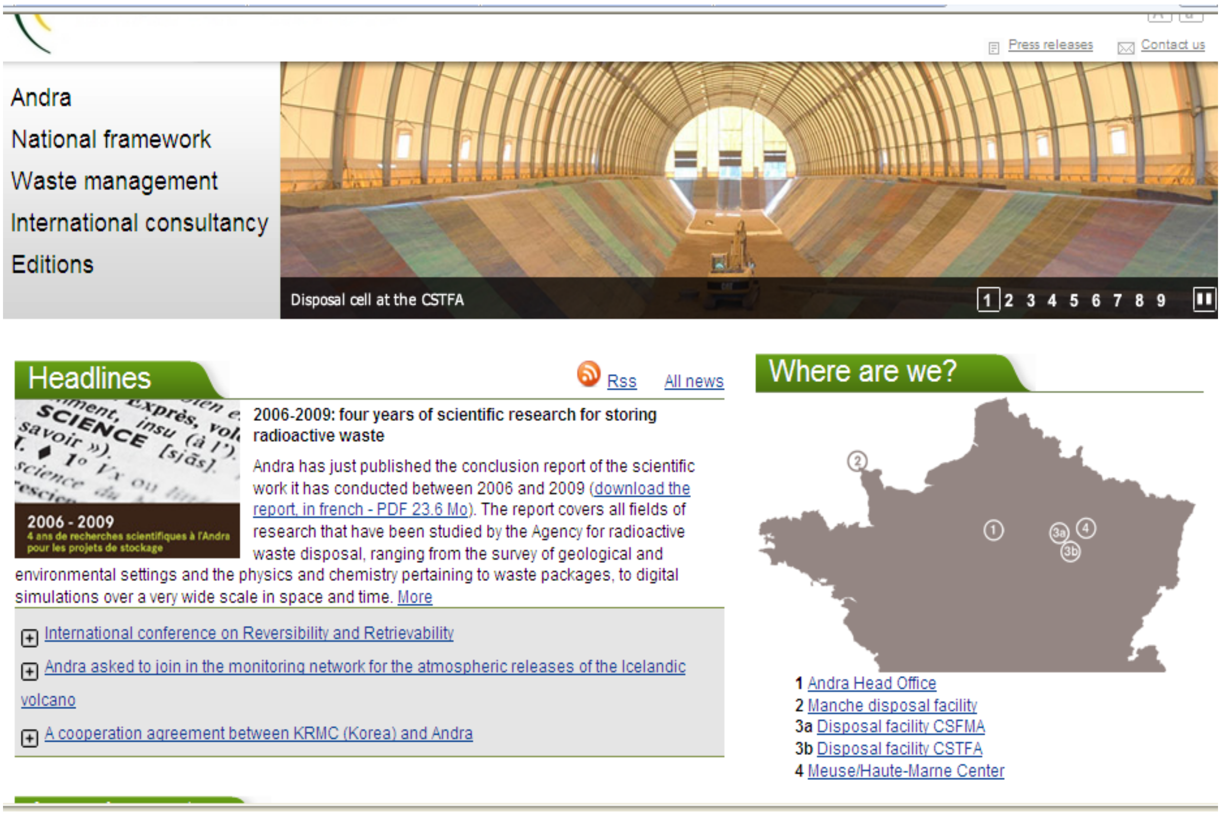


Fig. 23 – NDA RW classification

The RW management strategy involves the setting up of specific systems, taking into account the radiological, chemical and biological hazards.

All operations associated with management of a category of waste, from production to disposal, represent a waste management route, that must be adapted to the type of waste concerned. The operations within each route are interlinked and all the routes are interdependent. These operations and routes form a system which must optimised considering safety, traceability and volume reduction issues. ANDRA offers in the home page all information on nuclear waste management, including also the geographic location of waste (as indicated in Fig. 24)

Fig. 24 – French main geographic location of waste

Moreover it is important to note that about 90 % of the volume of radioactive waste generated in France are disposed in near surface disposal facilities (ANDRA's roadmap for RW disposal is also indicated in Fig. 25).

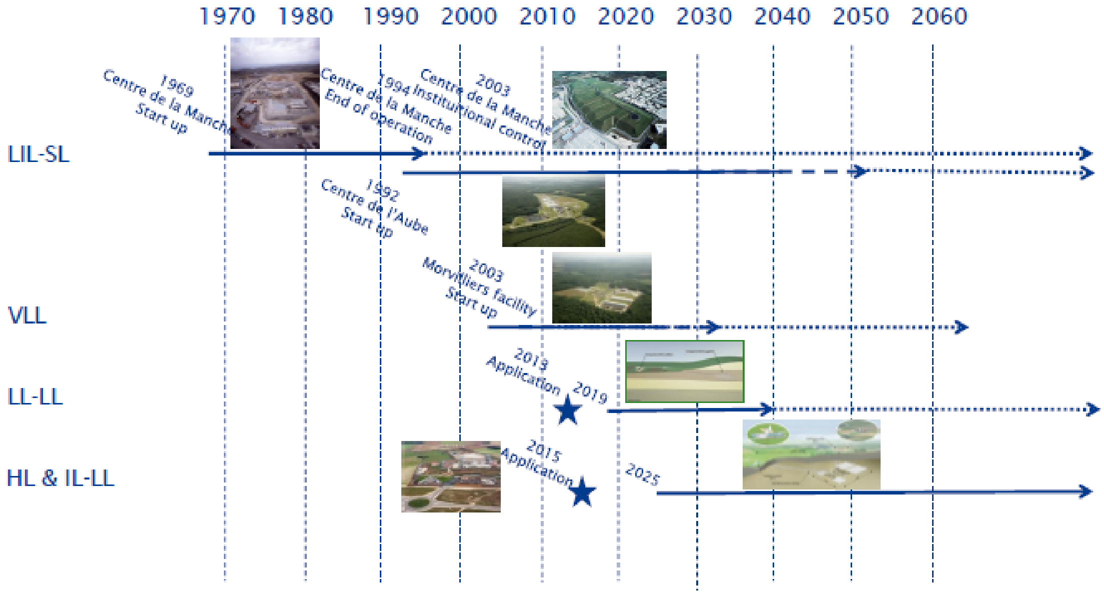
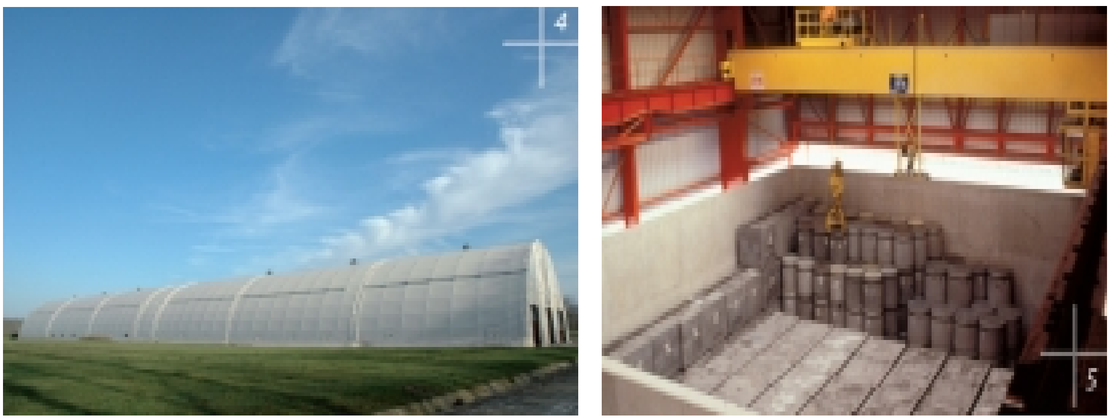


Fig. 25 –ANDRA’s roadmap for RW disposal

Andra has already worked on a large number of dismantling issues, such as the identification of a quantitative and radiological inventory of very low level dismantling waste, followed by the design and operation of adapted disposal facilities for very-low-level waste (CSTFA) and for low-& intermediate-level waste (CSFMA) in the Aube District (Figs. 26).



(a) (b)

Figs. 26 – Disposal cell for waste packages at the CSTFA(a) and at the CSFMA (b)

The existing solutions for RW management in France are briefly described as follows:

1. Very low level waste repository;

2. Low and intermediate level disposal facility.

3. High-level and long-lived waste regulated at national level

3.5.1 Very-low-level waste repository

The waste disposal facility located at Morvilliers in the Aube district, the scheme of which is represented in Fig. 27) has an overall capacity of about 650,000 m^3.

VLLW are subject to special processing before to be stored in the facility disposal inside metal drums or “big-bags”. The plastic and metallic wastes are compacted to reduce their volume, while liquid waste are solidified and then stabilized.

“*Once conditioned, waste batches are labeled and emplaced in successive horizontal layers (around ten on average) inside several metres deep disposal vaults excavated in clay. Once the disposal vault is filled, it is definitely closed and then capped with a compacted clay layer. This compaction process aims at restoring its initial low-permeability to the clay material*” [19].

At the end of 2007, the volume of waste disposed at Morvilliers was about 91,300 m^3. Waste is disposed in special vaults excavated in a clay formation, protected by a synthetic membrane and, in the future, by a clay cover.

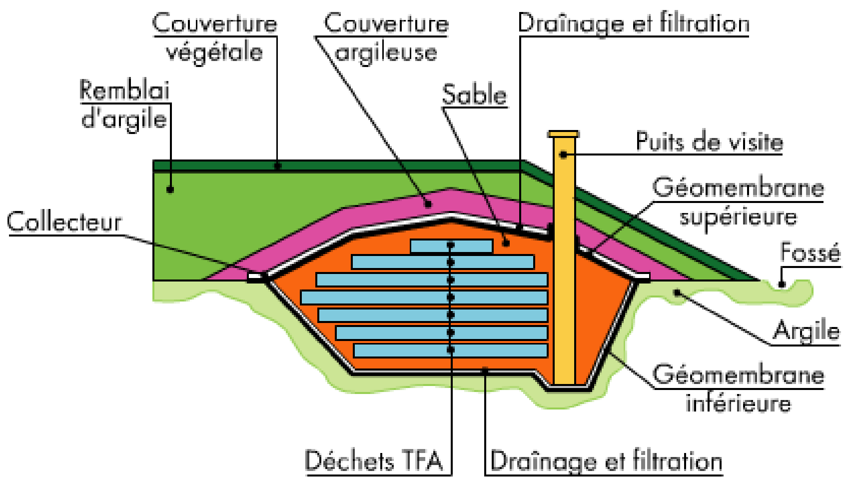


Fig. 27 –Schematic diagram of a disposal cell

3.5.2. Low and intermediate-level short-lived waste disposal facility

Low-and intermediate-level short-lived waste mostly comes from the nuclear power industry and the activities of the French atomic energy commission (CEA). Short-lived intermediate and low-level waste includes certain categories, like the tritiated waste, which have characteristics that make them unsuitable for acceptance at the CSFMA waste disposal facility (located in the Aube district) , even conditioned in specifically designed containers. Solution to manage this type of waste is still under study, therefore pending the creation of a suitable disposal facility, existing LLW-LL wastes are stored in the production/facilities sites (Fig. 28).

Fig. 28 – LLW-LL site

3.5.3 High-level and long-lived waste regulated at national level

During recycling, spent nuclear fuel is immersed in a chemical solution which enables the uranium and plutonium to be separated from the non-reusable residues. The 3-5% of spent fuel residues are non reusable, highly radioactive and some of these give off heat.

Disposal solutions for this type of waste are currently under study. ANDRA 2006 Planning Act "*…stipulates that for high-level waste and long-lived intermediate-level waste the research and studies have to be pursued according to three complementary venues, which were already mentioned as R&D venues in the December 1991 Waste Act:*

- *partitioning and transmutation of long-lived elements, so that an assessment can be made in 2012 of the industrial prospects of reactors allowing transmutation and a prototype installation set in operation before 31 December 2020;*

- *reversible disposal in deep geological formations, in order that a license application can be filed in 2015, and, subject to such an authorization, the repository can be commissioned in 2025;*
- *storage, in order, at least in 2015, to create new storage installations or modify existing ones to meet the needs*" [19].

The long-term-safety performance of a disposal facility for HL/IL-LL waste depends on the characteristics for disposing of waste packages. In order to prepare the public debate scheduled to be held in 2012-3, Andra initiated in 2005-6 to involve the local Information and Oversight Committee (Comité Local d'Information et de Suivi – CLIS) and associations provide them technical elements describing the project of the disposal facility.

The Andra published in 2005 and in 2009 Dossiers demonstrated the feasibility of a deep geological repository for HL and IL-LL wastes, including information about the siting, by selecting a restricted 30 km^2 area for further detailed investigations, before the final site selection in 2013.

The conditioning of low-level long-lived waste (LLW-LL) should take care of graphite or bituminized wastes, that contains, mostly, long-lived radionuclides. These RW might be put in concrete containers and submerged of cement with a concrete lid. To facilitate handling of these packages, it is planned to group them into metal containers.

High-level wastes are temporarily stored in adequate tanks before to be calcined and incorporated into a molten glass. The mixture is poured into a stainless steel container. The confinement capacity of this special glass matrix is particularly high and durable.

A package of HLW contains around 400 kg of glass for 11 kg of waste.

To facilitate future handling, transport, storage and disposal operations, each primary package is due to be placed in a steel disposal container. At present HLW are stored at production sites, in La Hague (AREVA), Marcoule (CEA) and Cadarache (CEA), indicated in Fig.29.

Fig. 29 – HLW site

Moreover the mentioned 2006 Planning Act on the sustainable management of radioactive materials and waste highlights that the research and studies on HLW shall be pursued according to the three following complementary venues, as already quoted:

1. **Partitioning and transmutation of long-lived radioactive elements** to performe on accelerator-driven reactors devoted to waste transmutation.
2. **Reversible disposal in deep geological formations** (Fig. 30) in order to choose a site and design a disposal facility so that, after having obtained all the Authorizations, the facility can be set in operation in 2025.
3. **Storage** in order to create new or modify existing storage installations, at the latest in 2015

Concerning RW management R&D programs are carried/carrying out by Andra and CEA as prescribed by the 2006 Planning Act on the sustainable management of radioactive materials and waste (Act 2006-739 of 28 June).

Finally it is important to note that Andra has organized, in its web page, a section dedicated to information, where it is possible to find downloadable documents and press releases (http://www.andra.fr/radioactive-waste/waste-management-company.htm).

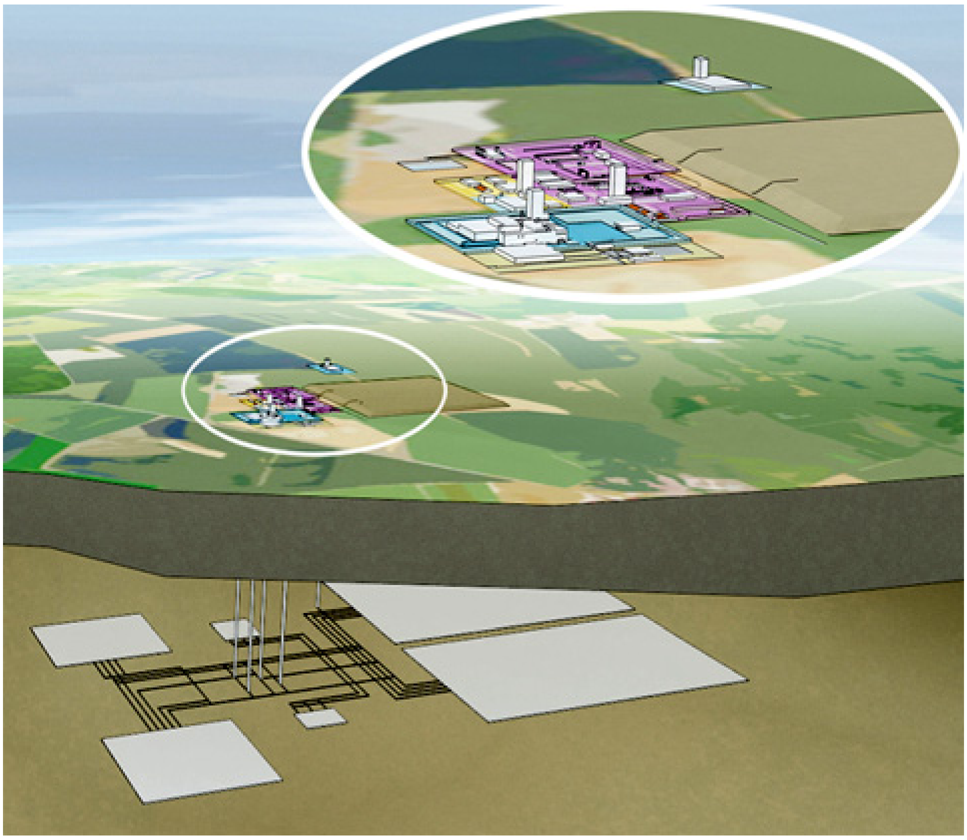


Fig. 30 – Schematic diagram of the installations at the future HL/IL-LL repository

3.6 RW management in Spain

In Spain the national policy related to RW management is established in a General Radioactive General Plan (GRWP) which is drawn up by the Radioactive Waste Company, ENRESA (http://www.enresa.es/) and submitted to the Ministry of Economy for the government approval. The public company - ENRESA- was created in 1984 by Spanish Parliament created a to manage low, intermediate and high level nuclear waste.

Spanish electricity output from nuclear energy is around 7 600 MWe, accounting for about 30% of total electricity production. Although Spain has an almost complete nuclear fuel cycle including uranium mining, it has not any reprocessing facilities.

Therefore up to now Spain reprocessed its fuel in France and the UK, while the low and intermediate-level waste (LILW) generated in nuclear and radioactive facilities, including waste arising from decommissioning, are disposed of in a near surface repository.

Most of the radioactive wastes generated in Spain are of the low and intermediate level type generally produced at hospitals, research centres, industries and nuclear power plants, containing radioactive isotopes whose radioactivity will be reduced by half in less than 30 years.

Fig. 31 – ENRESA home page

The mainlines of the RWM in Spain may be summarized as follows[20]:

- Residual material may be cleared after demonstration that the radiological risk is trivial.
- Tailings from uranium production are disposed in land burial shapes in situ.
- L&ILW are disposed in El Cabril facility.

The strategy for storage of spent fuel considers both wet and dry methods, that at present, are stored in the pools of all NPPs (a temporary dry storage facility was built for Trillo NPP spent fuel due to lack of capacity in its pool), waiting for a centralised away-from-reactor solution foreseen in 2010 for the medium and long term.

The RW management of spent fuel and HLW has been based exclusively on ensuring the availability of the scientific and technological know-how and capacity required for definitive disposal in deep geological formations. In particular the present GRWP establishes the following highlights:

- *"…No decision for a final solution will be taken before 2010. The geological studies for the siting process will be limited to maintain the existing information and to ensure its value, so* *that it can be of use in a further selection process when a decision is finally taken and for the safety assessments to be prepared.*

- *Additional work for the existing preliminary repository designs will be oriented to incorporate the criteria of retrievability.*
- *The Safety Assessment capabilities developed should be maintained in the future through exercises incorporating the experimental data and models of the research groups susceptible to standardisation at international level.*
- *In the meantime it will be necessary to carry out the widest possible campaigns, in order to facilitate better knowledge and understanding both of the problem to be solved and the technology to be used to achieve such solution.*
- *The feasibility and implications of new technologies, specifically partitioning and transmutation, should be also evaluated during this period of time* [20]…".

3.6.1 LILW management

The management of LILW is solved adopting a centralised disposal facility (El Cabril) (originally an uranium mine) in Hornachuelos (Córdoba). In 1986 ENRESA took responsibility for El Cabril facility (Fig. 32) and moved the waste from the mines to new built buildings on the same site while in the same time the national Government informed the local communities on the benefit provide them as a compensation.

El Cabril disposal facility is constituted by two platforms, for the disposal of LILW radioactive wastes, and is characterized by a suitable structures for very low level wastes. In addition, the facility has the resources required for the treatment and conditioning of wastes requiring such processes.

The disposal system (Fig. 32) is based fundamentally on the incorporation of natural and engineered barriers safely isolating the materials disposed of for the time necessary for them to be converted into harmless substances.

Fig. 32 – El Cabril disposal facility

As it is possible to find in the ENRESA web page, the basic objective of El Cabril disposal facility is to guarantee the protection of persons and the environment against ionising radiations also after it has ceased to operate. In order to achieve this goal the facility is characterized by three different barriers, the first of which made up of the conditioned waste and the container; the second one represented by the engineered structures housing the wastes and the third one formed by the natural terrain of the site at which the facility is located.

3.6.2 HLW management

Radioactive waste containing generally high concentration of all kind of radionuclides. There are two groups in this category: HLW vitrified waste arising from reprocessing in France of Vandellos I NPP spent fuel, and LWR spent fuel accounting a total expected of about 7 000 tU. In addition, other waste not acceptable in the El Cabril facility would be included in this category. The high level wastes consist basically of the spent fuel from nuclear reactors and other materials with high levels of radioactivity, normally with an appreciable content of long-lived radionuclides.

Once unloaded from the nuclear reactor, the spent fuel is temporarily stored in pools at the site of the nuclear power plants at which it was produced and subsequently moved to two nuclear power plants: Trillo and José Cabrera, waiting to be transferred in a Centralised Temporary Storage facility (Fig. 33) designed to house an amount of total material of about 12,816 m^3.

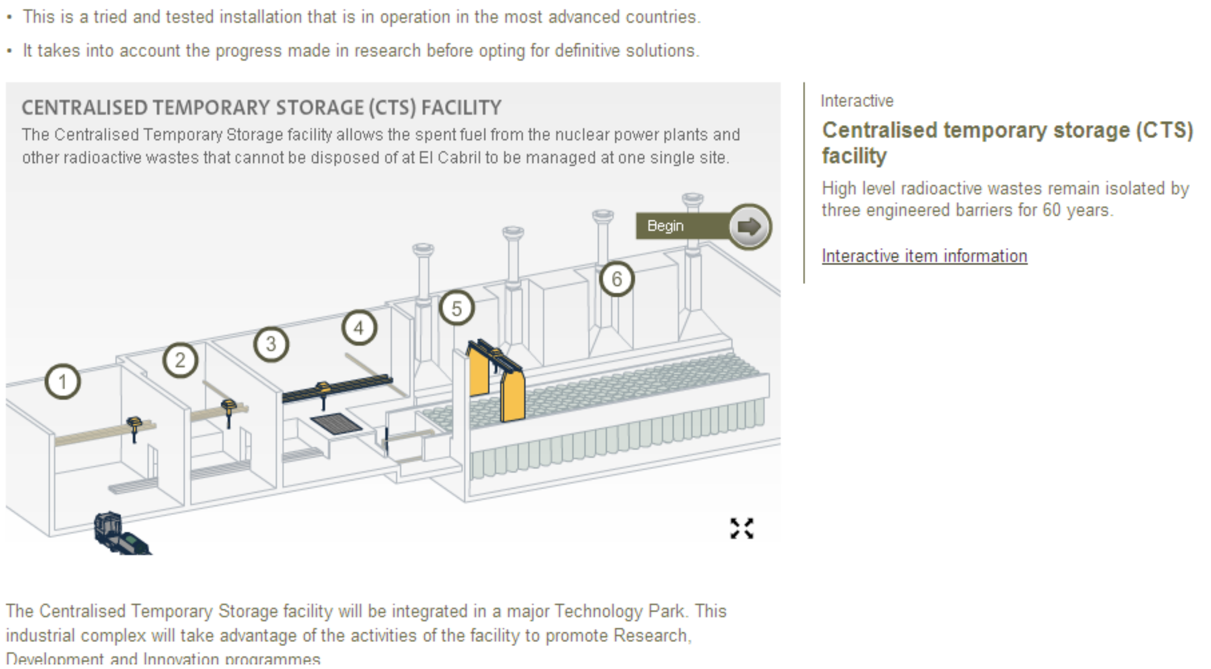


Fig. 33 – Centralised Temporary Storage facility scheme

R&D efforts of Enresa are focused, as clearly indicated on its web page:

- To provide know-how and tools allowing progress in safely management mechanisms for all types of radioactive wastes.
- To develop and verify technologies for RWM.
- To improve and promote the social, scientific and political RWM acceptance using transparent and clear information and making available to citizens all the materials required to understand RW management activity.

3.7 RW Management in Sweden

In Sweden, since the 1970s, the Swedish Nuclear Fuel and Waste Management Company (SKB) (http://www.skb.se/default____24417.aspx), manages all radioactive wastes deriving from Swedish NPPs and facilities The RWM include:

- A central interim storage facility for spent nuclear fuel (Clab) near Oskarshamn.
- Safe transport of the radioactive waste from nuclear power plants to the storage facilities is an important part of the system.
- A final repository for short-lived radioactive waste (SFR) in Forsmark.

3.7.1 LL-ILW management

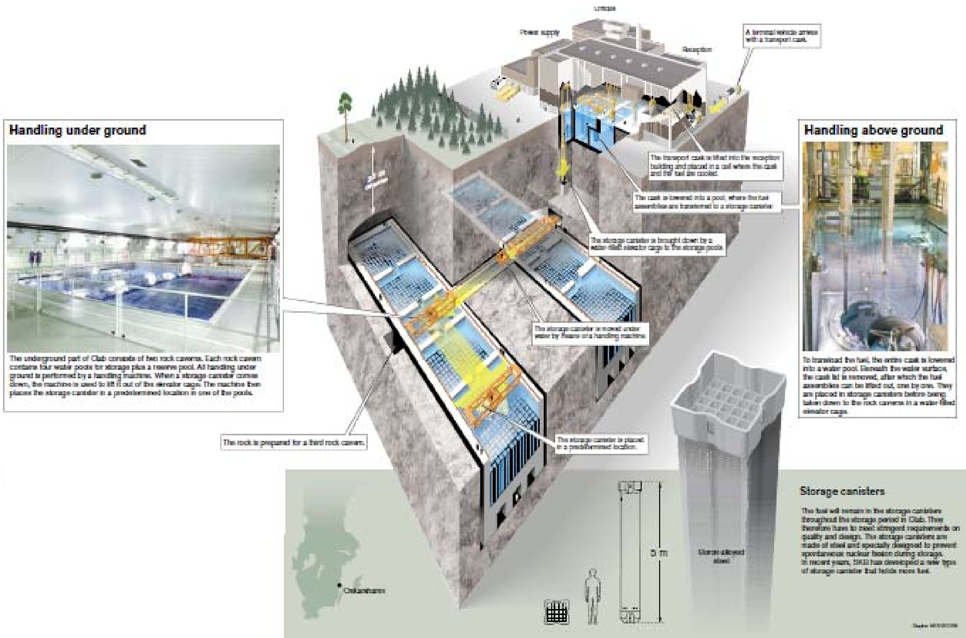
In Sweden, the RW were placed in steel and copper canisters prior to disposal in the bedrock.
As already said for the low and intermediate-level operational wastes is concerned, the efficient way to manage them is to store these wastes in rock vaults at Forsmark facility.
The facility (Fig. 34), located 50 metres beneath the bottom of the Baltic Sea adjacent to the Forsmark Nuclear Power Plant. The access to this facility is ensured by a large underground gallery where rather large vehicles can transport the solidified wastes and their containers into the excavated inner areas where they were inglobed in concrete. The Forsmark facility has the capacity to accommodate 63,000 cubic metres of waste and can be expanded if needed. So far nearly 31,000 cubic metres of the space has been utilized. Just under 1,000 cubic metres of waste is added every year [21].

Fig. 34 – SFR located in Forsmark

3.7.2 HLW management

In Sweden, the spent fuel from nuclear power operations, classified as high level wastes (HLW), is kept in a central interim storage facility (Fig. 35), also called Clab, in Oskarshamn, where the fuel is stored in deep pools of water 30 meters below ground. The water shields against radioactivity and cools the hot fuel. Radioactivity and heat generation are reduced over time, and after temporary storage the fuel has become easier to handle later in a final repository. At present about 5,000 tonnes of spent nuclear fuel are temporarily stored in the continuously monitored and controlled facility.

(a)



(b)

Figs. 35 – Oskarshamn interim storage facility view (a) and (b) scheme

The SKB solution for HLW is the geological disposal, based on the principle of multi barriers (three progressive protective barriers) (Fig. 36) constituted respectively by:

1. the canister, containing the spent nuclear fuel that was/should be firstly encapsulated in copper
2. the bentonite-clay that will protects the canister against corrosive attack, rock movements. If a fracture occurs in a canister, the bentonite clay buffer and undamaged parts of the canister will prevent water from penetrating into the canister.
3. the crystalline basement (primary rock)/caverns that after the disposal will be sealed.

These three barrier will prevent the radioactive substances in spent fuel from spreading into the environment.

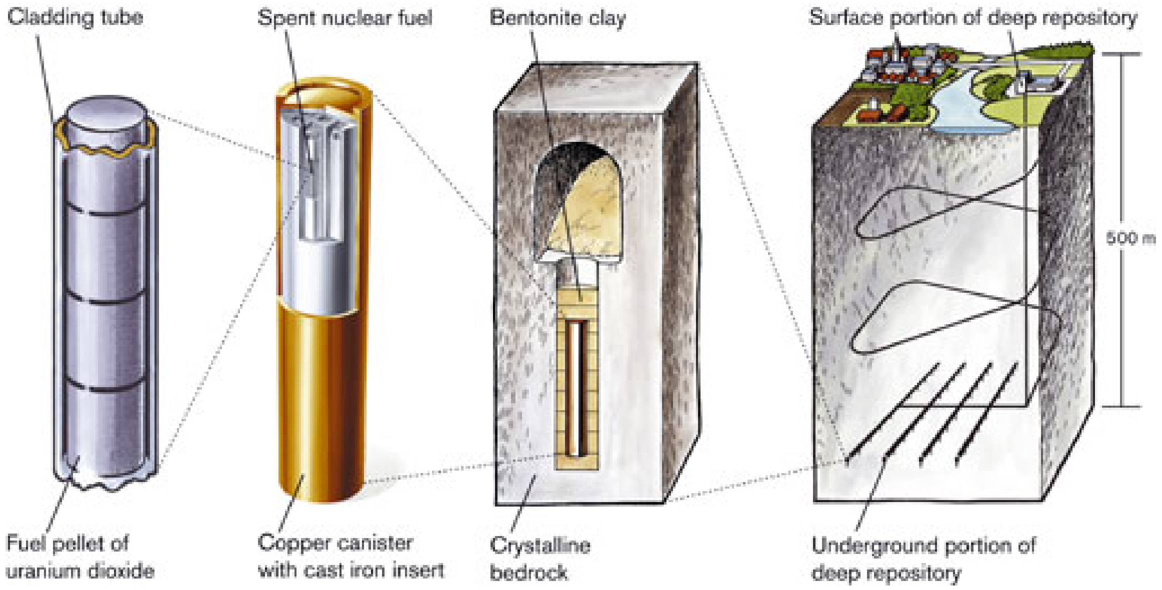


Fig. 36 – final repository scheme

SKB compiles new safety analyses as new knowledge is acquired and in particular when required for important decisions and applications. SKB's most recent safety analysis, SR-Can, was published in November 2006 and the next, SR-Site, will be published until the end of 2010 and included in the application for the final repository.

Moreover it is important to note that in 2002 surveys were initiated in Östhammar and Oskarshamn municipalities in order to collect detailed information about the prerequisites for a final repository. In 2010 SKB should submit applications to the Swedish Radiation Safety Authority (SSM) and to the Environmental Court to build the final repository in Forsmark (for HLW disposal). Furthermore SKB informs population on all safety analyses and activities by means of public authorities and international experts. The mass media also reports frequently on nuclear waste issues, that is a topic of particular public interest. Finally it is important to note that SKB involves citizens and Environmental organizations, such as the Environmental Organisations' Expert Committee on Nuclear Waste (MKG), to take an active role in the nuclear waste debate on final repository.

3.8 RW management in Germany

In Germany the responsibility for radioactive wastes, to be confined in the final disposal, is of the federal government that has charged the Federal Agency for Radiation Protection

(BfS)(http://www.bfs.de/en/bfs, Fig. 37). The German utilities store their low and intermediate radioactive waste in interim storage facilities situated at the nuclear power sites, due to the fact that there is no final repository for radioactive waste. The largest part of radioactive residues and radioactive waste produced in Germany arise from:

- The energy generation in nuclear power plants,
- The research and development laboratory,
- The medicine (with an amount less than 0.5 percent by volume) and industry
- The decommissioning or dismantling of nuclear installations.

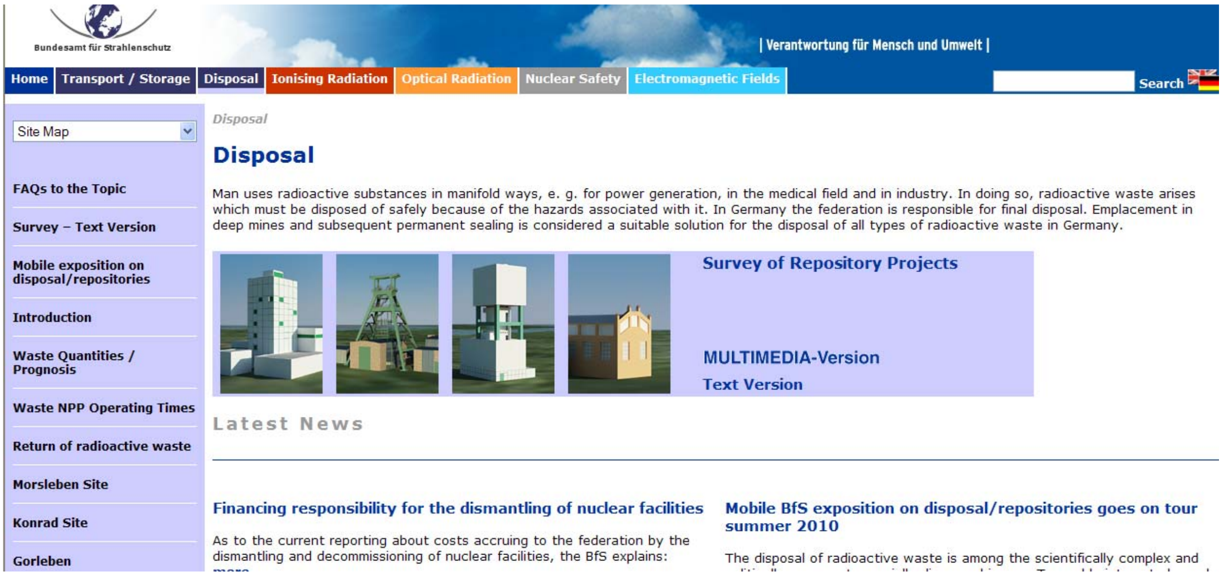


Fig. 37 – BfS web page

German, RW are divided into two groups: heat-generating wastes and with negligible heat generation wastes. The first type comprises mainly spent fuel elements and liquid high-level radioactive waste (fission product solutions) arisen from the reprocessing of spent fuel elements. In particular the liquid wastes are concentrated and melted into glass blocks (vitrified waste canisters).

As clearly indicated on BfS web page, at the beginning of 2009, the amount of radioactive residues with negligible heat generation were about 121,447 m^3 while approx. 1,914 m^3 of heat-generating radioactive residues existed. Apart from the spent ball-shaped fuel elements of the thorium high-temperature reactor (THTR), no spent fuel elements from power reactors are included in the aforementioned stock. The THTR ball-shaped fuel elements were declared as waste by the operator and have, therefore, been included in the waste statistics (interim products). It is important to highlight that, radioactive waste resulting from the treatment of fuel elements were reprocessed in French and British plants and that subsequently the resultants radwastes are returned to Germany as agreed in the relevant contracts. The main operation necessary to prepare RW for interim storage and /or disposal are:

- the compactation in order to reduce the overall volume of wastes;
- the immobilization, which consists in covering the RW in solid form by material such as the cement or concrete, bitumen, etc.
- the incineration, that consists in the burning of combustible wastes in order to attain a reduction of their volumes
- the solidification (including calcination, drying, cementation, bituminisation and vitrification), cementation of liquid, gaseous or liquid like RW in order to obtain a more stable RW

The Intermediate level and low-level radioactive waste were produced, especially, during the operation or dismantling of nuclear power plants. In this case radioactive wastes are compressed, packaged into drums and stored intermediately in casks. At present in the interim storage facility at Karlsruhe about 6,000 casks are temporary stored (Fig. 38).

Fig. 38 – Casks temporary stored in Karshrue

Currently, in Germany a decision on a site for a repository with heat-generating radioactive waste (according to the scheme showed in Fig. 39) in Germany is still pending, therefore HLW are stored at nuclear power plant sites and in the central interim storage facilities in Ahaus and Gorleben.

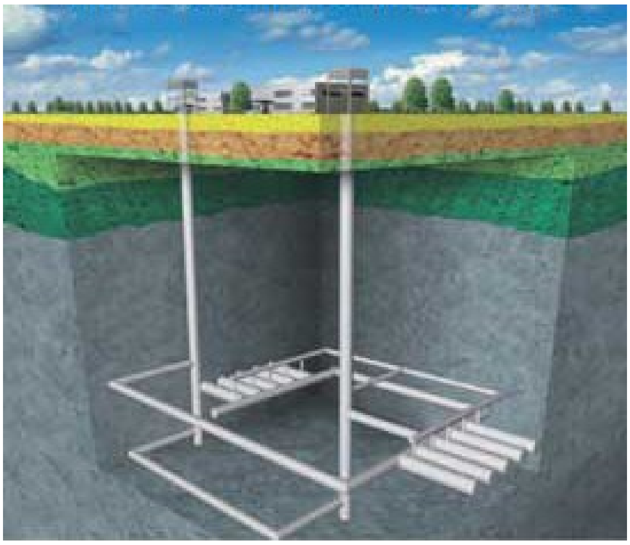


Fig. 39 – Final repository scheme

The risks connected to the high-level radioactive waste management as well as to the unsolved matter of the final repository siting represent in Germany the tricky point in the public debate and acceptance. Therefore BfS, as the other international Institutions, considers of relevant importance the information (publication are available at http://www.bfs.de/en/endlager/publika, as shown in Fig. 40) and participation of the citizens in the selection procedure to search a repository site.

Figs. 40 – Press releases and publications web pages

3.9 RW management in Switzerland

In Switzerland, the safe disposal of radioactive wastes, produced during the almost 40 years of nuclear energy production, is responsibility of the parties who produce them (at their own cost), i.e. primarily the companies that operate the country's nuclear power plants.

The legislation established that all RW categories must be stored in deep geological disposal facilities, typically at a depth of several hundred metres, characterized by a system of passive barriers to ensure that the protection of man and the environment is assured.

Swiss legislation regulates protection against radioactivity, the safety of nuclear installations and the safe disposal of radioactive waste. The Swiss Federal Office of Energy (SFOE) is the office responsible for all questions related to energy supply, energy use and also nuclear waste management (http://www.bfe.admin.ch/radioaktiveabfaelle/index.html?lang=en) (Fig.41).

Figs. 41 – SFOE web page

Most of radioactive wastes derives from the five nuclear power plants (produced particularly during the dismantling) and in a certain amount from the healthcare sector, industry and research; therefore in Switzerland a safe, secure and suitable disposal should be found for approximately 100,000 m^3 of radioactive waste material [22].

RWs in Switzerland are divided into the following categories:

a) high-level waste:

1. spent fuel not destined for further use;
2. vitrified fission product solutions from reprocessing of spent fuel;

b) alpha-toxic waste, with a alpha emitters content exceeding 20,000 Bq/g of conditioned waste;

c) low- and intermediate-level waste: all other radioactive waste.

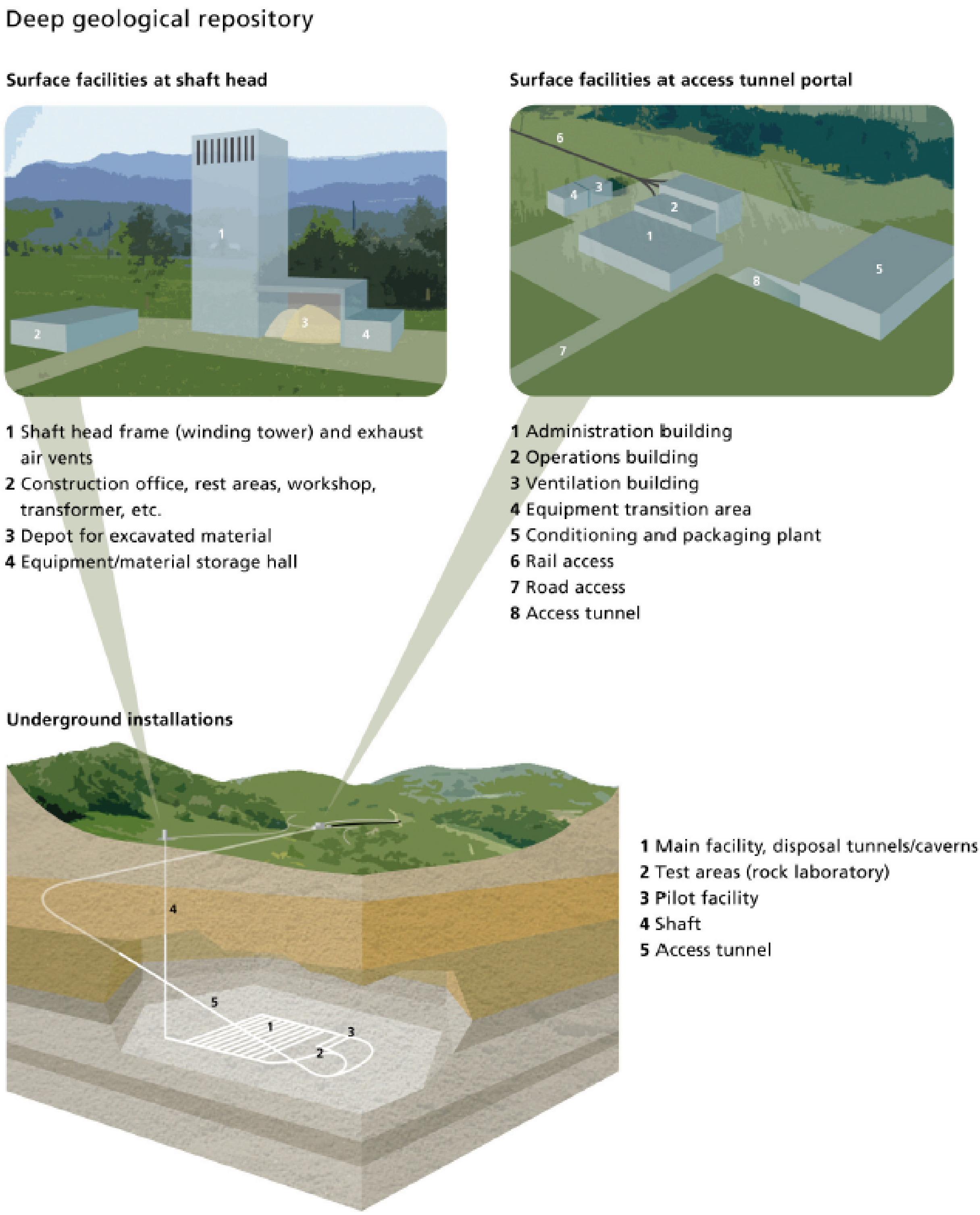
Due to these RW categories, therefore, two deep geological repositories should be necessary: one for low and intermediate level waste (L/ILW) and one for high-level waste (HLW). In the meantime, RWs are temporary stored in secure superficial halls located on NPPs and at two central interim storage facilities in the canton of Aargau. Furthermore, RWs are treated, conditioned before to be stored in interim facilities at nuclear power plant sites or in the mentioned centralised storage facility of ZWILAG and PSI in Würenlingen (canton Aargau) in the case of the RW deriving from medicine, industry and research.
To store high-level and long-lived intermediate-level waste, only a suitable disposal in geologically stable formations can ensure safety over the long timescales involved. In the "Sectoral Plan for Deep Geological Repositories" document [23] it was indicated/foreseen that the HLW repository should be available from 2040 and a L/ILW repository from 2030, taking into account the time for the construction of a rock laboratory and the operating licence for geological repositories. The searching for suitable geological repositories involves three important stages [23]:

1. identification of suitable siting areas based on safety and geological criteria. In this framework the National Co-operative for the Disposal of Radioactive Waste (Nagra) has already proposed siting areas on the basis of existing knowledge of geological conditions.

2. consultation process: the proposed siting regions may take part in decision making on the content of storage site projects and participate in studies on the socioeconomic effects and spatial planning impacts.

3. evaluation stage: it may be characterized by safety analyses taking into account geological studies, drilling exploration shafts, etc. and by the principles governing compensation measures and the monitoring of social, economic and ecological impacts as well as, the question of form of compensation.

The Swiss Federal Nuclear Energy Act stipulates that radioactive waste should be disposed in a deep geological repository like the represented in Fig. 42, passively safe in the long term [22]which should be accessible by shafts or tunnels.



Figs. 42 –Conceptual model of a deep geological repository for radioactive waste [23]

3.9.1 Information and communication

The Swiss Federal Department of the Environment, Transport, Energy and Communications (DETEC) established a Nuclear Waste Management advisory board to support the site selection procedure for deep geological repositories by promoting dialogue among all involved players and supporting them in the identification process of risks and barriers.

Moreover in Swiss, Federal government and cantons recognized that comprehensible and transparent information and communication are essential requirements for the successful implementation of the site selection procedure.

In addition documents, adjourned press releases, lectures, brochures, publications, etc. are available at the documentation section of SFOE web page.

4. Current RW management in Italy

In Italy the only operating nuclear facilities today are research and waste management facilities which do not set up any decommissioning plans, economical evaluation or provisions..

In the past, four nuclear power plants (i.e. Garigliano, Latina, Trino and Caorso), all of different technologies, were operated until middle of 80's, that at present are, at different stages, ongoing to be decommissioned according to a strategy for immediate decommissioning (IAEA level 3) established on late 90's, if repository will choose in time.

The spent fuel and the largest part of the radioactive waste to be managed in Italy derive from the operation of the above mentioned NPPs and from a few fuel cycle facilities, represented in Fig. 43.

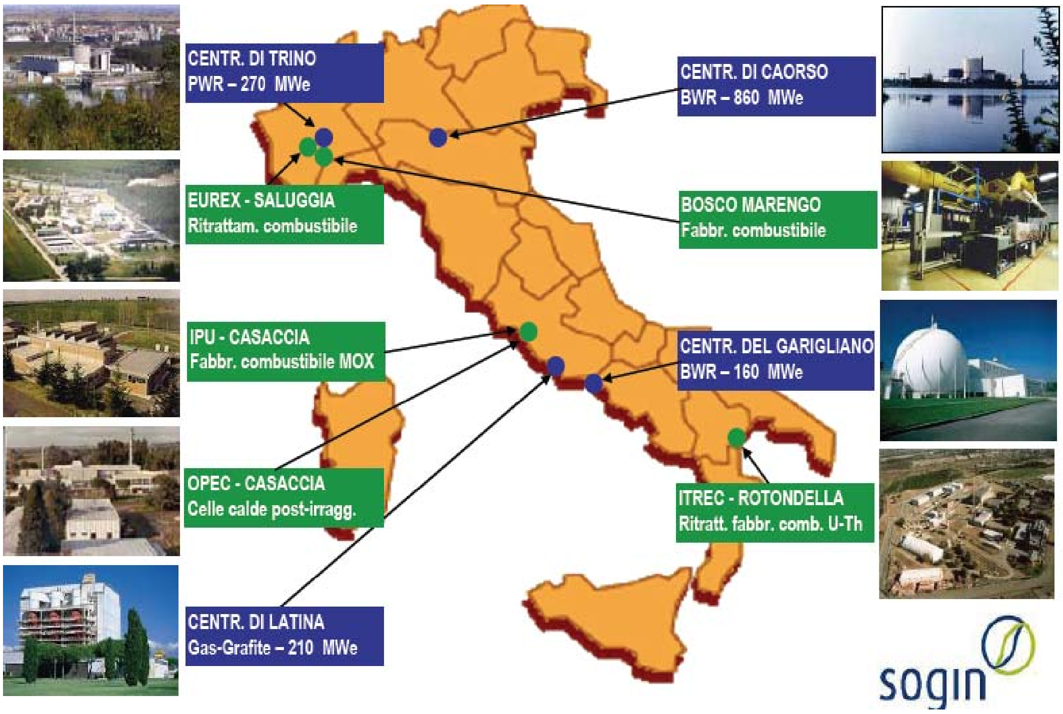


Fig. 43 – Location of Italian nuclear facilities

Italian waste management and decommissioning strategy agree to SAFSTOR strategy, in which the main goal is the conditioning or proper treatment of wastes in order to store them safely on site during the Safe Enclosure period and to transport them to the final repository when it will be available. As far as recycling, reuse, and release of radioactive materials are concerned, at present the Italian authorities do not indicate any "clearance level" for releasing or recycling materials from plant dismantling.

The responsibility of carrying out the decommissioning projects and to manage the spent fuel has passed in the 1999 to SOGIN Company (which includes all nuclear competences of ENEL), which is now completely owned by the Italian Government (Ministry of Economical Development).

Taking into account the changing situation in the country, So.G.I.N. might provide the decommissioning activity plans to foresee the complete dismantling of four Italian nuclear plants within 20 years, and evaluate all relevant technical, economic and legislative aspects of the matter. Furthermore since the national repository has not been chosen, dismantling activities will be initiated when the national repository should be under construction.

Part of spent fuel coming from Trino and Garigliano NPPs and all the one of Latina NPP were sent abroad under services agreements for reprocessing, including provisions for return to Italy of corresponding nuclear material and conditioned radioactive waste.

All the remaining spent fuel originated by the operation of research reactors is still wet stored in the plant or facilities of origin as well as the fuel of two experimental reprocessing facilities, shut down several years ago.

As far as the radioactive waste is concerned, almost all the wastes generated by the operation of nuclear installations are stored in the sites of origin. Additional amounts of radioactive wastes arise from a number of facilities using radioactive sources in medical, research and industrial applications. In table II it is summarized the Italian NPP intermediate and low-level waste

Table II - Intermediate and low-level waste[24]

Plant	Latina	Garigliano	Trino	Caorso
Operating period	1963 - 1986	1964 - 1978	1964 - 1987	1978 – 1986
Electric energy produced (GWh)	26082,196 (gross) 24840,356 (net)	12478,060 (gross) 11699,418 (net)	25027,636 (gross) 23843,767 (net)	29030,978 (gross) 27945,235 (net)
Intermediate and low-level waste produced during plant operation (m^3)	800	1880	920	3620
Waste per unit of net electricity generated (m^3/GWh)	0,03	0,16	0,04	0,13
Intermediate and low-level waste stored at plant site (m^3) [1]	850	2200	800	2000
Expected waste production for plant decommissioning (m^3) [2]	19.000	11.000	10.000	20.000

[1] The difference between the volume of waste produced during plant operation and the volume of waste stored at plant sites is due to:
- waste production continues, at lower rates, after plant shutdown;
- volume reduction of some low-level waste has been achieved by super-compaction of Garigliano, Trino and Caorso DAWs and by incineration of Caorso ion-exchange resins and DAWs;
- conditioning of Garigliano intermediate and high-level waste caused a volume increase.

[2] The volume refers to the waste to be treated; the volume of the treated waste to be disposed of will depend on the selected decontamination/treatment techniques and on the "clearance levels" for release/recycle of waste material.

A general criterion is in force in Italy for unrestricted release.
Radioactive materials can be unconditionally released from regulatory control if the concerned radionuclides comply with both a concentration and a radioactive half-life threshold:

- activity concentration ≤ 1 Bq/g;

- half-life < 75 days.

If both conditions above are not respected, a specific authorisation is required for releases, reuse and recycle of the materials concerned. The authorisation can be given provided that the following criteria are complied with:

a) Effective dose ≤ 10 μSv/year;

b) Effective collective dose ≤ 1 man·Sv/year (or activity concentration < 1 Bq/g, that is the general threshold of the Italian Law).

In order to implement the above criteria, derived concentration values are established, making reference to EU documents.
No specific criteria are available in Italian legislation for the release of radiological facilities and/or sites; therefore, a case-by-case analysis is employed.

4.1 RW regulation

In Italy all activities connected with RWs treatment and storage in the facilities, where they were generated, are regulated by specific conditions, attached to the licence, and technical specification of the facilities.
New and relevant waste management activities to be performed on a site (for example the construction of a temporary storage facility) may be authorised following the approval requirements established for the management of plant modifications of nuclear installations, as defined by Sec. 6 of Law n. 1860/1962 and according to the procedure defined in the Technical Guide n° 2/1975 *“Authorization procedure for nuclear installations modifications”*.
The authorisation may be granted either for a single or for a number of intermediate phases, until the “green field” status of the site(licenses will be issued for each phase). In 1999, the Ministry of Industry, Commerce and Crafts, now Ministry of Economic Development, issued a strategic document providing guidelines for the management of liabilities resulting from past national nuclear activities, including the establishment of Sogin.

Some key aspects of this new policy were:

 "*the treatment and conditioning of all radioactive waste stored in the nuclear sites;*

the start up of a concerted procedure, by means of a specific agreement between the Government and the local authorities, for the selection of a national site where to build a near surface repository for low and intermediate level waste and an interim storage facility of the spent fuel and the high level waste;

the adoption of the strategy for an immediate decommissioning (IAEA level 3) of all national shut-down nuclear installations, thus abandoning the previous "safe storage" option;

the establishing of a National Agency for the management and disposal of radioactive waste, whose main mandate would be to realize and operate the national radwaste disposal site;

the special fund allocation for all these activities by means of a specific withdrawal from the electric energy bills"[25].

For NPPs having the spent fuel still stored at the pools, the decommissioning plan is strongly influenced by the implementation of the strategy related to the removal of the fuel besides to the construction of an interim and/or final repository in order to gain the consensus of local communities and authorities.
It is important to note that Italy ratified the IAEA Joint Convention on the Safety of the spent fuel management and on the safety of the radioactive waste management" on February 2006.
Finally Sogin regularly adjourns its internet site with news, videos, press releases (Fig. 44) as well as publishes annual reports including decommissioning cost estimates and provisions in order to be transparent in front of the population.

Fig. 44- Sogin press releases home page

5. Conclusion

Nuclear energy continues to be a controversial issue for citizens, especially in relation to the associated risks. Therefore it is important to understand the point of view of civil society on nuclear technologies, the risks perceived and how to establish an effective communication before the decision-making. Analyzing adjourned international study as well as the basic information provided by multimedia, press and web page on the radioactive waste management. Web pages are considered an useful mean to respond to questions from the citizen in way both mediated and direct, because they can be continuously updated.

The main conclusion of this report may be summarized as follow:

1. the public acceptance towards nuclear energy is and may be influenced with a clear and transparent information;
2. the aspect of the stability and cost of energy supply are considered important by population as well as the economics aspects related to decommissioning and waste management. Europeans, indeed, accept and recognize the value of nuclear energy, not only as a means to decrease energy dependence but also as a way to contrast the climate changes.
3. people feel themselves less informed ("*only a quarter of citizens feel 'very well' or 'fairly well' informed*" [12]) on nuclear issues, particularly on RW management in respect of which they feel concern and also fear for the HLW. Opposition to nuclear energy is based mainly on this matter and the acceptance towards nuclear energy should increase if the waste disposal issue could be resolved.
4. Europeans continue to feel that risks related to nuclear energy are not correctly perceived. As the 2010 Eurobarmeter reveals, a substantial percentage of Europeans, even if is afraid of nuclear power plants, does not consider them as a risk, but possible risk source due to lack of security against terrorist attacks in NPPs, the misuse of radioactive materials and the disposal of radioactive waste.
5. the public consensus on the matter of interim/geological disposal is conditioned by the capability to develop technical solution and appropriate engineered infrastructure allowing to minimise potential long-term radiological impacts on humans and the environment. People would prefer EU legislation to regulate the RW management.

6. References

1. N. Tanaka, Nuclear for the Energy Revolution: IEA launches the nuclear roadmap, International Energy Agency, June 2010.
2. IAEA Classification of Radioactive Waste, General Safety Guide, Series No. GSG-1, January, 2010.
3. IAEA, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, IAEA International Law Series No. 1, Vienna (2006).
4. IAEA, Geological Disposal of Radioactive Waste, IAEA Safety Standards Series No. WS-R-4, IAEA, Vienna (2006).
5. ©AREVA, All about nuclear Energy from Atom to Zirconium, Communications Dep., AREVACOM, 2008
6. World Nuclear Association, Radioactive Waste Management, 2009
7. World Nuclear Association, Treatment and Conditioning of Nuclear Wastes, 2009
8. Compaction of Radioactive Waste, NUKEM Technologies GmbH (2007).
9. Cementation of Radioactive Waste, NUKEM Technologies GmbH (2007).
10. EPA, Handbook Vitrification Technologies for Treatment of Hazardous and Radioactive Waste, United States Environmental Protection Agency, EPA/625/R-92/002, May 1992, (www.epa.gov/nscep).
11. EU site http://ec.europa.eu/energy/nuclear/waste_management/waste_management_en.htm
12. CIRTEN-UNIROMA1 RL 1161-2010
13. European Commission, Europeans and Nuclear Safety Report, Special Eurobarometer 324/ Wave 72.2 – TNS Opinion & Social, March 2010.
14. European Commission, Attitudes towards radioactive waste, Special EUROBAROMETER 297, Wave 69.1 – TNS Opinion & Social, Report 2008.
15. OECD®, Public attitude to nuclear power plant, NEA 6859, 2010
16. IEA, Nuclear energy, October 2009

17. W.E. Falck and K.F. Nilsson, Geological disposal of radioactive waste: moving towards implementation, JRC reference report 2009.

18. NDA, Into nuclear decommissioning, Insight, issue 3, 2010.

19. Andra web site http://www.andra.fr/international/index.html

20. NEA, Radioactive waste Management, RWMC Regulators' Forum, NEA/RWM/RF(2004)1.

21. http://www.skb.se/upload/publications/pdf/Engelsk_low_res.pdf

22. http://www.bfe.admin.ch/radioaktiveabfaelle/

23. SFOE, Sectoral Plan for Deep Geological Repositories - Conceptual Part, 2008

24. R. De Felice, G. Bolla, L. Brusa, G. Ruggeri, Decommissioning of Italian Nuclear Power Plants. Experience and future plans, IDS 2000, June 13-16, 2000, Knoxville, TN.

25. NEA, Radioactive waste management and decommissioning in Italy, http://www.nea.fr/rwm/profiles/Italy_report_web.pdf