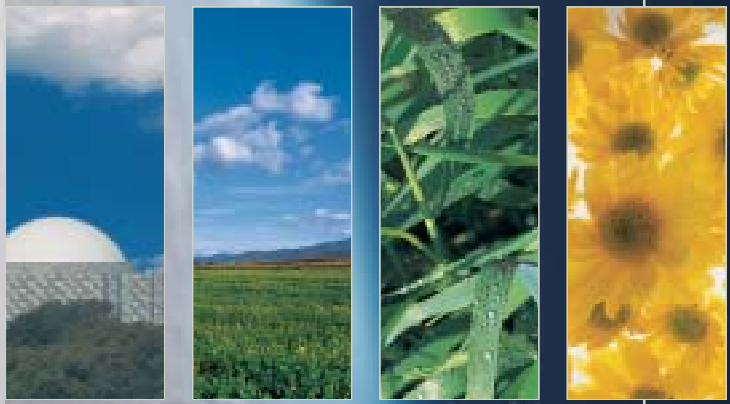
Radioactive Waste Management: Situation, Analysis and Perspectives



FUNDACION PARA ESTUDIOS SOBRE LA ENERGÍA

Volume 2

AN OVERVIEW OF THE SITUATION IN THE MAIN OECD COUNTRIES

Radioactive Waste Management: Situation, Analysis and Perspectives

VOL. 2

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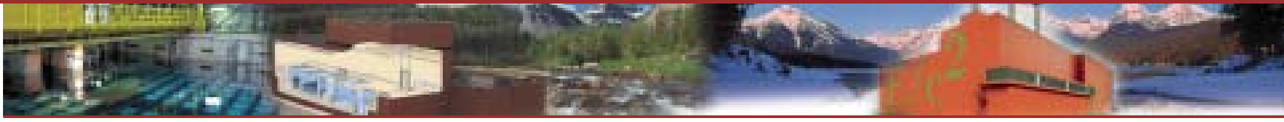
Prologue



The Foundation on Energy Studies has been established following the initiative of the dean of the Polytechnical University of Madrid and its directors of the Mining and Industrial Engineering schools. The Foundation involves the different schools of engineering related to energy and three entities pertaining to the Central State Administration: Ciemat, IDAE and the National Energy Commission.

The Foundation provides a supporting role to the Administration to take the necessary steps in this field and they also encourage public opinion to request and fulfill these efforts. Currently, the energy issues require more studies and views in order to have a solid foundation for political and business decisions.

This document presents a study on radioactive waste management, an especially sensitive topic on the subject of nuclear energy. The report does not attempt to recommend policies or guidelines for this subject, but to place correctly the issue, describing what is known and not known, what should be done and could be done, in order to face the risks that these wastes may pose.

The study is presented in two-volumes: the first volume reviews the different aspects of spent fuel management: technical, safety and public opinion issues, making a specific analysis of the situation in Spain. The second volume summarizes the status of waste management in the main OCDE countries. The report is complemented with two separate booklets: a technical summary of the work performed and an executive summary.

The study has been conducted by the following technical team:

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Although this study has been carried out with the financial support of UNESA, Enresa, the Nuclear Safety Council, Ciemat and the National Comission of Energy, they have not been involved in its preparation.

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Summary

Executive summary

Introduction

The Spanish Foundation for Energy Studies (Fundación para Estudios sobre la Energía) has drawn up the study "*Radioactive Waste Management. Situation, Analysis and Perspectives*". The objective of this executive summary is to summarize the main aspects of this study.

Nuclear energy and radioactive isotopes are widely used in activities such as electricity generation, medical applications and industrial processes. All these activities may produce radioactive waste, the management of which is required in order to protect human health and the environment.

The greatest volume of these radioactive wastes is of the low and intermediate level type. The technologies necessary for the suitable management of this type of waste have been developed thanks to the technological efforts made over the last thirty years, and they are now available for use. In most of the OECD countries, among them Spain, this has allowed safe and environmentally friendly waste management systems to be installed and put into operation on an industrial scale. The low and intermediate level radioactive waste now disposed of in the main OECD countries amounts to 12,000,000 m^3. This gives an idea of the technical and operating experience that has been acquired.

The establishment and operation of management systems for low and intermediate level wastes is also necessary in order to be able to address the dismantling of the nuclear power plants at the end of their operating lifetime. In Spain, for example, the dismantling activities carried out at the

Vandellós I plant, or those foreseen for the dismantling of Zorita, would not have been possible if the El Cabril disposal facility and the rest of the systems and processes involved in low and intermediate level waste management had not been in operation.

The most important high level radioactive waste produced in the world is the spent fuel removed from the nuclear reactors. Work has been on-going since the nineteen fifties to develop technologies for the management of spent fuel, this having allowed it to be handled, conditioned and temporarily stored safely. However, to date this type of waste has not been eliminated or definitively disposed of.

This study focuses precisely on spent fuel and high level waste. Although the report is mainly technological and environmental in its approach, consideration has been given also to other main variables relating to the management of these materials, such as strategic and economic issues and the question of social acceptance.

1. International situation and perspectives of Spent Fuel (SF) and High Level Waste (HLW) management

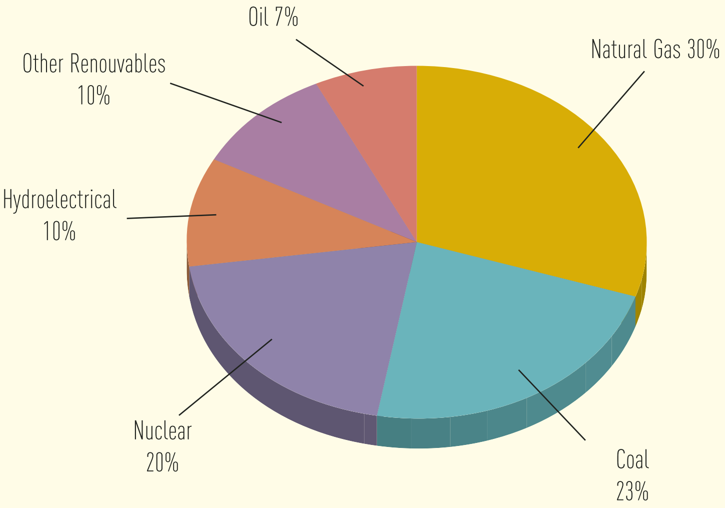
Nuclear energy and Spent Fuel generation

Nuclear power provides 16% of the world's electricity, as base energy, and its contribution to total power has progressively increased, its percentage contribution having remained steady over the last 20 years with respect to total energy sources. There are more than 440 commercial reactors in operation in the world, in 34 countries, amounting to an installed electrical power of more than 370,000 MW. In the OECD area nuclear power provides 23.4% of the electricity generated, with 351 reactors in operation as of the end of 2005. Some countries, such as Finland, Japan, Korea, China, India and Russia, are building new nuclear power plants, and others, such as France, the United States and South Africa have construction plans. Germany, Sweden and Holland, on the other hand, have considered or are discussing the phasing out of this type of energy.

In Spain the commercial use of nuclear energy began in 1968 with the coupling to the electrical grid of the country's first nuclear power plant. At present there are eight reactors in operation with an installed power of 7,728 MWe*[1] , which between them produced 60.110 GWh in 2006, 20% of the electricity generated in Spain, figure 1. Nuclear power is the third generating source in terms of contribution to national production, after Natural gas and Coal.

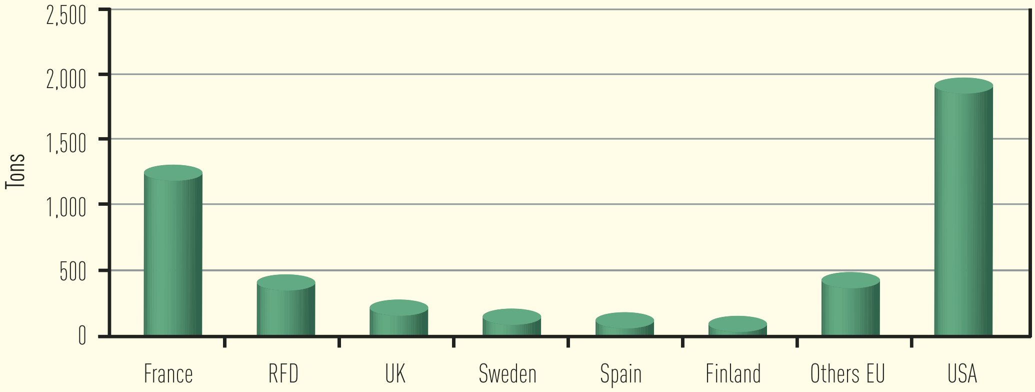
It is estimated that some 10,500 t of spent fuel are produced every year in the world, and this is expected to increase to 11,500 t by the year 2010. Given that less than a third of this quantity is reprocessed, some 8,000 t are added every year to the inventory of spent fuel in temporary storage. In 2003, the accumulated amount of spent fuel existing in the world amounted to some 275,000 t, and the fuel stored to some 186,000 t, the remainder (89,000 t) having been reprocessed. At the end of 2005, the Spanish nuclear power plants had a total 3,370 t of spent fuel stored in their pools, and it is estimated that the current plants will generate a similar amount by the end of their service lifetime, which for planning purposes is currently considered to be 40 years. Spain is the 5th largest producer of spent fuel in the EU (figure 2).

[1] Due to the definitive shutdown of José Cabrera NPP in April 2006



Source: UNESA

Figure 1. Structure of electricity generation by type of fuel in Spain in 2006.



Source: WNA

Figure 2. Annual spent fuel generation. 2006 estimate.

Characteristics of Spent Fuel in Light Water Thermal Reactors (LWR)

The largest part of spent fuel, figure 3, is made up of the original U, which represents 95% of the mass percentage of the fuel, the rest being activation and fission products and actinides and their transuranic daughter products (TRU): Np, Pu, Am and Cm.

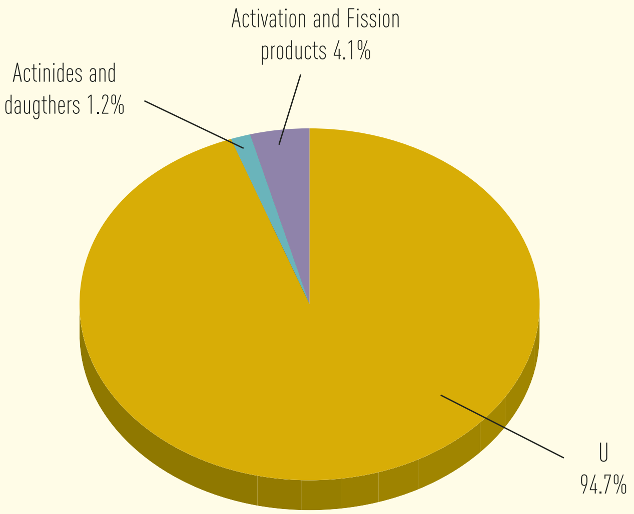


Figure 3. Mass percentage in a pellet of spent fuel with a burnup of 40,000 MWd/tU (Enresa).

The levels of radioactivity in spent fuel are very high. During the first 200 years the radioactivity arises mainly as a result of beta and gamma-emitting fission products. After this period of 200 years the transuranic elements, basically alpha particle emitters, will be the greatest contributors to the radioactivity of the fuel. After 100,000 years, the radioactivity will be due fundamentally to U, Np, Pu and their radioactive decay products, as well as to the fission products Tc-99, I-129,Cs-135 and other long-lived products (figure 4).

Basic principles of radioactive waste management

The main objective of radioactive waste management is its treatment with a view to protecting human health and the environment now and in the future, without this implying a burden for future generations.

In the management of spent fuel, as in all practices involving radiations, the public and environmental protection objectives are based on the dose limitation system recommended by the International Commission for Radiation Protection (ICRP). This system is the basis for the *Spanish Regulations on Protection against Ionizing Radiations.*

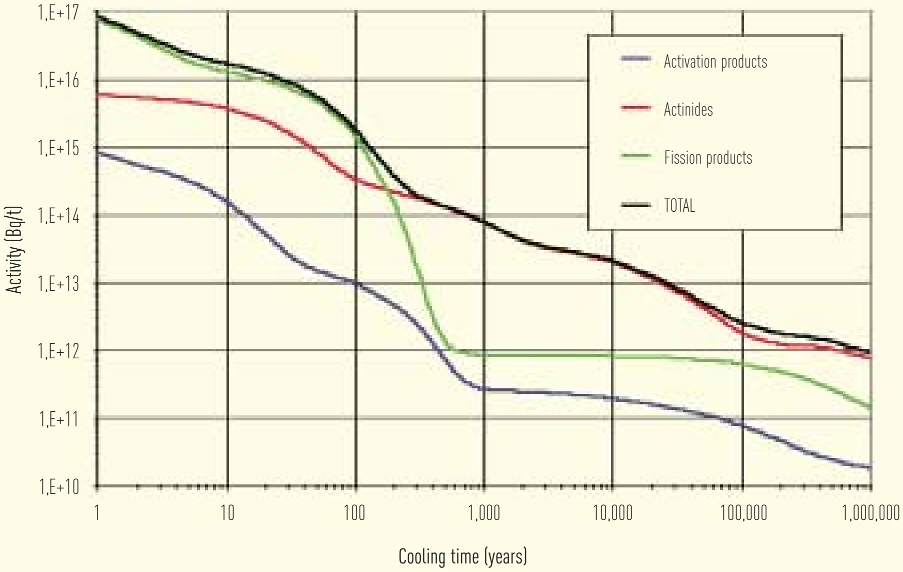


Figure 4. Total radioactivity of reference spent fuel (Enresa)

Spent fuel management options

"Spent fuel management" is the term applied to the set of technical and institutional measures aimed at ensuring that the spent fuel does not constitute an obstacle to the normal operation of the nuclear power plants and that the technical measures do not, individually or jointly, imply a risk for people, animals and the environment.

Once its energy production stage in the reactor has finished, nuclear fuel is stored in spent fuel pools at the plant itself, for removal of the decay heat it produces. As from this moment, the following lines of action are open:

- **Open cycle:** following an indefinite period of temporary storage (either under wet conditions in pools or dry in casks), the fuel is conditioned and encapsulated in preparation for definitive disposal.

- **Closed cycle:** following a period of temporary storage, the spent fuel is reprocessed to separate the uranium and plutonium from the rest of its components, for subsequent use, as energetic materials, in a new process of nuclear fission, improving the **U** energetic potentiality. The HLW produced are conditioned by vitrification and stored pending final disposal.

- **Advanced closed cycle:** includes the closed cycle and the partitioning and transmutation of the minority actinides and certain fission products to reduce its activity and radiotoxicity.

In the closed cycles, both the high level waste and the long-lived waste not eligible for disposal close to the surface must be disposed of in a Deep Geological Disposal (DGD) facility, the same as the spent fuel considered as high level waste in the open cycle option.

The decision to adopt one spent fuel management strategy or another is a complex issue involving both political and economic factors and questions relating to the conservation of resources, environmental protection and public opinion. The last of these has become a predominating factor in decision-making in many countries.

Spent Fuel management costs

The cost of electricity production includes both the electricity-generating nuclear power plant investment, operation and maintenance costs and those corresponding to the fuel cycle (front end, prior to the fuel entering the reactor, and back end, following its removal from the reactor as spent fuel). Generally speaking, for any of the cycles considered, the cost of building and operating the nuclear power plant is far higher than that corresponding to the fuel cycle. By way of an example, figure 5 shows the electricity production cost structure in the case of the open cycle, where it may be appreciated that investments in the plant represent around 62% of the production unit cost, 22% corresponds to plant operation and maintenance and 11% to the cost of the front end of the cycle (uranium ore, concentrate, conversion, enrichment and fuel manufacturing), while the cost of the back end of the cycle (temporary storage, encapsulation and definitive disposal in a DGD facility) amounts to only around 5% of the total unit cost, that is, between 0,15 and 0,2 c€/kWh.

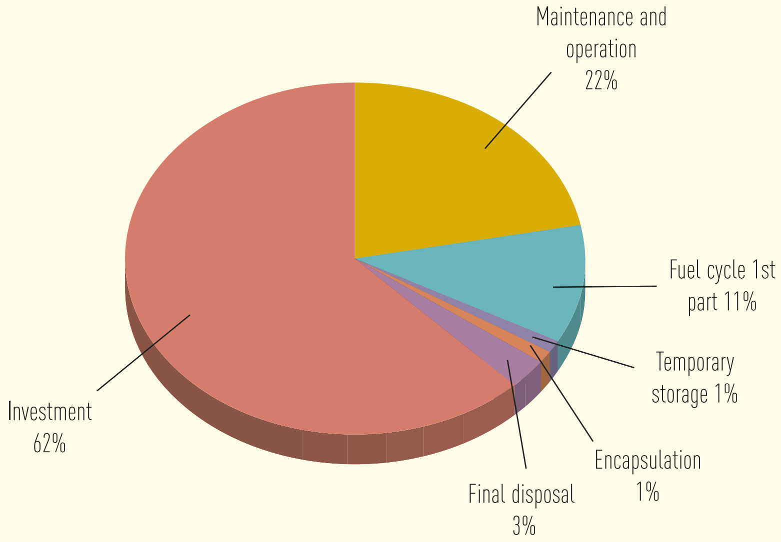


Figure 5. Unit cost structure for electricity production with open cycle.

2. Situation and perspectives of spent fuel and high level waste management in Spain

Initial situation

The situation of spent fuel and high level waste management in Spain may be described in terms of the following characteristics:

- A typology of wastes already generated or foreseen that presents very little variation, with 80% of the total volume to be managed consisting of spent fuel from the light water plants and having similar physical, chemical and radiological characteristics, 13.4% being conditioned wastes arising from fuel reprocessing performed in the past and the remaining 6.6% being the wastes that it is estimated will be generated in the future dismantling of the Spanish nuclear power plants.

  The lack of diversity as regards the typology of the wastes to be managed will simplify management due to the homogenization of processes and solutions that this brings.

- A total volume of spent fuel and long-lived high level wastes to be managed amounting to some 13,000 m^3, the fifth largest among the European Union countries and equivalent to 6% of the EU total.

  The medium size of Spain's nuclear program and of the volume of wastes to be managed would appear to constitute more of a difficulty than an advantage, since as it cannot be considered a small program, it would appear to be inevitable that certain of the facilities required for management, such as the disposal installations, will need to be implemented in the country. On the other hand it is not sufficiently large to benefit from economies of scale at the industrial or technological level.

- The absence of future commitments with other countries in relation to reprocessing, re-elaboration or treatment of the spent fuel stored in Spain, as is reflected in the text of the national General Radioactive Waste Plan (GRWP), provides considerable flexibility in the definition of strategies and future decision-making, this being particularly important in a sector in which – due to its characteristics – decisions have long-lasting effects and are difficult to reverse.

- The commitment with France regarding the return to Spain of the wastes arising from the reprocessing of the spent fuel from Vandellós 1, the dismantling of Zorita and certain specific situations of potential plant pool saturation require that appropriate solutions be applied to increase the temporary storage capacity by around the year 2010.

Strategy established in the GRWP

The GRWP has determined that a centralized temporary storage (CTS) facility is an essential management element for the interim storage of these wastes for a period of 60 years, regardless of whatever individual solutions might be adopted at each plant as a second option aimed at solving the specific problems that might arise in the short term in the event of a delay in the development of such a CTS facility.

Providing the Spanish system with a centralized temporary storage facility for spent fuel and long-lived high level waste would appear to be an appropriate decision offering strategic advantages in terms of safety, security, economics and operation compared to any other alternative.

However, the five-year period foreseen for the siting, construction and start-up of the installation might be insufficient, especially as regards finding a satisfactory solution to the process of negotiation and public acceptance required for its location. The recent parliamentary resolutions issued recognizing the convenience of such a facility, and the interministerial commission set up in this respect, are very valuable instruments that favour compliance within the timeframe established in the program.

The GRWP does not establish any strategic definition nor any schedule for the activities constituting the definitive management of the wastes dealt with here. On the other hand, the estimate of the costs and the needs regarding the transfer of financial resources to the Fund for radioactive waste management is performed assuming an open cycle with direct geological disposal of the spent fuel. The Plan estimates the cost of final management to be more than 3,000 MM€, equivalent to 50% of all SF management and 25% of the total cost estimated for complete management of all types of radioactive waste, including the dismantling of the plants.

Analysis of the feasibility of different types of SF cycles in the Spanish case

The alternative of the **open cycle** with direct spent fuel disposal in a DGD facility is recognized across the world as being a feasible solution and one that is to be recommended for a number of reasons relating to non-proliferation and the fact that its costs may be estimated more reliably than those of the alternatives. The above is thanks to the technological knowledge acquired as a result of the R&D efforts made internationally over the last forty years. It is the solution chosen in the EU by countries that have nuclear programs for exclusively civil applications, such as Sweden and Finland, and by the United States for the spent fuel arising from commercial nuclear power plants, although there are no yet DGD facilities under commercial operation for spent fuel disposal.

The Spanish technological potential would appear to be sufficient to address this alternative successfully, thanks to the knowledge acquired through the R&D program carried out by ENRESA over the last twenty years, along with that which might be acquired if this process of generating know-how were to continue in its two dimensions of domestic work and international cooperation.

In view of the financing system that has been in place since 1984 and the transfers of financial resources that have been made to the Fund for radioactive waste management during this period, and their foreseen continuation in accordance with the estimates of the GRWP, Spain also has sufficient economic capacity to successfully address this alternative of the open cycle with direct disposal of the spent fuel in a DGD repository.

Thanks also to the geological knowledge developed in recent years, it would be reasonable to believe that Spain's geology offers stable rock formations having the characteristics required to house a DGD facility with the necessary guarantees.

The alternative of the **closed cycle**, with reprocessing on the basis of the technology and processes currently used on an industrial scale in France and Great Britain, and subsequent recycling of the fissile materials recovered in thermal or fast reactors is an option that Spain ceased to consider in the early 1980's, mainly for economical reasons. The conditions that led to this decision have not changed substantially, as a result of which no strategic change in this respect is foreseen.

In addition, the application of this alternative, with reprocessing of the spent fuel from the light water plants in the currently existing reprocessing facilities and subsequent vitrification of minority actinides and fission products, would rule out the possibility of their being transmuted in the future.

The management of spent fuel on the basis of advanced reprocessing and separation, followed by **transmutation** of the long-lived radioactive elements in new generation fast reactors has potential advantages, such as greater exploitation of the energy content of the spent fuel and the lower radiotoxicity and smaller volumes of wastes to be disposed of in a DGD facility. Nevertheless this option is still associated with too many essential uncertainties for it to be considered as a real technological alternative at present, and it remains for it to be contrasted with appropriate cost/benefit analyses, once the information required for their performance is available. It does not appear to be likely that the more advanced countries in this kind of technologies, France and USA, will have industrial installations for advanced separation, transmutation target fabrication and advanced reactors in which transmutation will be at least partially feasible available before the year 2050.

The closed spent fuel cycle based on multiple reprocessing and recycling, with or without subsequent transmutation, would require as a central characteristic the availability of new types of fast reactors. The design, construction and operation of these new reactors would require something like a century of nuclear activity.

In summary, P&T is an option of great potential interest that might significantly contribute to reducing the radiological inventory to be managed in a DGD, as well as to radioactive waste minimization, but it will require major R+D efforts for its development. Such efforts would be meaningful only in a context of continuous use of nuclear fission energy for electricity production.

Spain's scientific and technological capacity would appear to be insufficient for significant contributions to be made to this option, at a reasonable cost, unless they were made in coordination with other countries within the framework of international cooperation projects.

The cost estimates for this option, which are still very preliminary and present important uncertainties, would exceed those foreseen in the current GRWP for the final management of spent fuel.

For all these reasons, and for the associated long-term implications, this fuel cycle option should be considered a long-term strategy or energy policy issue rather than a simple waste management option.

Importance of the CTS and DGD facilities for the Spanish program

▶ **Centralized Temporary Storage**

Different temporary fuel storage systems under operation in the world are now demonstrated technologies, with more than 50 facilities operating in more than fifteen countries. To this is added the experience of plant pool operation and, in the case of metallic containers, the experience acquired from using fuel transport casks.

The more or less prolonged temporary storage of spent fuel cannot be considered as constituting an SF management option but rather the initial stage of any type of management.

Once start-up of the CTS facility were achieved, as scheduled in the GRWP, providing the possibility of safely storing the spent fuel for the next sixty years, Spain would be in a highly consistent and flexible situation as regards its management strategy, with the possibility of selecting any of the fuel cycle options:

- The lifetime of the CTS facility and the Fund for radioactive waste management provide the time and the financial resources required for the development of the repository.

- If, during this sixty-year period, there were sustained increases in the price of uranium and decreases in the price of the reprocessing service, such that the option of the partially closed cycle with recycling in thermal or fast reactors were to become competitive with respect to the open cycle option, Spain would be in a position to choose this option, since it would have intact spent fuel in the CTS facility available for reprocessing, the necessary financial resources provided by the Fund and a future availability to receive the high level wastes arising from reprocessing in the repository thanks to the performance of the corresponding activities over time.

- Even if over the forthcoming decades there were a satisfactory solution to the uncertainties existing in relation to new reprocessing, separation and multiple recycling technologies, and the future transmuting reactors proved to be competitive, Spain would also be in a position to adopt this option if future energy policy decisions were to consider this appropriate.

Deep Geological Disposal

There is international consensus regarding the need for deep geological disposal for the final management of these wastes, regardless of the technological option chosen for spent fuel management, be it the open cycle or any of the different variations of the closed cycle, with or without transmutation.

The isolation of spent fuel and high level waste in geological formations through the use of multiple barrier systems is considered to be the safest and most feasible solution capable of guaranteeing compliance with the restrictive safety limits and conditions imposed upon this type of facility with currently available technologies. DGD is a concept recommended by the main International Organizations responsible for nuclear matters, based on the accumulated knowledge acquired through the R&D programs of the EU and other advanced countries.

Nevertheless, social opposition to this concept has delayed its implementation. Now, two countries, the United States – which already has a repository in operation for TRU non heat-emitting wastes – and Finland, have selected a site for construction of a DGD facility and foresee its operation prior to 2020. Sweden and France have advanced underground laboratories, and although they have not yet appointed a site for construction of a DGD facility, foresee the operation of such an installation by around the year 2025.

The national programs that have most advanced in recent years have opted for an approach based on a process of decision-making in clearly defined stages, including social agreement and parliamentary support. This allows for flexibility and for adaptation to political-social and scientific-technological development (or regression). Retrievability is an essential element in this flexibility, since it will allow decisions taken to be reversed.

The reference of the countries in which DGD programs are most advanced (United States, France, Sweden or Finland) shows that completion of the set of activities required to make such an installation available, i.e. the previous generation of know-how, the facility siting process, site characterization and the construction of the installations, requires some 40 / 50 years of continuous activity.

The Spanish GRWP establishes, for the purposes of planning and cost estimates, that the DGD facility would start its operation around the year 2050. In this respect a period is foreseen, from 2025 to 2040, for decision-making and site characterization, the installations being built between 2040 and 2050. It does not, however, specify any scheduling of activities for the period 2006 to 2025, which would appear to be incoherent with the objective of starting up the repository in 2050.

In order to have a repository in operation by 2050, it would be necessary to establish a specific and detailed schedule of the activities to be performed in both the short and long term, along with the corresponding milestones of partial compliance, especially .

It should be taken into account that both the encapsulation plant and the repository will need to be assessed by the Nuclear Safety Council. The establishment of an explicit schedule for the development of these installations would allow the CSN to plan beforehand its personnel training needs, the acquisition of know-how and assessment of the different activities and processes to be performed over time.

International CTS's or DGD's?

Just as there is currently an international market for spent fuel reprocessing services , it is probable that if the advanced closed cycle were to reach industrial dimensions there would also be a market offering services covering its different stages, including transmutation. However, and with the exception of a Russian initiative, there is no international market for temporary storage services without reprocessing, and an increasing number of national legislations are prohibiting the final disposal of spent fuel from plants outside their frontiers and of the wastes arising from the treatment or reprocessing of this fuel. Despite the efforts of organizations such as the IAEA to achieve the siting and construction of an international repository, especially for the spent fuel and wastes from countries not having favourable geological formations or with small nuclear programs, it would appear to be unlikely that there will be an international market for future geological disposal services in the short or medium term.

The above underlines the idea that both the CTS facility and the DGD repository are necessary elements for responsible environmental management in a country having a nuclear program of the dimensions of the Spanish one. Consequently, it would appear to be advisable to focus management efforts (technical, social and communication-related) on programs for the siting and construction of installations for which there would not appear to be any solution other than the one that each country might implement by itself, i.e. the CTS and DGD facilities, each with its respective characteristics, priorities and schedule.

Technological and R&D capacity

In Spain there is an important mismatch between the dimension of the nuclear program (and consequently of the quantities of SF to be managed) and the limited infrastructure at scientific and technology facilities adequate for the study of spent fuel behaviour and its evolution with time. The GRWP foresees that this mismatch will be reduced through the provision of new installations, presumably to be installed at the CTS facility, for assessment of the evolution and behaviour of irradiated fuel in the long term. The provision of these new installations should go hand in hand with a program for the incorporation and preparation of the scientific personnel in charge of their operation and for collaboration with universities and research centres.

The R&D activities relating to the study of spent fuel and its encapsulation are just one part of the technological developments required to make a repository available. There is also a need for activities relating to geological medium characterization methods to progress steadily in parallel and in coordination with the other activities, especially as regards the geomechanical, hydrogeological and geochemical characteristics of the crystalline and sedimentary formations available in Spain, at the reference depths for the repository. These activities should continue to be carried out simultaneously with participation in international R&D projects with infrastructures and underground laboratories unavailable in Spain and generating knowledge of interest for our program.

It would also appear to be necessary to establish an R&D action plan allowing for tracking of the scientific and technological knowledge generated at world level in the fields of partitioning for transmutation, the manufacturing of fuels for transmutation and transmutation itself, with a view to orienting future updates of the GRWP depending on the perspectives regarding the feasibility of transmutation.

The R&D efforts to be made in this field should be proportionate to Spain's nuclear program and to the country's waste management needs, through participation in international R&D programs in the field of transmutation, especially those of the EU. This participation should in all cases have technological objectives adapted to our needs and providing realistic economic returns.

Financing of management

One of the essential elements of the strategy established in Spain for waste management is the financing system. The financial resources to be collected for application to future management activities are estimated in the different revisions of the GRWP. These estimates are, therefore, essential in order to make management possible, especially in view of the fact that at the time when each future revision of the plan is issued, the remaining operating lifetime of the plants will be less, as a result of which the margin for rectification of the rate of transfers to the fund will be smaller.

Consequently, it is of prime importance that the cost estimates and budgets be drawn up as accurately as possible, and that the mechanisms for the control of compliance and budget tracking for the main items be particularly effective.

Another issue to be considered as regards the economic aspect of spent fuel management is the potential increase in its cost, or uncertainty in this respect, due to the performance of tasks relating to the advanced closed cycle based on transmutation, in relation both to its short and medium-term scientific and R&D aspects and to its potential aspects in the long term. If it proved to be feasible, this option should be considered as constituting a new energy strategy alternative rather than simply a waste management option. For the latter there is already a strategy based on accessible solutions that are economically compatible with the financial resources available or foreseen (open cycle). In keeping with the above, and in order to avoid uncertainties as regards the sufficiency of the financial resources required for waste management, it would not appear to be recommendable that the resources of the Fund for radioactive waste management be applied to activities relating to the advanced closed cycle, which should be financed using resources from other sources.

Importance of public communication, public participation and social acceptance

In questions relating to science and technology, and especially to nuclear energy and wastes, most of the population misunderstands or simply has no understanding of the basic concepts underlying the information reaching them one way or another through the media. The members of the public clearly do not need to know very much about these issues, but often they become easy prey for tricksters and alarmists precisely because of their lack of knowledge. Consequently, it is easy to end up by perceiving very negatively the very fact of having to manage industrial wastes that pose a risk for health and the environment, like radioactive wastes.

The misunderstanding of this management by most of society is largely due to this low degree of scientific knowledge, which prevents the average man in the street from understanding such basic issues as, for example, the fact that waste in general is inseparable from our vital activities, however much we might like not to recognize it. Although we obviously need to minimize all types of waste and recycle whatever materials may be recycled, at present it is inevitable that industry, like domestic life, will generate any number of leftover materials of no further use, this implying the need for them to be appropriately treated.

One way or another, living with nuclear energy for civil use has become commonplace for the Spanish public, especially in hospitals and in the vicinity of nuclear power plants. Having nuclear energy perceived as being something natural, just one more element in the collective existence of the Spanish people as regards their relationship with industry and with its advantages and disadvantages will be possible only by improving the information provided to them in this respect, promoting public participation in decisions involving them collectively and, to the extent possible, making the debate on the solutions to be adopted in relation to radioactive waste a more objective one.

Radioactive waste management in Germany

1

Klaus Kühn

1. Introduction / general overview

Research and development (R&D) for nuclear power generation started in 1955 in the Federal Republic of Germany. The first power generating reactor, VAK Kahl (15 MWe), started operation in 1960. Between 1965 and 1970, nuclear power plants (NPPs) with 250 to 350 MWe and 600 to 700 MWe were ordered. In the following years, bigger plants with up to 1,300 MWe were constructed. The last one started operation in 1989.

Since then, nuclear power contributes about 30 % to electricity production in Germany. Moreover, nearly 50 % of base-load capacity is generated by NPPs.

In September 1998, a new Federal Government was elected, consisting of a coalition between SPD and Bündnis 90/Die Grünen. This Federal Government decided to phase out nuclear energy in Germany. The Government negotiated a contract with those utilities operating NPPs. This contract was initialled on June 14, 2000, and signed on June 11, 2001. In this contract every operating nuclear power plant was given a so-called "remaining amount of electricity still to be produced until its shut-down". The German Atomic Act (Atomgesetz, AtG) was appropriately amended in April 2002. The 17 presently operating NPPs with a total net capacity of 20,339 MWe are shown in Table 1 together with their remaining amount of electricity to be generated until shut down.

Since November 2005, a new Federal Government, consisting of a great coalition between CDU/CSU and SPD is in office. This Government sticks to the old decision of phasing out nuclear energy in Germany. With the worldwide renaissance of nuclear power, however, the discussion on this issue also started in Germany, especially with regard to the problem of global warming.

The early reactors are meanwhile shut down and are being decommissioned. Two of them were completely dismantled and their areas were recultivated. Three bigger NPPs are being decommissioned and dismantled at present.

Type	Name	Net Power (MWe)	Operating since	Remaining production (TWh as of 1/1/2000)
PWR	Biblis A	1167	1975	62.00
PWR	Biblis B	1240	1977	81.46
PWR	Brokdorf	1370	1986	217.88
BWR	Brunsbüttel	771	1977	47.67
PWR	Emsland	1329	1988	230.07
PWR	Grafenrheinfeld	1275	1982	150.03
PWR	Grohnde	1360	1985	200.90
BWR	Gundremmingen B	1284	1984	160.92
BWR	Gundremmingen C	1288	1985	168.35
BWR	Isar 1	878	1979	78.35
PWR	Isar 2	1400	1988	231.21
BWR	Krümmel	1260	1984	158.22
PWR	Neckarwestheim 1	785	1976	57.35
PWR	Neckarwestheim 2	1305	1989	236.04
BWR	Philippsburg 1	890	1980	87.14
PWR	Philippsburg 2	1392	1985	198.61
PWR	Unterweser	1345	1979	117.98
Total		**20,339**		**2,484.18**

Table 1.1. Nuclear Power Plants in Germany.

1.1. Radioactive waste categorization

With regard to radioactive waste management, it was already decided in the late fifties / early sixties of last century to dispose of all types of radioactive waste in deep geological formations. Consequently, there exist only waste categories taking into account surface dose rates on the waste containers: low-level waste (LLW), intermediate-level waste (ILW), and high-level waste (HLW). No segregation of radioactive waste with regard to halflives of specific radioisotopes was ever performed. This has two consequences:

1. In Germany, there exists no separation between short-lived and long-lived LLW and ILW.
2. Disposal of short-lived LLW and ILW on or near the surface was never considered.

In connection with the Konrad repository (cf. Chapter 3.3), an additional waste classification was introduced: non-heat generating waste and heat generating waste. Spent fuel, if considered waste, belongs to the latter category. The definition of non-heat generating waste is: "Rock temperature in the Konrad repository must not be increased by more than 3 K by emplacement of this waste."

1.2. Radioactive waste quantities

Quantities of radioactive wastes in Germany are given in tables 1.2 and 1.3. Both tables show those quantities which already exist and also those which will be produced until the year 2040 taking into account the above mentioned phasing out of nuclear power.

	Existing End 2000	Prognosis 2001-2010	Prognosis 2011-2020	Prognosis 2021-2030	Prognosis 2031-2040	Total
Nuclear power plants	23,000	31,000	46,000	73,000	22,000	195,000
Public activities	53,000	27,000	8,000	3,000	11,000	102,000
Total	**76,000**	**58,000**	**54,000**	**76,000**	**33,000**	**297,000**

Table 1.2. Quanties of non-heat generating waste until 2040 [m³].

	As of end 2000	Prognosis 2001-2010	Prognosis 2011-2020	Prognosis 2021-2030	Prognosis 2031-2040	Total	Total Volume
				Number			**m³**
HAW-canisters	84	4,582	112	0	0	4,778	908
Public activities	0	840	7,576	2,400	0	10,816	2,814
AVR + THTR spheric fuel elements	908,705	0	0	0	0	908,705	1,890
				Mg			
LWR fuel elements	3,142	3,962	1,819	24	0	8,947	18,258
Rossendorf fuel elements	2.3	0	0	0	0	2.3	49
FRM-II fuel elements	0	0.35	0.35	0.35	0.35	1.4	108
							ca. 24,000

Table 1.3. Quanties of heat generating waste until 2040.

Quantities of non-heat generating wastes are shown in table 1.2. The first line indicates the quantities produced by nuclear power plants. The sharp increase to 73,000 m³ between 2021 and 2030 is caused by the then foreseen dismantling of NPPs according to the phase out program. Line two indicates the quantities of waste generated by public activities. Nearly 80 % of this total amount are already existing or will be produced shortly until 2010, mainly by the two big Nuclear Research Centres at Karlsruhe and Jülich and by the meanwhile being decommissioned prototype reprocessing plant WAK (cf. Chapter 4.1). The total amount of non-heat generating waste until 2040 will be about 300,000 m^3 all of which is going to be disposed of in the Konrad repository.

Quantities of heat generating wastes are given in table 1.3. About 4,800 canisters with vitrified HLW originate from reprocessing German spent fuel in France and in the United Kingdom. Under the respective reprocessing contracts, also about 2,800 m^3 of heat generating ILW will be produced. All these quantities are or will be shipped back to Germany in order to be disposed of there.

Nuclear power generation without reprocessing will produce about 9,000 Mg of spent LWR fuel. Accordingly packed for disposal, this will be a volume of 18,300 m^3. The rest of other spent fuel shown in table 1.3, stems from different research reactors.

2. Institutional framework

Basis for all nuclear activities in Germany is the German Atomic Act (Atomgesetz, AtG) which originates from December 1958 and which was amended several times meanwhile. The latest amendment was decided in April 2002.

2.1. Implementer

With regard to radioactive waste management, there exists a clear separation of responsibilities between the Federal Government and the nuclear industry: § 9a (3) AtG designs the Federal Government to be responsible for the construction and operation of repositories for radioactive wastes. All other activities within the nuclear fuel cycle are within the responsibility of nuclear industry. This includes spent fuel package, transportation, and interim storage, reprocessing of spent fuel, waste treatment, transportation and interim storage.

Within the Federal Government, the Ministry for the Environment, Nature Conservation and Reactor Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU) is in charge of the construction and operation of repositories. BMU delegated this task to the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS). BfS is a Federal Office working for and on behalf of BMU. In order to realize repository projects, BfS signed a contract with DBE (Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH). So, DBE is working on behalf of BfS as what is called "the third party".

2.2. Licensing authority

In Germany, no central or Federal licensing authority does exist for nuclear installations. According to the Federal Constitution (Grundgesetz) and the German Atomic Act (AtG), licensing is performed by a Ministry of that Federal State on which's territory the respective nuclear installation is going to be located. So, the Konrad repository e.g. is located in the Federal State of Lower Saxony. In consequence, the Ministry of Environment of Lower Saxony (Niedersächsisches Umweltministerium, NMU) has issued the license for Konrad.

The 4th Amendment of the German Atomic Act (AtG), decided in 1976, prescribes the performance of a specific licensing procedure for radioactive waste repositories which is called "Plan Approval Procedure (Planfeststellungsverfahren, PfV)". A big disadvantage of this PfV is that it has very little flexibility. In consequence, the internationally used step-wise procedure in licensing and realizing a radioactive waste repository is not very much favoured by this procedure.

3. LLW & ILW management

As already mentioned in Chapter 1.2, there is no differentiation between short-lived and long-lived LLW and ILW in Germany. Consequently, no disposal of these waste types on or near the surface was ever performed. All LLW and ILW have to be disposed of in a deep geological repository in Germany. Three projects have to be mentioned in this connection:

1. Asse Research Mine (Forschungsbergwerk Asse, FBA)

2. Morsleben Repository (Endlager für radioaktive Abfälle Morsleben, ERAM)

3. Konrad Repository (Endlager Konrad)

3.1. Asse Research Mine (FBA)

The Asse Research Mine was a former mine for the production of potash and rock salt. It is located in the county of Wolfenbüttel in the Federal State of Lower Saxony. Salt production stopped in 1964. From 1965 until 1995, FBA was used as a R&D-facility for the disposal of radioactive waste in salt formations. For LLW, different emplacement techniques were developed, tested, and used between April 1967 and December 1978. Respective techniques for the emplacement of ILW were developed and tested between September 1972 and December 1977. Within these test series, about 125,000 drums with LLW and about 1,300 drums with ILW were emplaced into the Asse Research Mine.

In parallel and also afterwards until 1995, a great number of in situ-investigations was performed in the Asse Research Mine for the disposal of heat generating HLW and spent fuel in salt formations, but without using real waste.

Since 1995, backfilling and decommissioning of the Asse Research Mine is underway. License application for the final closure of the facility will be handed to the competent licensing authority in early 2007.

3.2. Morsleben repository (ERAM)

The former potash and rock salt producing mine Bartensleben stopped production in 1969. It was located on the territory of the late German Democratic Republic (GDR) about 40 km west of the city of Magdeburg. After reunification of Germany, the location of this site is now named Morsleben in the county Ohrekreis in the Federal State of Saxony-Anhalt.

Under the regime of the former GDR, the mine was selected to serve as the repository for the disposal of LLW and ILW originating from the GDR nuclear power plants at Rheinsberg and Greifswald which were shut down after reunification and are being dismantled at present. The Bartensleben mine was then named "Endlager für radioaktive Abfälle Morsleben – ERAM". Waste emplacement started in 1971 with a provisional license. In 1986, ERAM got a definitive and timely unlimited license from the then responsible licensing authority "Staatliches Amt für Atomsicherheit und Strahlenschutz, SAAS". After reunification of Germany in 1989, waste emplacement continued until 1991 and after an interruption again from 1994 until 1998. A total amount of about 36,800 m^3 of waste was disposed of in ERAM.

The license application for decommissioning and final closure of ERAM was delivered by BfS in September 2005 to the competent licensing authority, which is the Ministry for Agriculture and Environment (Ministerium für Landwirtschaft und Umwelt, MLU) of the Federal State of Saxony-Anhalt.

3.3. Konrad repository

The former iron ore mine Konrad (figure 1.1) is located in the municipality of Salzgitter in the Federal State of Lower Saxony. Mining of iron ore stopped in 1976. After extensive studies of feasibility to turn this mine into a repository for LLW and ILW, PTB, the predecessor of BfS, formally applied for a respective license in August 1982. After a lengthy process, this license was finally granted by NMU in June 2002 to BfS. As expected, the license was immediately sued. It took the court roughly three and a half years to decide. This decision was made public on March 8, 2006:

- The court fully confirmed the license issued in June 2002.
- All safety related objections of the plaintiffs were rejected.
- The court denied the possibility of an appeal.

For some sophisticated rules of procedure this last decision has to be confirmed by the Supreme Court of Administration (BVG Leipzig). This is expected for early 2007.

After a positive decision of BVG Leipzig, alteration of the mine and construction of the repository can begin and will last for about four years. That means, emplacement of radioactive waste could start in 2011/12.

The licensed capacity of the Konrad repository will enable the disposal of all the 300,000 m^3 of non-heat generating waste shown in table 1.2.

Figure 1.1. Shaft Konrad Nº. 1.

4. Spent fuel and HLW management

4.1. Strategies

In the early years of nuclear power production in Germany the clear objective was to reprocess all spent fuel from LWR power reactors. Therefore, a pilot reprocessing plant named "Wiederaufarbeitungsanlage Karlsruhe (WAK)" was constructed from 1967 until 1971, neighbouring the Karlsruhe Nuclear Research Centre. It was operated from 1971 until 1990. A total amount of 207 Mg uranium and 1.16 Mg plutonium was reprocessed at WAK. This former pilot plant is now being dismantled since 1993.

After a lengthy process of discussions the idea of constructing and operating an industrial reprocessing plant in Germany was finally given up in 1989. Contracts for reprocessing spent fuel from German NPPs were signed with Cogema in France and BNFL in the United Kingdom.

The German Atomic Act (AtG), which formerly stipulated reprocessing, was amended in 1994. This amendment also allowed direct disposal of spent fuel in Germany. The latest amendment, however, dated April 2002, now prohibits reprocessing of German spent fuel as of July 1, 2005, onward. In consequence, all spent fuel has to be stored until it can be disposed of in a repository.

As already mentioned in Chapter 1.2, it was decided very early in Germany to dispose of all types of radioactive waste in deep geological formations. For the disposal of HLW and spent fuel the clear objective always was to construct and operate the repository for these wastes in a salt formation. The salt dome of Gorleben is under investigation for this purpose since 1979 (cf. Chapter 4.2.3).

In recent years, the idea of partitioning and transmutation (P&T) initiated large R&D-programs internationally, especially in France. The recent GNEP initiative in the United States (Global Nuclear Energy Partnership) also follows this line. In Germany, only relatively small R&D-programs for P&T are performed at the two research centres at Karslruhe and Jülich.

In all aspects and facets of radioactive waste management, there always was an extensive international cooperation, be it on a bilateral or a multilateral basis. This aspect applies especially for the field of R&D. Germany also always actively participated in international activities and programs of IAEA, OECD/NEA, and EU.

4.2. Installations

Interim storage

Three central facilities for interim storage of spent fuel and HLW are in operation in Germany:

1. BZA Ahaus

2. TBL Gorleben

3. ZLN Greifswald

The facility BZA at Ahaus, located in the county of Borken in the Federal State of Northrhine-Westphalia, started operation in 1992. It has a licensed capacity of 3,960 Mg HM which equals 420 positions for storage casks. At present, six CASTOR-casks with 60 Mg of spent LWR fuel are stored. In addition, 305 CASTOR-THTR/AVR-casks are in store which contain all the spherical graphite fuel elements originating from the former German prototype gas-cooled reactor THTR (cf. table 1.3, line 3). Because of the smaller size and weight of these casks, they only occupy 50 positions (figure 1.2). In 2005, 18 CASTOR-MTR 2 casks, containing all spent fuel elements from the former Research Reactor Rossendorf near Dresden were shipped to BZA and are now stored there.

The interim storage facility at Gorleben, located in the county of Lüchow-Dannenberg in the Federal State of Lower Saxony, started operation in 1995. TBL Gorleben has a licensed capacity of 3,800 Mg HM which equals 420 positions for storage casks. At present, five CASTOR-casks with 36 Mg of spent LWR fuel are being stored. In addition, TBL is being used for the interim storage of vitrified HLW which Germany has to take back under existing reprocessing contracts from France and the United Kingdom. 75 storage casks of CASTOR-HAW-28 and TN-HAW-28-type, containing 28 HLW-canisters each, are already in store (figure 1.3). This equals a total amount of 2,100 HLW-canisters.

Figure 1.2. CASTOR-THTR/AVR-casks in BZA Ahaus.

Figure 1.3. TBL-Gorleben "Transportbehälterlager Gorleben - TBL".

The interim storage facility at Greifswald, located in the county of Ostvorpommern in the Federal State of Mecklenburg-Vorpommern, started operation in 1999. It has a licensed capacity of 585 Mg HM which equals 80 positions for storage casks. In ZLN, all spent fuel elements originating from the shutdown NPPs at Rheinsberg and Greifswald of the former German Democratic Republic are in store.

Because transportation of spent fuel elements in CASTOR-casks from different NPPs to the interim storage facilities at Ahaus and Gorleben were always accompanied by heavy, sometimes even violent manifestations of anti-nuclear demonstrators and thereby caused the strict and strong commitment of police, the Federal Government which was established after the elections in September 1998, was no longer willing to tolerate these transports. It changed the situation by the respectively mentioned amendment of the German Atomic Act AtG in April 2002. By introducing § 9a (2) Satz 3, all utilities operating NPPs are now obliged to construct and operate separate interim storage facilities on the NPP site. All these single interim storage facilities are meanwhile licensed for a storage time of 40 years and are either already operating or under construction. As an example, figure 1.4 shows the interim storage facility at NPP Biblis A.

Figure 1.4. Spent fuel storage facility at NPP Biblis A.

Spent fuel conditioning

In order to test the packaging of spent LWR fuel elements in containers which are suitable for disposal in a salt repository, the German nuclear industry constructed a pilot conditioning facility, named "Pilot-Konditionierungs-Anlage (PKA)" at the site of Gorleben adjacent to the interim storage facility TBL. Construction of PKA started in early 1990. The final license for operation was issued by NMU in December 2000. The capacity or throughput of the facility is 35 Mg HM / year (figure 1.5).

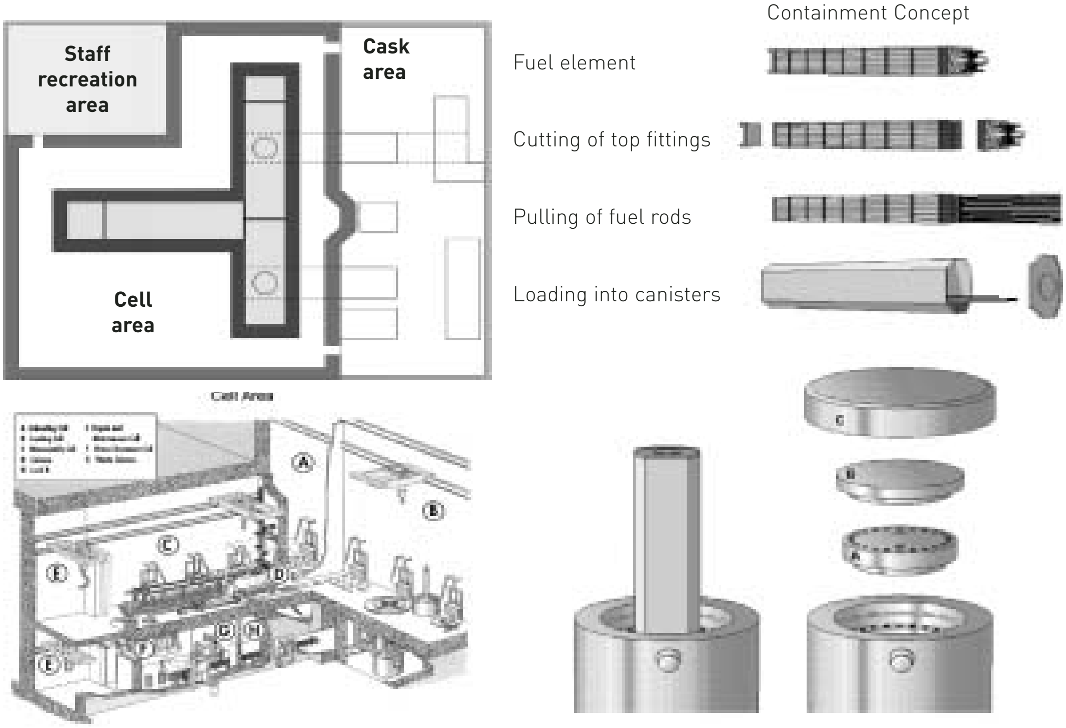


Figure 1.5. Pilotkonditionierungsanlage - PKA (Pilot Conditioning Plant).

Up to now, however, PKA was not put into operation by the nuclear industry because the Federal Government has not yet decided where the repository for spent fuel containers will be located (c. Chapter 6).

Repository

As mentioned in Chapter 4.1, Germany's concept in the sixties, seventies, and eighties of last century was to reprocess spent light-water reactor (LWR) fuel. After the successful operation of WAK the plan was developed to construct and operate what was called a "Nuclear Fuel Cycle Centre (Nukleares Entsorgungszentrum, NEZ)" at that time. Core of that NEZ was to be a large industrial reprocessing plant. Besides including all waste treatment facilities, a constituent part of NEZ was also an underlying geological formation suitable for the disposal of all types of radioactive waste to be generated within the NEZ. After some lengthy and also difficult site selection process, the Federal Government and the State Government of Lower Saxony agreed in June 1977 to investigate the site of Gorleben for the construction of the NEZ. Many discussions, public hearings, but also manifestations followed. After a large public hearing with international participation, named "Gorleben Hearing", the State Government of Lower Saxony decided in May 1979 not to permit the construction of the NEZ at Gorleben. It simultaneously decided, however, that the underlying voluminous Gorleben salt dome should be investigated for its feasibility to host a repository for radioactive waste.

In consequence, site exploration from the surface started immediately after this decision and lasted until 1983. After publishing all results, a great number of scientific, political, and also public hearing and discussion meetings were held. In summary of all these, the Federal Government decided to sink two shafts for underground exploration. These two shafts were sunk between 1985 and 1996. Within the next two years, the underground infrastructure was mined and equipped. In early 1998, underground exploration of the first possible emplacement area (EB 1) was started.

The above ground situation of the Gorleben site at that time is shown in figure 1.6. In the foreground of the picture are the surface facilities of the Gorleben exploratory mine with Shafts No. 1 and 2. In the upper part of the picture one can see the GNS facilities, namely the interim storage hall TBL and the pilot conditioning plant PKA.

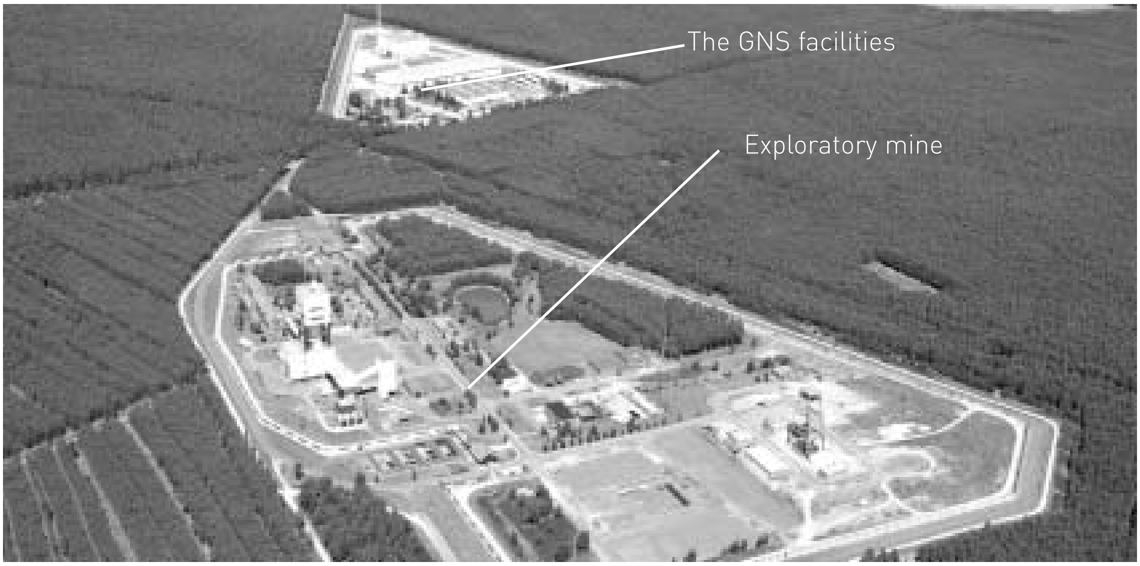


Figure 1.6. The whole Gorleben site.

Exploration from the surface and from underground delivered a very good picture of the geology within, around and above the Gorleben salt dome. This situation is shown in figure 1.7. The geological situation on the exploratory level at a depth of 840 m is shown in figure 1.8. The exploration of the whole salt dome, however, is not yet completed so that a final statement on the suitability of the Gorleben salt dome to host a repository can not yet been made.

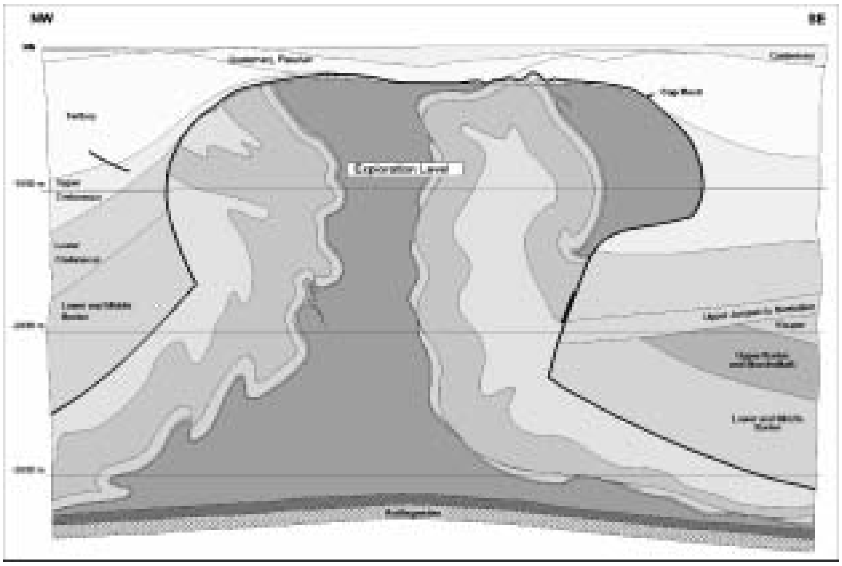


Figure 1.7. Gorleben Salt Dome - Geological cross section.

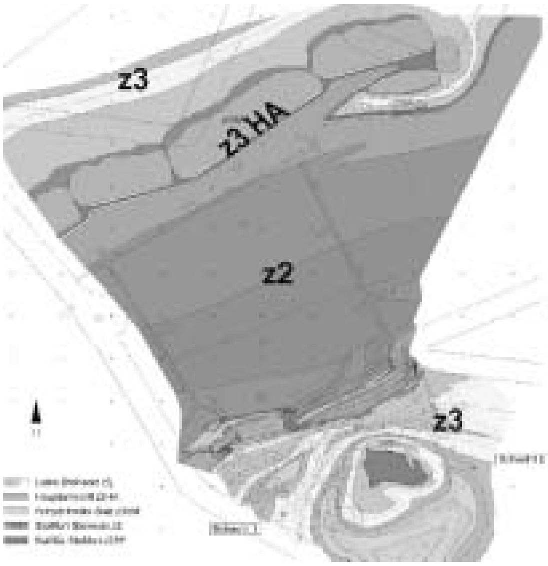


Figure 1.8. Gorleben Salt Dome - Geology on the exploration level.

Why and what happened? As mentioned already several times, a new Federal Government was formed after the elections in September 1998, consisting of a coalition between SPD and Bündnis 90/Die Grünen. This government decided to phase out nuclear energy in Germany (cf. Chapter 1.1). Within the also mentioned contract between the Federal Government and the utilities (initialled on June 14, 2000, and signed on June 11, 2001), both parties agreed to establish a moratorium on the further underground exploration of the Gorleben salt dome for a minimum of three and a maximum of ten years. This moratorium became effective on October 1, 2000, in spite that the Federal Government acknowledged in Appendix 4 to that contract, that all results hitherto achieved during site exploration are positive.

After signatures of the contract, the Federal Government formulated twelve issues (originally called "doubts – Zweifel") in order to justify the moratorium. These issues were not directly related to the exploration of the Gorleben salt dome, but to radioactive waste disposal in geological formations in general and to salt formations in special. BfS was instructed by BMU to clear these issues. In consequence, BfS contracted several experts to elaborate on these issues. In October 2005, BfS held a workshop to discuss the results. Shortly after this workshop, BfS published a summarizing report in November 2005 resulting in the positive resolution of the issues. The Gorleben moratorium, however, was not lifted.

In October 2005, a new Federal Government was formed after another elections consisting in a great coalition between CDU/CSU and SPD. In the respective coalition contract, signed November 11, 2005, one can read on the issue of radioactive waste disposal: "CDU/CSU and SPD admit national responsibility for the safe disposal of radioactive waste and approach the solution of this problem in a rapid and success-oriented manner. We intend to solve this problem during this coming period of legislation."

In spite of all these results, declarations, and statements nothing has happened until now. The moratorium on the Gorleben salt dome exploration is still effective. What will happen in the future is completely open.

4.3. Main restrictions and uncertainties

The main uncertainty for the whole German spent fuel and HLW management system is the unsolved question of where the respective repository will be located.

The Federal Government elected in September 1998 (cf. Chapter 1), even neglected the ongoing activities for the projects of the Konrad repository and the Gorleben exploratory mine. It established a new approach for HLW and spent fuel disposal:

1. It issued the so-called "One Repository-Only-Concept" which meant that only one repository should be constructed and operated in Germany for all types and quantities of radioactive wastes.

2. It tried to initiate a new site selection procedure – starting from a "white map" of Germany – in order to find "the best suitable site" for that repository.

For the second objective, BMU installed a specific committee in February 1999 which was given the name "Arbeitskreis Auswahlverfahren Endlagerstandorte (AkEnd) – Committee on a Site Selection Procedure for Repository Sites". Neglecting the ongoing Konrad and Gorleben projects, BMU instructed this committee to develop a procedure and criteria for the selection of repository sites for radioactive waste. AkEnd worked for nearly three years and delivered its final report to BMU in December 2002. This ministry, however, never evaluated and commented AkEnd's report publicly.

So, the question if the moratorium will be lifted and the exploration of the Gorleben salt dome can be finished or if another site (or other sites) will be searched for, selected, and investigated – with or without the recommendations of AkEnd – is still unsolved. The court decision (OVG Lüneburg) on the Konrad Repository, mentioned in Chapter 3.3, also contains three important statements with regard to this issue:

1. The concept of "One-Repository-Only" is a non-binding political declaration of intent and is not in agreement with the Atomic Act (AtG).

2. Also, a comparison between different sites is not necessary in order to fulfil the political request to find "the best site".

3. The demand for retrievability, too, is not justified by law.

This whole complex issue must and can only be solved politically within the Federal Government. The new Federal Government, being in office since November 2005, promised to do so within this present period of legislation (cf. Chapter 4.2.3).

The main reason for all these difficulties is the decision taken back in 1976, to give responsibility for the construction and operation of repositories to the Federal Government. Following this decision, there always was a strong political discussion of this issue. This discussion was strongly influenced by the political parties, especially those forming the Federal Government. This became extremely evident when the Federal Government was formed in late 1998 with participation of Bündnis 90/Die Grünen.

These difficulties can only be overcome if all parties would agree that a repository for HLW and spent fuel is needed in Germany and where this repository should be located.

4.4. R&D needs

R&D for the disposal of radioactive wastes in geological formations has been performed in Germany since 1965. It resulted in the operation of ERAM and in the licensing of the Konrad Repository for the disposal of LLW and ILW. Furthermore, nearly all R&D-results necessary for the design, construction, operation, and closure of a possible repository in the Gorleben salt dome are achieved.

4.5. Safety and licensing

What is still missing – but what can easily and quickly be achieved with existing knowledge and results – is the elaboration of a "Total Systems Performance Assessment (TSPA)" for the projected Gorleben repository. This assessment is not only necessary for the eventual site evaluation of the Gorleben salt dome, but also for the step-wise procedure of realizing a repository for HLW and spent fuel. This assessment also is an indispensable compartment of the safety case which finally has to be handed over by BfS to the competent licensing authority.

If the decision will be taken to construct and to operate the repository in the Gorleben salt dome, then NMU will be the responsible licensing authority (cf. Chapter 2.2.).

5. Costs and financial aspects

As already mentioned in Chapter 2.1, all activities within the nuclear fuel cycle – with one exemption: radioactive waste disposal – are within the responsibility of nuclear industry. This means at the same time that nuclear industry has to pay for all its activities.

The utilities operating NPPs are additionally obliged by law to build financial reserves (assets) in order to be able to pay at an appropriate time for decommissioning of their NPPs and for disposal of all radioactive wastes being generated by operating and dismantling their NPPs.

All costs for the design, construction, and operation of radioactive waste repositories in Germany have to be paid by the producers of wastes, according to the "polluter pays principle". In contrast to the situation in many other countries, there exists no specific waste fund in Germany, be it public or be it private funds.

Based on the German Atomic Act (AtG), a specific decree was established in April 1982 named "Endlagervorausleistungsverordnung (EndlagerVlV) – Repository Prepayment Ordinance". The latest amendment of this decree dates from June 2002.

The financial system according to this ordinance works as follows: All planned expenses for repository projects must be taken in advance into the yearly budget of BMU. This budget is part of the Federal Budget which has to be approved by the German Parliament. At the end of the respective year, BfS – acting on behalf of BMU – sums up all the expenses which it has spent for repository projects during this year and issues respective invoices. According to a specific ratio key which is fixed in the EndlagerVlV, all waste producers have to pay for these invoices accordingly. The ratio key for different repository projects, e.g. for Konrad or for Gorleben, is of course different for different waste producers, like e.g. a utility operating three NPPs or a public research centre. These invoices issued by BfS also include the so-called "project related R&D-costs". In summary, this system of covering the expenses for the construction and operation of waste repositories is called a "system of pre- and re-financing".

In addition, basic research for radioactive waste disposal is also paid for by money from the Federal Budget, namely by the "Bundesministerium für Bildung und Wissenschaft (BMBF) – Ministry of Education and Research" and by the "Bundesministerium für Wirtschaft und Technologie (BMWi) – Ministry of Economics and Technology". The contribution from these two ministries for basic R&D for disposal, however, has decreased drastically over the recent years.
The total costs which occurred until the end of the year 2006 for the Konrad Repository project and which were already paid for by all the different waste producers, sum up to 913 million €. The total costs for this repository are presently quantified with 1,873 million €. The respective figures for the Gorleben repository project are: 1,472 million € already spent and paid until the end of 2006, and 3,420 million € expected total costs.

6. Social, public opinion & communication aspects

Social and public debates and discussions accompanied the issue of radioactive waste management and especially disposal from the very beginning in Germany. As already mentioned, these discussions were and are especially influenced by the different political parties.

There is general agreement within the public opinion that radioactive waste repositories are needed in Germany. This agreement differentiates, however, as soon as a specific site is named. With regard to the Gorleben repository project, it must be mentioned that the directly concerned community is in favour of the project and that it pleads for the continuation of the underground exploration. The Konrad Repository is accepted in general by the local public, even if there still exist several groups of opponents.

With regard to communication aspects it has to be said that every detail of the two German repository projects has been published. Consequently, everybody who is interested in the subject has access to all information he wants to see.

In summary and as already mentioned, the issue of radioactive waste disposal, including siting, construction, and operation of repositories, can only be solved in Germany when the Federal Government is willing to take the necessary decisions.

Radwastes management in France situation and perspectives

2

R. Guillaumont

1. Introduction and general overview

This report focuses on the current radwastes situation in France, but as the massive use of nuclear energy of fission started in France at the turn of the middle of the 20 th century it gives also figures on "legacy radwastes". Foresights on radwastes extend over the period necessary to implement launched (or near to be launched) nuclear programmes. Indeed the "future French radwastes" situation will depend on coming energetic choices, which are too much dependent on economic issues and on the versatile views of society on nuclear energy. For these reasons no realistic figures can be given after, say 2030.

The open literature on French nuclear situation, particularly on radwastes, is very large whatever are the designed target (public, experts), the level of information (general, specific) and the sources (government, nuclear operators, groups of experts, associations of citizens including opponents to nuclear energy). Recent documents issued in 2005 can be found at the web sites indicated in references. The figures given in this report aim at understanding the nature and the amounts of radionuclides found in French sub-assemblies of spent nuclear fuel (SF) and, consequently, in nuclear wastes from reprocessing, as well as for the radionuclides found in all other radwastes. Safety analysis cases in radwastes management, which have a major impact on decisions, are based on this information (producers, locations, quantities).

The main producers of radwastes are: EDF, Areva, CEA and then, with regard to quantities, many small laboratories which work on radioactive matter (research in radiochemistry field, use of radionuclides in biology and nuclear medicine) and the users of sealed sources (research, industry). Andra is in charge of radwastes management and to follow the inventory of all radioactive matters.

An important step in French radwastes management has been recently overcome with the law passed on June 28, 2006 " Loi n° 2006-739 de programme relative à la gestion durable des matières et déchets radioactifs" (Programmation law with regard to the sustainable management of radioactive matters and radwastes)

1.1. French nuclear programme overview (present and past)

Reactors and nuclear fuel

In the following Unat is for natural uranium, Udep is for depleted uranium and Urep is for uranium coming from reprocessing.

EDF operates 58 PWR reactors (34 of 900 MWe type, 20 of 1300 MWe and 4 of 1500 MWe), which produce 420 TWhe/year (2005). This needs each year1050 tons of UOX fuel (Unat enriched at 3.7 to 4.2 % in U235 depending of reactors and sub-assembly loads), 100 tons of MOX fuel (Udep with 3 to 8 % of civilian Pu, depending of sub-assemblies reloads) and 40 tons of URE fuel (Urep enriched at 4% in U235). All the following weights are expressed in tons of IHM (initial heavy metal). Twenty-eight reactors of 900 MWe can accept MOX but only 20 are fuelled at 30 %. The first loading of a PWR with MOX has been made in 1987. Two 900 MWe PWR are fuelled with URE fuel. All other are initially fuelled with UOX fuel. Management of UOX and MOX fuel sub-assemblies is a complicated topic depending of reactor and fuel burn up (BU). Refuelling of most of the 900 MWe PWR is made each year, but six are refuelled each 18 months like the 1300 MWe. The period between two loadings is 11 months for the 1500 MWe reactors. Today UOX BU is licensed up to 52 GWd/t per sub-assembly and up to 42 GWd/t per sub-assembly for MOX. Average BU is lower (45 GWd/t for UOX and 38 GWd/t for MOX). There are immediate plans to increase these BU (up to a parity of 52 GWd/t max for UOX and MOX and 62 GWd/t max for the 1300 MWe). Today the average mass yield of fuel is 2.8 g/MWh (an increase of 17 % in 10 years). In the 10 coming years BU could attain 70 GWd/t max (900 and 1300 MWe). The French choices to use PWR (in 1973) and to close partially fuel cycle (in 1995) necessitated respectively to have Uenr and to reprocess spent fuel (SF).

Each year about 8 500 tons of Unat are necessary to produce 1050 t of UOX, which needs 5 10^6 SWU (Separation work unit). Enrichment gives around 7 500 tons of Udep (0.25 to 0.3 %) which are stored as U_3O_8. Reprocessing of 850 tons of SF UOX (presently average BU is 33 GWd/t, coming soon to a BU of 45 GWd/t) give around 8.5 tons of Pu used to make MOX fuel. Over the SF yearly unloaded 200 tons of UOX and 100 tons of MOX are stored. In addition 280 tons of Urep are enriched in U235 abroad, giving 40 tons of URE fuel, which are also stored as SF when unloaded. The stockpile of separated Pu from UOX does not increase but it increases in SF at a rate of 2.2 tons/year in UOX and 2 tons/year in MOX, where Pu isotopic composition is changed from its initial value. SF MOX is not reprocessed today but reprocessing could be done in the reprocessing plant of la Hague if diluted with UOX in proportion 1 to 1. The fast neutron nuclear reactor Phenix (250 MWe) is connected to the grid and used for irradiation experiments. The CEA operates experimental reactors for research purposes.

EDF has operated 6 GGR reactors (power 70 to 540 MWe) between 1963 and 1994, one HWR (70 MWe) between 1966 and 1985, one PWR (300 MWe) between 1967 and 1991 and one FNR (1200 MWe) between 1985 and 1997, presently all under decommissioning. SF from thermal neutrons has been reprocessed in the UP2 400 plant (the Hague) and Pu directed to MOX. Some research reactors have been dismantled as well as many facilities of the fuel nuclear cycle or experimental facilities.

Facilities for the nuclear cycle

Around 75 000 t of Unat has been extracted from several places in France. Extraction of Unat from ores containing 10 to 300 kg of U per ton ended in 1991 and all facilities (from mine to yellow-cake as rich as 800 kg/t) are presently closed. Today yellowcake comes from abroad. All the facilities to prepare UOX and MOX fuel exist: conversion of yellow-cake to UF_6 (Malvesi: yellow-cake to UF_4, Pierrelate: UF_4 to UF_6, 14 500 tons of U/year), enrichment of Unat by diffusion of UF_6 (Tricastin 10.8 10^6 SWU/year), reconversion of UF_6 to UO_2, pellets, pins and sub-assemblies fabrications (Romans, 820 tons UO_2/year and 1200 tons UO_2/year in 2008). A part of Urep (U_3O_8) to be enriched abroad is transformed in UF_6 at Pierrelate

French civilian PuO_2 for MOX is obtained as an end product together with Urep in the reprocessing plant UP2 800 (the Hague, 850 tons/year) and processed for MOX fuel fabrication (pellet and pins at Melox plant -Marcoule- and at Belgonuclaire plant -Mol-, Melox and sub-assemblies at FBFC -Dessel). Melox is licensed for 145 tons of MOX and will be upgraded to 195 tons. The part of Urep not enriched is stored as U_3O_8 as it is for Udep (Pierrelate). EDF purchases also UOX sub-assemblies on the international market (Westinghouse). Figure 2.1 shows the quantities of radioactive matter handed each year in France.

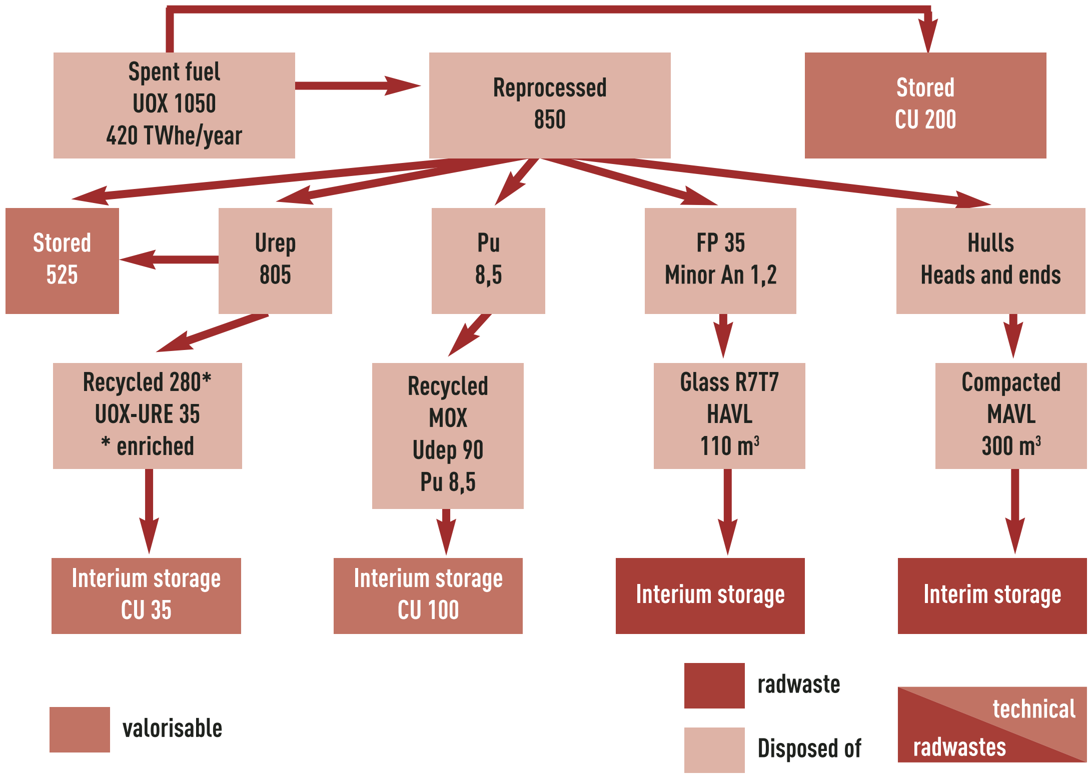


Figure 2.1.

Military programme

French military programme conducted by CEA started in 1950 to produce military Pu which has been recovered in UP1 (400 t/year capacity) reprocessing plant (1957 to 1997) at Marcoule from 18 500 t of irradiated fuel in three GGR (presently dismantled): G1 (1956-1968), G2 (1958-1984), G3 (1959-1984). G2 and G3 were connected to the grid giving each 5.8 GWhe. UP1 has also reprocessed SF from EDF GGR. High-level enriched U235 has been produced by gaseous diffusion in Pierrelate plant. This plant is presently dismantled. Irradiation of Li to produce T is conducted in the reactor Celestin in Marcoule. Celestin's reactors, launched in 1963 and 1968 have produced Pu up to 1993. Nuclear weapons are renewed in Valduc.

Radwastes generation, storage, disposal of

Operating reactors and implementing industrial processes in the nuclear fuel cycle facilities lead, or have led (since the fifties) to large amounts of radioactive radwastes. When they come from electricity production or military needs one speaks clearly of nuclear radwastes. Research in many nuclear fields and the use of radionuclides in industry and health care add radwastes to nuclear radwastes. Some historical radwastes linked with Ra industry and industry of rare earth exist. All the radwastes located in France are fully described in the last National inventory set up by Andra in 2006 (previous versions 2002 and 2004).

There are many facilities to store radwastes packages and non-conditioned radwastes at CEA and Areva sites. There are two centres for the disposal of radwastes. One for short-lived radwastes, CSA (Centre de stockage de l'Aube) at Soulaines with 10^6 m^3 capacity and another for disposal of very low level radwastes (Centre de stockage de Moronvilliers) near Soulaines with 0,65 10^6 m^3 capacity. All the capacities of there repositories are sized to accept radwastes foreseen for the present nuclear configuration and identified legacy radwastes. The first centre for disposal of short-lived radwastes, CSM (Centre de stockage de la Manche) near la Hague created in 1960 after the decision to stop sea dumping, has been closed and is now under monitoring (0.5 10^6 m^3 capacity).

1.2. Radwastes categorisation

In France radwastes are categorised according to the activity (very low level-VLL, low level- LL, medium level-ML and high level-HL) and the half-life (very short-lived-VSL, short-lived-SL and long-lived-LL, depending on the two figures 5 and 30 years) of the main radionuclides they contain. Table 2.1 gives the recent categorisations introduced for the purpose of radwastes management. This categorisation of radwastes is a pragmatic view based on the possible routes in term of principles of management rather than on limits of activities defined "a priori" and given on Table 1 only as guidelines. Considerations for defining the different classes of radwastes depend also on safety (including radiological and chemical aspects).

This categorisation does not take into account some sealed radiation sources, TENORM (Technical enhanced natural occurring radioactive materials) and radwastes from uranium mining. It does not allow a fine classification. For instance Andra has defined for geological disposal around 100 different families of radwastes packages dispatched in "typical classes" with similar characteristics. Finally the "identification of producer" of waste and it "solvability" are considerations, which do not appear in the categorisation, but which are very important in practice. Further comments are given in sections 3 and 4.

Activity	Life duration			
	Short lived SL (T < 30 y)		Long lived LL (T > 30 y)	
Very low level VLL	VLL-SLW	Ground VLLW disposal Recycling	VLL-LLW	Ground VLLW disposal Recycling
Low level LL	LL-SLW	LML-SL* disposal (CSA)	LL-LLW	Disposal to be set-up for wastes with LL radionuclides **
Medium level ML	ML-SLW	Disposal to be set-up for waste with tritium	ML-LLW	Disposal to be set-up***
High level HL	HLW	Disposal to be set-up***	HLW	Disposal to be set-up***

* Except some radwastes with T
** Natural radioelements, Ra226 and daughters (radium radwastes), Cl36, C14 (graphite)
*** Law passed on June 28, 2006 (article 3)

Indicative limits of activities.

Considering all radionuclides the activity of MLW range from 30 to 30 10^3 Ci/t, LLW are less active than 30 Ci/t (down to say 100 Bq/g) and HLW are more active than 30 10^3 Ci/t. Considering beta/gamma and alpha emitters the limits are the following : ML-SLW, beta/gamma less than 10 Ci/t, alpha emitters less than 0.1 Ci/t, ML-LLW, beta/gamma less than 10^4 Ci/t, alpha emitters above 0.1 Ci/t, HLW, beta/gamma up to 10^6 Ci/t, alpha emitters, above 10^4 Ci/t. The figures are the following for VLL-SLW and VLL-LLW, 10^{-4} to 10^{-2} Ci/t, for LL-SLW, beta/gamma less than 10 Ci/t, alpha emitters less than 0.1 Ci/t, for LL-LLW, beta/gamma emitters 10^{-2} Ci/t to 1 Ci/t, natural alpha emitters 10^{-3} to 10^{-1} Ci/t.

Additional limits for some radionuclides allow distinction between VLLW and LLW. For instance they are (in Bq/g) 10 and 130 10^6 for Co60, 10^3 and 10^6 for T, 100 and 600 10^3 for Pb210, 10 and 330 10^3 for Cs137, 10 and 5 000 for Ra226 and 10^3 and x100 10^3 for C14.

Finally there are limits for VLL-LLW containing Ra226 considering their disposal site, few Bq/g in classical centres (few quantities), 10 Bq/g in specific VLL-LLW disposal (Moronvilliers and for less than 10^6 tons), around 20 Bq/g in U mining disposal (average value of 3.8 to 29 Bq/g), 200 Bq/g in specific disposal of radium wastes (average value of 10 to 1600 Bq/g) to be created for 60 10^3 tons.

Table 2.1. Categorisation of radwastes.

Management of radwastes is done through channels, which consist of the following operations: sorting out (according to activity-half-life and possibility of burning, compacting and melting), processing and conditioning (to avoid dispersion of radionuclides). These operations lead to interim storage or to disposal.

Most of the radwastes are conditioned in packages designed for transportation and interim storage or disposal. But there are many radwastes, mainly MLLW, waiting for conditioning. They come from the precedent generation of reactors (generation I), which has produced as much radwastes as the present generation will give, but providing 50 times more electricity. Plans to achieve their conditioning extend over more than 25 years. Present conditionings will be used, but some specific radwastes necessitate new ones. Disposal of "ultimate radwastes packages" in appropriated structures and in an ultimate site is the last step foreseen for all radwastes.

1.3. Radwastes generation (present and foresights)

All radwastes, and other radioactive matters not considered as radwastes, are fully identified in quantities and location. The 2006 inventory conducted by Andra (March 2006) is based on careful examination of the declarations of producers. Forecast of packages production and radwastes have been done up to 2020. The extension of nuclear waste production after 2020 depends of many factors. For the purpose of disposal of waste some scenarios have been proposed by Andra. The figures for radwastes generation are given in tables 2.2 and 2.3.

Equivalent Cubic meter of packages*	End 2004 % of total volume % of non-conditioned	Annual rate production	% of total activity
HLW	1850 0.2 16	0.13/tSF	91.8
ML-LLW	45 500 4.4 64	0.183/tSF	8.2
LML-SLW	795 000 ** 76	17 000	0.055
LL-LLW	47 150*** 4.6 78	30 000 total expected	0.013
VLLW	145 000 **** 14		0.031

*Anticipate the same conditioning as today for "non conditioned" radwastes
** 13 % conditioned but not disposed of
*** 35 000 with Ra, 11 150 graphite
**** 17 000 disposed of

Table 2.2. Situation end 2004 (last figure of the 2006 national inventory).

Cubic meter	2004 Total % conditionned	2010 Total % conditionned	2020 Total % conditionned
HLW	1850 84	2520 87	3620 100
ML-LLW	45 510 36	490500 53	54 800 83
LL-LLW	47 120 16	48 500 27	105 000 93
LML-SL	795 000 87	930 000 91	1 195 000 94

VLLW are estimated to 580 000 m^3 in 2020 (Moronvilliers)

Table 2.3. Foresights considering continuation of present situation and conditioning programmes.

There are two views for foresights: quantities of packages of radwastes can be calculated according the pursuit of the present situation and dates can be given, or new conditionings for different reprocessing scenarios are used, but no date can be given (tables 2.4 and 2.5). The EDF policy is to reprocess all sub-assemblies of UOX SF according the possibilities of the Hague plant. In case of an increase of the demand of plutonium SF MOX could be reprocessed as well.

Activity	Lifetime SL	LL
All UOX SF reprocessed with same conditioning as today		
LLW	Disposed of in LML-SLW disposal (CSA)	LL-LLW
MLW		80 600 m³ of ML-LLW 120 000 packages
HLW	6300 m³ of HLW 36 220 packages	
HL	5 400 sub-assemblies of MOX in interim storage	

Table 2.4. Foresights considering different managements of SF and new conditionings.

Activity	Lifetime SL	LL
All SF reprocessed with new packages more concentrated in actinides		
LLW	Disposed of in LML-SLW disposal (CSA)	LL-LLW
MLW		81 100 m³ of ML-LLW 199 850 packages
HLW	6330 m³ of HLW 36 320 packages	
HL	5 400 sub-assemblies of MOX in interim storage	

Table 2.5. Foresights considering different managements of SF and new conditionings.

About 50 % of the 20 000 t of PWR SF already reprocessed in la Hague plant came from foreigner electricity producers and the corresponding radwastes must be returned to foreign countries according to contracts or according to the law (passed on December 30, 1991). A complete system of attribution based on 'Residue Unit" (RU) has been set up for each type of waste coming from either conditioning of high level radioactive solutions, pieces of sub-assemblies, effluents processing and technological radwastes. For instance 1 CSD-V equal 70 000 RU of FP. Return of foreign CSD-V packages to Japan, Germany, Belgium, Switzerland and the Netherlands is in progress since 1995 and will ends in 2011. Around 60 % in average of vitrified radwastes are already returned (90 % to Japan). For Spain the process will start in 2011 and in 2015 for Australia. The return of other packages will follow those of CSD-V.

1.4. Reactors and facilities decommissioning-dismantling, cleaning up of sites

Nuclear reactors

Five nuclear reactors (3 GCR, 1 PWR, 1 HWR) have the status of "Interim storage facilities" and 4 are in situation of final shutdown (3GCR, 1 FNR). For its "first generation of reactors" (all except the FNR Superphenix) EDF has changed its strategy of decommissioning in 2001, going from a three steps decommissioning after a deferral period of 50 years (partial decommissioning, interim storage of equipment and radwastes for 50 years, complete dismantling) to a two steps process (decay of radioactive materials during 50 years cancelled). It will be implemented by 2025. This change aims at proving the feasibility of decommissioning and dismantling and at preparing massive dismantling of the present Generation II reactors (beginning after 2010). Implementation of this new EDF policy started with one GCR. Planning for the next decades is set up. The site of the HWR should be released by 2015.

Superphenix has been operated only 320 days over10 years at nominal power. Since 1998, fuel unloading, sodium interim storage and dismantling of non-nuclear facilities are authorized. Sodium of the secondary circuit is in solid form in tanks. Complete dismantling is expected to last for 20 years in 3 steps, primary and second circuits and sodium treatment, internal reactor structure removal, complete structures demolition. Sodium will be transformed into caustic soda, which will be used to manufacture concrete blocks (50 000 t from primary circuit - 25 Bq/g in Na22 and 50 Bq/g in T and 33 000t from secondary circuit). A facility should be constructed to implement this conditioning. Blocks could be in interim storage on site for 30 years. Only blocks from secondary circuit are immediately compatible to VLL waste disposal (Moronvilliers) due to their low content in T.

The radwastes expected from the dismantling of these reactors are the following: VLLW (15 000 t of metal, 1500 t of non metallic material, 50 000 to 100 000 t of concrete), ML-SLW (30 000 t of metal, 20 t of non metallic material, 15 000 to 70 000 t of concrete), ML-LLW (400 t of metal, 18 500 t of graphite). Interim storage for these radwastes is under consideration. A disposal site for graphite radwaste is expected by 2010.

Facilities of nuclear fuel cycle

Many facilities operated by Areva and CEA in la Hague, Marcoule, Cadarache and other places are to be cleaned up and some to be decommissioned.

For instance UP1, sited at Marcoule (operated between 1957 and 1997) is under dismantling. UP1 has reprocessed UNGG fuel coming from G1, G2, G3 and EDF GGR. Some large facilities to prepare metallic fuel dissolution, linked to UP1, are also under dismantling. Many radwastes have been already disposed of, decreasing activity of the plant to 65 % of its initial value. There are many reprocessing radwastes from UP1 plant stored at Marcoule (conditioned like sludge in bitumen from decontamination of effluents – 12 000 packages and 55 000 drums in trenches - or not conditioned like sludge - 2 500 drums expected -, pieces of structure of sub-assemblies containing T –1500 packages expected -, identified radiant radwastes -3 500 m^3 -, others radwastes – 30 t).

A large programme of revision of conditioning is running to improve safety of interim storage and to sort out packages between LML-SLW and LML-LLW. New storage facilities have been constructed. A programme, almost the same, is under implementation at Cadarache for 3 000 m^3 of radwastes in trenches and 900 m^3 in pits.

UP2 4000 sited at la Hague (operated between 1987 and 1966) has been progressively integrated in UP2 800 (1998). A total of 4 900 t of metallic U-GGR SF have been reprocessed as well as 4500 t of PWR (1976) and some Phenix SF when a facility to cut PWR type sub-assemblies and to dissolve uranium oxide was completed. Reprocessing radwastes have been stored without conditioning in tanks and silos except LML-SLW disposed of in the CSM (now under monitoring as already said). Some have been already processed (HL-LLW since 1989 up to 97 % of activity, technological ML-LLW up to 50 to 70 % in weight) and packaged, but large quantities are pending. A large programme for conditioning all the radwastes coming from UP2 400 has been set up including the sludge from the cleaning of primary highly active effluents (STE2). The beginning of industrial operations is by 2010 and will last over 20 years. For 2030, Areva foresees the production of 7000 m^3 of LL-SLW, 5000 m^3 of VLL-LLW, 13 500 m^3 of ML-SLW and 150 m^3 of HL-LLW. Production of packages will be each year compatible with the capacities of la Hague storage facilities or with the capacities allowed to Areva for disposal of radwastes (no more than 10 % of the amounts).

In addition to the decommissioning of UP1 and connected facilities and the taking back of radwastes from UP2 400, two large operations, there are some experimental reactors (pool, fast neutrons), accelerators, irradiators, laboratories (dry and wet processes), storage facilities, operated by CEA, which will be cleaned and decommissioned during the 15 following years. The amounts of VLLW (500 t) and SLW (200 m^3) produced each year could be accommodated with the CEA allocations to dispose of radwastes. For the ML-LLW and HL-LLW (SF of Celestin not able to be reprocessed, pieces of high activity) around 450 t in total, a new storage facility should be constructed.

2. Institutional framework

General

Radwastes management is directly under the control of DGSNR (Direction Générale de Sûreté Nucléaire et de Radioprotection), which is a part of the French nuclear safety authority (NSA) and for some part under the control of Euratom and IAEA. Radwastes, as other wastes, are subject to provisions of the law dealing with the "elimination of wastes and recycling of materials" (law 75-633 July 15, 1975) and radwastes management is regulated by many decrees and statements. It lies on the basic principles of radiological protection of workers, the public and the environment. NSA takes care of their application. NSA has followed the international review (2003, 2006 in Vienna) of radwastes management reports as required in the "Convention on the safety of spent fuel and radwastes" signed by 41 countries since1997. NSA provides Basic Safety Rules (BSR), which are guides for nuclear operators and radwastes producers. The III 2f BSR (issued in 1991) deals with the safety of geological disposal. It is under revision, according to the lessons learnt from the last safety cases analysis conducted by Andra.

NSA has also a prominent role outside its strict regulatory domain. In the years following 1990 several important initiatives for LLW management have been set up and have led to strict principles and regulations. NSA and producers of radwastes have defined the leading principles of radwastes management. Examples are: the cut-off of radionuclides concentration in the processes of decontamination of primary effluents before the release of ultimate gaseous or aqueous effluents in environment (in the case of gaseous T, C14 and I129 that are difficult to capture quantities handed in facilities are limited), the minimisation of the radiological impact for disposal of packages of radwastes with an upper limit at 0.3mSv/year (short and long term). NSA takes care of possible cumulated effect of the releases of ultimate effluents. NSA has set up a consortium of European NSA to harmonize practises in nuclear safety.

Finally in 2003 the Government has decided to hand over to the NSA the responsibility to set up the so called "PNGDR-MV" (Plan national de Gestion des Déchets Radioactifs et Matières Valorisables), a draft to the PNGDMR (Plan National de Gestion des Matières et Déchets Radioactifs), the establishment of which is required by the 2006 law. This last document is aimed at: defining clearly what are radwastes, defining long term solutions for each type of radwastes, taking care of "legacy radwastes", making coherent the global system of management, preparing institutional decisions. It is based on the National inventory of radwastes set up by Andra. Many parties including environmental associations contributed to a global thinking and to the elaboration of the PNGDR-MV document.

The law 2006-686 passed on June 13, 2006 on "Transparency and security on nuclear concerns" creates an independent NSA under the direction of 5 commissioners. Their nomination occurred in November 2006.

Definition of a radwaste

The definition of a radwaste is a matter of discussion not considered in this paper. NSA considers that every material which has possibly been in contact with a radioactive contamination or which has been activated by radiation is a VLLW subject to regulation. The concepts of "exemption" and of "clearance" for radioactive materials are not applicable in France. The first lies on the definition of thresholds of activity (Bq/g or Bq/cm^2 or total activity) for limited quantities of matter (1 ton for instance) above which no control is necessary to assure radiological protection when recycled materials are used. The second lies also on the consideration of thresholds of activity (Bq/g or Bq/cm^2 or total activity less than, or equal to, those for exemption) for possible uses of decontaminated materials. Universal clearance levels are such that for any pessimistic scenario the radiological impact is less than 0.01 mSv/year (recommended dose by IAEA -safety rule RS-G-1.7- and Euratom - directive 96/29). The main reason invoked by NSA to not apply exemption and clearance is the difficulty of the application of these concepts to be sure that the limit of 0.01 mSv/year for added dose to an individual of the public is respected. ASN consider that against the advantages of clearance, it is impossible to consider all possible scenarios, that the parameters in safety analysis are subject to discussion, that protocols of measuring radioactivity are difficult to implement at industrial scale and finally that there is a risk to make artificial radioactivity ubiquitous, as natural one. For these reasons in 1990 the decision was taken to store and then dispose of VLLW coming from nuclear zones of Basic nuclear installations (BNI) in a special repository. Extension to other facilities than BNI is under consideration.

This position is not coherent with international recommendations and some practices in Europe. Some exceptional authorisations of clearance could be given (conditional clearance) for special cases of addition of radionuclides to monitored solid materials (except product in contact with human beings). Recycle in nuclear industry of special materials, contaminated at very low level of radioactivity, the fate of which could be monitored, could be also possible. Cases have been submitted to NSA and are studied, but today no implementation has occurred. A global thinking on all these complicated concerns is going on.

3. LLW and MLW management

3.1. Present situation

Low radiotoxic radwastes

VLLW (without specification of SL or LL) comes from the parts of BNI categorised as "nuclear zones" according to NSA approval. It is the same when BNI are under decommissioning. They are disposed of in the special VLLW repository (Moronvilliers). This disposal, opened in 2003, is of a ground level type where packages are disposed of in alveolus excavated in clay, according to criteria of admission. The totality of radioactivity of the VLLW will stand under the limit of a BNI. For other nuclear facilities from where VLLW could come from, there is no systematic disposition other than the analysis of the radiological impacts to make a choice of an ultimate destination.

TENORM are VLL-LLW and come from non-nuclear industries (oil, gas and mineral industries) and from some wood ashes. They contain natural radioelements Ra, U and Th and their daughters (at level up to some kBq/g, exceptionally 100 kBq/g when coming from oil and gas industry) and potassium. The TENORM must be fully characterised and a safety analysis conducted before their acceptation in Technical centres for industrial radwastes, according regulations (EU directive 96/29). These centres are equipped to detect radioactivity above fixed thresholds. If radioactivity is over, NSA is alerted and remediation put in action if necessary. Management of TENORM is under reconsideration, particularly with regard to their quantities.

Radwastes from processing of U ores or other ores (mainly rare earth and phosphorous in France) are in large quantities. Uranium has been mined in 18 sites and processed on 8 sites between 1948 to 2001. That produced 76 000 tons of U and 50 Mt of VLL-LLW (20 Mt with 3.8 Bq/g and 30 Mt with 29 Bq/g). These radwastes are relatively homogenous, either blocs of broken ores processed by static leaching or sand and mud coming from milled ores processed by dynamic leaching. U radwastes from mining are disposed of *in situ,* near the place of their production (old open air mine, basins or bottom valley closed by dams up to 50 m high, all covered with natural materials) and managed to take care of radon migration and daughters. They are disposed of in 17 sites with capacities ranging from 4 to 11 10^6 tons. The sites are monitored and submitted to specific regulations. Discussions about the final management of these radwastes are not closed. The question about the adequacy of the provisions taken with regard to their potential radiotoxicity is under reconsideration. Mining refuses (less than 0.03% in U) have been reused before 1982 and since this date they are stored at open air on sites production. Their management is under consideration.

Finally radwastes from research and medical applications are managed according special status. In general their activities are low, after decay of very short-lived radionuclides (100 days) and their quantities much less than those of nuclear radwastes. After some processing ultimate residues are disposed of in LML-SLW disposal (CSA). In the category of VLL-LLW are the historical radwastes coming from radium industry or remediation of polluted sites. In theory Andra is in charge of collecting all these "non nuclear" radwastes, particularly when producers are non identified or non solvable (see next).

High radiotoxic radwastes

The LML-SLW coming mainly from electricity production are packaged and disposed of in LML-SLW (CSA), open since 1992 and foreseen to be in operation up to 2050 (capacity of 10^6 m^3). The previous repository for LML-SLW (CSM) open in 1969 has been closed in 1993 and the 0.5 10^6 m^3 packages are presently under monitoring. CSA can receive some ultimate radwastes coming from the processing of medium active medical or industrial radwastes (mixed SL biological chemical waste) or some extra radwastes (some radioactive sources, few VLL-LLW) as said above.

The long-lived nuclear wastes (LL-LLW) are (or will be) 18 400 t of large pieces of graphite coming from dismantling of GGR reactors (6 from EDF et from CEA) and 5 600 t of small pieces of graphite from reprocessing of metallic U SF (Marcoule UP1 and the Hague UP 400). They contain traces of T, Co60, Cl36 (around 1.5 kBq/g) and C14 (around 100 kBq/g), but a complete characterisation is necessary. A special package for conditioning these materials is under consideration to dispose graphite waste (around 5 000 packages) in a geological repository expected by 2009 by producers

The long-lived radioactive waste (LL-LLW) are various materials containing Ra and its daughters (typical activity is 5 kBq/g in Ra far above activity of VLLW at 10 Bq/g) coming from processing of minerals (rare earth -RE-, Zr) or from research on U extraction or from remediation of historical Ra industrial sites. Industry of rare earth has produced 13 300 t of residue from processing of monazite. The most active (1.85 kBq/g) are stored at Cadarache (5120 tons) and la Rochelle (161 tons) and the less active (75 Bq/g) are stored at la Rochelle (8400 tons). There are also, stored by the producers of RE, 19 500 tons rich solutions in RE (25 %) contaminated with Ra (5 to 20 Bq/g) and 2 000 tons of rich residues (100 Bq/g of Ra) which are considered as possible resources of RE. The CEA store also 27 600 t of different materials and hydroxides (4 600 t) with concentrations in Ra is ranging from 10 to 200 Bq/g. The total inventory of LL-LLW with Ra is around 60 000 t at an average value of 220 Bq/g of Ra. All these materials will be disposed of in a special repository.

Repositories for graphite and radium radwastes could be sited together in sub-surface (15 m deep) but according different concepts of confinement (daughters of Rn must be trapped for instance by wet natural material) and different regulations (BNI or other specific installation allowed to receive radioactivity).

Radwastes containing T come for 90 % from military activities and from various research centres. Their activities range from HL to VLL (4.6 % HL, 30.7 % ML, 53.7 % LL and 11 % VLL). They are mainly LML-SLW. Radwastes containing T cannot disposed of in LML-SLW repository (CSA), or exceptionally, neither in VLLW repository (Moronvilliers), because for these facilities the release of aqueous and gaseous effluents are limited to very low levels and because the total content in T should be less than for instance 4 000 TBq for CSA. Specific activity of T is 9 700 Ci/g or 10^{12} Bq/g. There is no management (storage or disposal), which could avoid dispersion of T in the environment, and no choice has been done for the final management of these radwastes other than interim storage. Only 185 t of metallic VLLW with T have been disposed of in CSA.

These radwastes are stored at Valduc. There are presently 10 000 packages for 2100 m^3, 4 10^{15} Bq (5 % being HL; 10 % being VLL, 85 % being LML) 96 % coming from military activities. For 2020 the amount will be 3 300 m^3. Others radwastes with T could be packages of alloys Al-Li irradiated targets for T production (2 300 m^3, 8 10^{13} Bq) presently stored in Marcoule and some few packages from CEA conditioning facilities. Radwastes from ITER are foreseen to be around 30 000 m^3 after 20 years of operation (30 % VLL-SLW, 60 % ML-SLW, 10 % ML-LLW). Possible destinations of these radwastes containing T are under consideration.

The number of "sealed radioactive sources" not in use (radwastes), or which will be declared as radwastes in the coming years, is important and their activities and life very different. More than 10 000 are stored at CEA or at EDF and 30 000 by the users. More than 140 000 have been produced by CEA. There are 8 millions of ionic devices (smoke detectors and lightening conductors). Many historic sources (made before1956 for artificial radionuclides) are probably unknown. The management of sources is under consideration but the problems are numerous, both of administrative and technological nature. For instance only few have been accepted in CSA due to their high resistant conditioning not compatible with regulations of the centre after several centuries.

3.2. Foresights

Some changes will occur in the management of LLW and MLW. The road map is given in the law passed on June 28, 2006 (see later).

4. Spent fuel and long-lived radwastes management (ML-LLW, HL-LLW)

4.1. Strategy

The strategy of EDF is to reprocess all UOX SF, to recycle Pu once in MOX fuel and to concentrate resulting Pu in SF MOX. This strategy decreases the volume of SF to be stored by a factor of 7 and preserves use of Pu once recycled for possible "Generation IV" reactors. EDF could reprocess French MOX, but not before 2030-2040. Reprocessing and recycling of Pu in MOX earn SWU and Unat. EDF did not bet on the possibility to replace the Generation II reactors by Generation IV reactor and launched EPR belonging to the Generation III reactors. One EPR is under construction.

In this section the objectives of the present management of SF and HLW are discussed as well as milestones of programmes for conditioning, interim storage, geological disposal and partitioning and transmutation.

Present situation

The LLW are highly toxic and come from nuclear electricity production and military activities. Unreprocessed nuclear fuel is not a radwaste.

The aim of reprocessing, with regard to radwastes management, is to recycle Pu and a part of Urep and to minimise Pu in HL-LLW. Urep must be enriched to be recycled. Their recovery and quality must be of high level. The yield of the Purex process used for separation of these elements from all others elements present in SF is 99.98 % with decontamination factors of fission products up to 10^7 (0.4 GBq/g). Pu contains less than 500 ppm of U. Reprocessing leads since 2001 to two type of "standard packages". The first are CSD-V, stainless steel container filled with "nuclear glass" including all non volatile FP, minor actinides (Np, Am, Cm), the soluble and non-soluble losses of U and Pu and the chemicals used to implement Purex process. These HL-LLW packages release a thermal power around 2 kW (and 0.2 kW after 100 years). Nuclear glass R7T7 wasteform has a good to high resistance to leaching depending of temperature. The second type of packages are CSD-C packages, stainless steel containers (same shape as CSD-V) filled with high-compacted metals shaped as "pancake", which include zircaloy hulls from pins, stainless steel heads and ends of sub-assemblies, and some other materials (very few part of Pu losses). They do not release heat. The 850 tons of UOX SF yearly reprocessed give 500 packages CSD-V and 850 packages of CSD-C containing 25 tons of fission products, 0.85 tons of minor actinides, 0.170 ton of U and 0.17 kg of Pu. The 100 m^3 of glasses and 300 m^3 of metallic radwastes share at equality the Pu losses. Finally technological LML-LLW are conditioned in concrete. All other radwastes from reprocessing are LL-SLW, send to CSA. Primary gaseous effluents are processed and decontaminated and then released in atmosphere. The volume of aqueous primary effluents is reduced by evaporation and the solid residues are included in CDS-V packages. Ultimate aqueous effluents containing mainly T and iodine are discharged to the sea.

The ratio of the volume of crude SF over the volume of radwastes from reprocessing is 4, (2m^3 over 0.5 m^3 by ton of U) but to draw a conclusion on this reduction of volume, with regard of radwastes management, a deeper discussion of the fate of packages has to be conducted.

This situation has not been so clear as it is today. Before 1995 processing of primary reprocessing effluents gave slugs, which were conditioned in bitumen. Conditioning was not made in line with reprocessing. There are still HL-LLW and ML-LLW stored in the Hague and waiting for conditioning. The quantities are the following for HL-LLW : 730 m^3 of solution from reprocessing of UOX and 250 m^3 of specific solution from reprocessing of GGR (UP2 400), 11 000 tons of spent fuel, and 158 000 m^3 for ML-LLW.

The reprocessing plant of la Hague will be able to reprocess 100 to 150 tons of MOX in 2010-2015. Concluding runs on several tons have been made.

Depleted uranium is stored as U_3O_8 at Pierrelatte and Bessines (240 000 t today and 350 000 t in 2020). As already say separated Pu, around 8.5 t/year, is used to produce 100 t of MOX fuel with a buffer quantity of around 10 t. About 30 % of the 850 tons/year of Urep is enriched abroad to give 50 t of UOX fuel (URT) used to refuel two 900 MWe reactors. The other part is stored as U_3O_8 at Pierrelatte (17 000 t today and 25 000 t in 2020). There are 13 300 tons of thorium nitrate and 20 000 tons of thorium hydroxide stored at la Rochelle.

Other ML-LLW are coming from activated structure of nuclear reactor (control rods) and from military activities. There are in storage important quantities of various civilian and military radwastes (packages of mud from decontamination of aqueous effluents in bitumen, packages of hulls and head-ends of bundles in cement, packages of glasses, and non conditioned materials in tanks). Finally all ML-LLW and HL-LLW packages are stored in la Hague and Marcoule (HL) and in la Hague, Marcoule, Cadarache and Valduc (ML) (see section 1.5).

Foresights

No major qualitative change in French nuclear energy policy is expected for the next decades. Accordingly radwastes management of SF and reprocessing radwastes will stay as they are for the short term. No major change which could lead, for instance, to new packages containing less actinides in glass or in other wasteforms is foreseen, because partitioning and transmutation will not reach industrial level before 2050, is so, and because no new industrial ceramic wasteforms are ready. Only punctual improvements will occur like conditioning of HL-LLW from the reprocessing of GGC fuel (metallic fuel U-Mo). A new nuclear glass and a new line of production at high temperature (large capacity furnace at 1200 °C) must be set up at la Hague. Section 4.2 deals also with foresights.

The road map for the next future is given in the law passed in June, 26, 2006. This law has taken into account the results of 15 years or research (law enacted on December 30, 1991).

The results of the researches realised during the last 15 years are numerous. The National Commission of Evaluation (NCE) has produced 11 annual review reports and in January 2006 a final evaluation report, as required by the 1991 law. Many others reports have been published (CEA, Andra, NSA, OCDE). Large technical debates have risen. The researches have been conducted simultaneously along three lines : i) partitioning and transmutation (P&T) of long-lived radionuclides found in HL-LLW and ML-LLW, ii) geological (reversible or not) disposal of these radwastes through investigations in an underground laboratory, iii) processes of conditioning and surface or sub-surface long-term interim storage.

Line 1 has dealt with (i) the partitioning of minor actinides Np, Am and Cm and three fission products, Tc Cs and I, from the Purex high level nitric aqueous solution presently vitrified, (ii) the preparation of experimental pins of fuels (U and minor actinides) or targets (minor actinides without U) for irradiation, (iii) the irradiation of these pins in nuclear reactors, (iv) nuclear modelling and measurement of nuclear data needed to core design studies for transmutation, (v) experimental studies on ADS devices (Accelerator Driven Systems), (vi) an ADS preliminary design study, (vii) studies of P&T scenarios.

Line 2 has dealt with (i) geological and geochemical investigations on three sites up to 1996, (ii) selection of one site in clay at Bure, and construction of an underground research laboratory (URL), (iii) detailed heavy geological reconnaissance by 3-D seismic survey, numerous cored boreholes and *in-situ* hydraulic tests, (iv) measurements of clay rock parameters both on samples and *in situ* (v) laboratory and *in situ* migration experiments of radionuclides in clay, (vi) generic studies for disposal in granite, in cooperation with foreign countries, (vii) behaviour study of some long-lived radionuclides in the biosphere (viii) research on candidate materials for engineered barriers, (ix) engineering studies, (x) modelling and numerical simulation, (xi) inventory and characterization of waste.

Line 3 has dealt with (i) improvement of industrial conditioning of nuclear waste, (ii) ageing and leaching of industrial radwaste packages and spent oxide fuels, (iii) studies for new conditioning for separated actinides and long-lived fission products, (iv) design of containers for long-term interim storage or for deep disposal of SF or radwastes from reprocessing, (v) design of surface or su-surface stores for interim storage, mainly with regard to heat dissipation.

It is obvious that the whole objective of the law was to find solutions to reduce the toxicity of the ultimate nuclear waste by decreasing the long-term radiotoxicity of the packages sent, in a final step, to a geological repository (transmutation, choice of the best conditioning, choice of a site with minimal scientific uncertainties for long-term confinement). Geological disposal cannot indeed be avoided by transmutation. Long-term interim storage offers the flexibility, if needed, for the implementation of transmutation or disposal, but it cannot be considered itself as a definitive solution for waste management.

▶ In short the results were the following

The goals of partitioning have been successfully achieved at laboratory scale and partially at an engineering demonstration scale. This opens the door to industrial application, but new partitioning methods have to be developed to achieve separation of elements in line with the preparation of fuel or target transmutation, a key issue for transmutation. Indeed there are two main issues to overcome to achieve transmutation, the first is to find compounds or composites able to sustain strong irradiation conditions without any consequences on the safety of reactors and the second issue is to transmute actinides preferentially by fission with high yields. It is well known that fast neutrons, which operate in FNR (critical) or in ADS (sub-critical), are the best options. Some test materials showed rather good performances and it can be said today that although the principle of transmutation in FNR with experimental pins is demonstrated, it has to be fully demonstrated at a larger scale. Despite numerous experimental results obtained both on fuels or target and on transmutation systems, too much remained, in 2006, still unknown. It is a long way to show how to bring together in operation partitioning, fuel fabrication and their recycling and transmutation in FNR or ADS. Nevertheless, scenario studies shed a light on the potentiality of different possible transmutation cycles. The results emphasized the key question of curium management.

With regard to line 2 the research priority has been given to investigate the Bure site and its deep clay layer (the Callovo-Oxfordian between 400 and 550 m below ground). Data have been collected (i) on regional and local geology and hydrogeology and (ii) on geochemistry and mechanical properties of the clay layer. Full designs for a potential repository consistent with the numbers of packages assumed to be disposed of in 2020 and according to scenarios (full or partial reprocessing) have been proposed. The clay shows a remarkable lateral continuity and a good homogeneity in composition and structure. Neither faults nor connection by convective flow between the upper and lower aquifers through the clay have been found so far, in any of the boreholes or drifts. This is also shown by the isotopic composition of waters. Poreal water in clay has a very long residence time. Water composition has been determined and the diffusion coefficients of the fastest diffusive elements (Cl, I, Cs) have been measured in the laboratory and are being measured by *in situ* experiments at Bure URL, still going on. Preliminary mechanical data are available but they must be confirmed over time.

The conditioning of ML-LLW radwastes to produce industrial packages has been greatly improved over the last 10 years. Their volume has been reduced and their quality improved. Today, conditioning and characterisation of the radwastes packages are well controlled, notably for vitrified residues. The empirical ageing models, including leaching, of both containers and wasteforms in several different environments have been consolidated and their behaviour can reasonably be forecasted with regard to long-term storage and disposal. SF have been studied as other wasteforms. Ceramics (ternary oxides or phosphates) for the incorporation of each actinide and for I, Cs and Tc have been developed at laboratory scale and their ageing and leaching investigated.

The evidence has been brought that industrial storage is possible during about a hundred years in the recently built storage facilities. For a longer storage or for disposal, each family of radwastes package or spent fuel sub-assemblies has to be encapsulated into containers. Demonstrators of such containers are presently under investigations to prove their durability, which is sought for durations centuries of thousands of years (disposal). When long-term storage means several centuries, the main problem pointed out was to find a long-lasting special concrete able to accommodate large variation in temperature and chemical corrosion. Although the most stringent standards are proposed for concrete, the evidence of its durability over several hundred years has not yet been afforded. Preliminary designs for store facilities have been studied.

The June, 26, 2006 law

For the coming years the policy (objectives, strategy and financing) for radwastes management is defined in the "programme law" passed on June 26, 2006. The "new law on radwastes and recyclable materials management" stipulate to : i) continue research on P&T, geological disposal and storage according to the "PNGMDR" document, ii) improve transparency and democratic control on these topics (clarification of wording, set up of a new NCE, set up new local Committees for information and for the following of researches - CLIS -, debates within the Parliament), iii) improve economic development for sitting facilities, iv) set up structures and financial resources for these actions (Andra, financing made secure for coming years and on the long term).

Researches and studies must be : directed to prevent and limit charges for future generations and consequently their definitive security has to be assumed and clarified in term of complementarily with regard to ML-LLW and HL-LLW.

The milestones for managing these radwastes are : i) 2012 survey on the possibility to use ADS or FNR for transmutation, ii) 2020 possible set up of a prototype facility for transmutation, iii) 2015 address files to NSA for licensing a geological disposal which could be launched in 2025 and set up new storage facilities or modify those presently used (if necessary). For other radwastes and radioactive matters milestones are : i) 2013 launching a LL-LLW disposal, ii) 2008, survey on the long term radiological impact of radwaste from mining, survey on radwastes containing T, storage before their disposal, disposal of sources, iii) 2009 survey on TENORM.

Special status is given to geological disposal : radwastes packages could be left in disposal facilities indefinitely, reversibility must be considered in studies, it will not last less than 100 years, it will be defined in a new law before 2015.

The "PNGMRD" will define precisely before the end of 2006 the objectives of radwastes management: decrease of the toxicity of radwastes including the use of reprocessing, interim storage and geological disposal as a final solution, conditioning before 2030 of the radwastes produced before 2015, and the meeting points for RD. It will have a section describing international studies.

The improvement of the democratic process includes a special status for the members of NCE (independency reinforced) and a special status for the sitting of a geological disposal : public debate , reports of NCE and NSA, consultation of local instances, consultation of OPECST (Parliament office for studies of scientific and technical choices), law on the reversibility, authorisation by the "Conseil d'état" (Highest administrative judicial French authority) after a public inquiry, new law for the closure. Along the process of sitting periodical debates will be organised by the "Nuclear committee on transparency and security". The CLIS will be reorganised : extension of competence to all the researches fields, new composition with extension to qualified people, local elected people, new organisation with a national elected people as President. The missions of Andra will be extended to the evaluation of costs and to public information at all levels. Its financing will be distinct for general activities, research on sitting and construction of disposal facilities. To implement the law many decrees have to be promulgated before the end of 2006 : on the PNGRD, on the financing for Andra and for the control of the long term financing of nuclear activities (a new commission will be set up the CNEF- National commission on financial evaluation), on the economical development of region where sitting facilities is expected.

4.2. Installations in operation and in project or programme

The industrial installations for conditioning radwastes, to store or to dispose of packages are well adapted to the present situation. Interim storage of CSD-V and CSD-C packages is an industrial operation in large facilities that can be extended as needs will appear (2015 for CSD-V) and which can last 100 years without refurbishing. All packages resulting from 40 years of electricity production can be accommodated on around 7000 m^2.

The life of the La Hague reprocessing plant is expected to end around 2030-2040. The next reprocessing plant should be an "Integrated Treatment Recycling" plant with MOX fuel preparation, as it is anticipated world-wide for "Generation IV reprocessing plants" if necessary. The present plant is, and will be, in continuous improvements to follow the increase in BU of UOX/MOX SF (processing, engineering, conditioning of radwastes to minimise the ratio CSD-V/ton SF) and to reduce costs. There are programme to improve MOX performances (microstructure of blended oxides, addition of Cr_2O_3, new cladding)

URT fuel must be over enriched compared to UOX (at 4% versus 3.7%) to take into account the presence of U236, which capture thermal neutrons. It contains U232 (72 y) coming from Pu236 decay (2.85 y), which follows U235 in gaseous diffusion. The future French enrichment plant will enrich Urep.

A "Research and Development" programme is in progress. An immediate interest is to look at the possibility to manage together U and Pu (which make reprocessing proliferation resistant). Such management is presently included in the Japanese Rokkasho-Mura plant where U and Pu will be co-precipitated to oxide. It is also envisaged in the last US programme GNEP (Global

Nuclear Energy Partnership) where reprocessing plants are considered, but without getting pure Pu. Areva studies the COEX (co-extraction) process in the perspective to contribute to the design of the next future reprocessing plants. USA market is of interest, this country being reconsidering its back end fuel cycle policy (which lies today on direct disposal of SF).

For the future of nuclear energy in the perspective of "Generation IV reactors", research in aqueous reprocessing is also mandatory to manage together U, Pu and all minor actinides for their recycling-burning in FNR. Flexibility of the future reprocessing processes is aimed at adapting reprocessing to the needs of reactors (fuel fabrication mainly) and at fulfilling as far as possible the GIF (Generation IV International Forum) criteria. Pyrochemical processes will be also studied to process quickly very active materials that could appear in transmutation steps of actinides, following pilot experiments in USA (EBR2 where SF was Uenr at 45 %, Pu 0.1% FP 5%) or in Russia (MOX SF).

If the long-term management of Pu is secured, it is to say if its fate is clearly identified over one or two centuries (recycling) present reprocessing can be considered to help geological disposal. Indeed extension and cost of a disposal depends on two limiting factors, volume for ML-LLW and heat for HL-LLW, because the temperature in the host rock must be kept below 100 °C. Compared to direct disposal of SF it is clear that reprocessing fulfil volume criteria. Any improvement in reducing the volume of ML-LLW is a bonus. With regard of heat criteria the elimination of Pu contributes to decrease the release of heat over thousands of years. The gain in space depends of the rock. In clay it could be up to 60 % if all UOX and MOX SF would be reprocessed. A quicker reprocessing after unloading of SF would lower the quantity of one of its daughter Am241 (heating isotope over centuries) in HL-LLW packages adding a reducing factor of 2 to the gain in space. A better reprocessing leading to the separation of all actinides and short-lived heating fission products (Cs and Sr) would give a factor 10. Of course that means that P&T strategy would have been implemented.

Reprocessing is a key issue of the future of nuclear energy. Since the dispositions of GIF several initiatives have appeared to which France has plans to contribute. The GNEP organisational programme, launched in 2005 by USA, proposes to complete the objectives of GIF as follows. In the short term : encourage launching of new reactors particularly for developing countries (low power reactors), in the long term : develop new technologies proliferation resistant, for recycling Pu and other actinides and develop advanced burners of Pu and actinides. For both actions it is proposed to set up an international system of nuclear services (enrichment, reprocessing) under international control. The USA "Advanced fuel cycle initiative" programme (AFCI) has the objective to develop technology of reprocessing, to which France could contribute

4.3. Main restrictions and uncertainties

All the French radwastes are well identified (except some sealed sources) and foresights on radwastes packages production are reasonably correct in the framework of the continuation of the present nuclear activities and of the programmes of conditioning for the" non-conditioned" radwastes. Coherent technical and administrative channels of management with end-solution for the long term are operating, or are identified. Responsibilities in management are defined. There are many regulation requirements to assume radiological safety. France seems presently in the front line with regard to political and administrative aspects of radwastes management since June 2006. So the main uncertainties for radwastes management lie in the real possibilities of implementation. They depend of many economical factors

If radioactive matters not considered today as radwastes, like the different kinds of uranium, would change of status in the future new channels of management will be necessary for these matters.

The first French LML-SLW disposal (CSM) has opened in 1969. During the first years rules to accept LML-SLW were not so strict as they were later. Some packages containing quantities of long-lived radionuclides higher than those allowed today have been accepted. Packages easy to retrieve have been taken out of the repository before its closure. Safety case analysis before to start a monitoring period has shown a low radiological risk at long term. NSA has authorized the disposal of the remaining packages, difficult to retrieve, balancing the radiological and economical costs of the operation.

4.4. R+D needs. Generation of technology and knowledge

The needs on R and D are directly linked with the statements of the 2006 law.

4.5. Safety and licensing

As previously said safety and licensing are in charge of NSA.

5. Costs and financial aspects

For all radwastes including radwastes the principle "Polluting-Paying" is applied. The producer of a radwaste must pay for its elimination if there is a channel management including interim storage if needed. The 2006 law secure financing for back end nuclear cycle radwastes and decommissioning-dismantling radwastes. If there is an impossibility to pay (legacy radwastes for instance) specific public funds can be exceptionally called for (state budget). The problem is for radwastes without presently end-solution, which are in interim storage. The period of storage is not defined. According the 2006 law Andra, a public agency, is now in charge of storage. Question of financing is under consideration. Andra is also in charge of radwastes without owners or non-solvable owners. There are few radwastes with these statuses.

Cost of radwastes management is higher than cost for non-radioactive wastes and increases with the nocivity of radionuclides contained. They must be fully characterised and that contributes to an important part of the cost.

The cost of the back end fuel cycle, the conditioning of historical radwastes, the dismantling of facilities and the facilities for geological disposal are estimated to 60 Billions of Euros

6. Social, public opinion and communication aspects

As in other countries the public appreciation on radwaste (and on the use of nuclear energy in general) is controversial. There are opposite positions between anti-nuclear people and nuclear technocrats. The main points in debate are: civilian nuclear has kept practices of the military nuclear activities, very low risk can have tremendous consequences as shown by Chernobyl accident, waste management lead to low doses of which effect on long term are difficult to understand, reprocessing opens ways to radioactive terrorism. Local oppositions on potential disposal of radwastes are sometimes intense. Recent opinion inquiry shows that public has no confidence in the official information on radwaste. Real efforts, but too recent, have been done to give an objective information on nuclear problems, but in general the dialogue is difficult to be established.

Debates on energy in 2003 aimed at preparing a "law on energy" included debate on nuclear energy (and radwastes) but only pro-nuclear people went in tribune. The law was passed in 2005. The first large debate on radwastes occurred in 2005 (September 2005 to end of January 2006). It was asked by the government to prepare the 2006 law. All documents coming from all partners (institutional bodies as well as non governmental organisations) were carefully prepared since April 2005. The evening debates, lasting hours, in several places interested to known about radwastes were followed by more or less people depending the topic considered. Nevertheless all arguments, for and against a given solution for management of nuclear wastes (P&T, geological disposal, storage) and other radwastes have been clearly expressed and directed to the government.

The learning's of these debates are the following ones. It was clear that people want to be "secured" and not "reassured", and they asked the major question: how can we have confidence about management of a litany of radwastes ?.Four main points emerged from the debate, centred on time, consensus, territories and reversibility. It was understood and acted that technological, industrial and economical uncertainties push back P&T after 2050, that we have time to take a decision on geological disposal (interim storage is secure, experiments have to be continued at Bure, sociological problems are not solved) and that the next milestone could be 2020. Every people agrees to take into account all radwastes and other radioactive matter which could be categorised as radwaste in future, to consider radwastes management in the context of nuclear energy extension or recession, to evaluate all risks including proliferation, to look at management and milestones in a coherent way, to improve inventory and "PNGDR-MV", to separate expertise and control, to come to a voluntary and active participation of public (declassify documents, pluralist expertise at each level, access to information). With regard to sitting installations all people agree to change economic subvention to real local development (increase of employment and demography) with the support of nuclear companies and government. Reversibility of disposal of radwastes drives acceptability and reconciles ethic and transmission of charges to next generations but this statement is difficult to understand. Is its objective a politic alibi or is it really coming from the precautionary principle? Which is the target : conditioning or packages? Is P&T necessary included in reversibility? How long does it will stand, one century or several centuries after periodical reconsideration?. Can long term storage turned out to indefinitely storage? The final positions of people were contrasted: "stop to make radwastes and we will speak after" or "decide to go to disposal of LLW " or in between "take time to study disposal and storage and decide later". Sometimes people with opposite positions came to the same conclusion ecologists people and financing people are for interim storage as long as possible, vertuous people and making business people are for disposal

Conclusion

The production and the nature of radwastes in France will stand as it is for a long time according to French nuclear energy policy and the technical possibility to launch new "nuclear systems " which could qualitatively change waste packages (P&T foreseen in 2050 at the best case). More than 96 % of the total activity of SF will go in glass packages for the present nuclear fleet of reactors. For other radwastes not directly connected with electricity production the situation will remain more or less the same as today.

French situation in radwastes management is under the control of NSA. For the short term there are channels to eliminate most of the LML-SLW, exceptions are mainly the LML-SLW containing T and some sealed sources and devices based on ionising radiations. A technical end-solution for ML-LLW (radium radwastes and graphite) has been set-up. A ground level disposal site has to be found to implement it. MLL-LLW and HA-LLW coming from reprocessing are the main concerns for future. They are presently kept in interim storage facilities that can last as long as one century. The deep clay layer (Callovo-Oxfordian) investigated at Bure, in the framework of the 1991 law, shows adequate properties for a long lasting confinement of the most mobile radionuclides. The 2006 law statements are aimed at sitting a geologic repository in this formation.

References

Webb sites on radwastes management

MINEFI – DGEMP. Information on nuclear energy and radwastes
http://www.industrie.gouv.fr/energie/nucleair/f1e_nuc.htm

MINEFI – DGEMP ; Law passed on December 30, 1991
http://www.industrie.gouv.fr/energie/nucleair/f1e_nuc.htm

MINEFI – DGEMP. File on the law passed on June 28, 2006 (preparation, debates)
http://www.industrie.gouv.fr/cgi-bin/industrie/frame23e.pl?bandeau=/energie/nucleair/be_nucle.htm&gauche=/energie/nucleair/me_nuc.htm&droite=/energie/nucleair/debat-2006/projet-loi-dechets.htm
(include links particularly to definitions)

Parliament, legislative file
http://www.assemblee-nationale.fr/12/dossiers/gestion_dechets_radioactifs_programme.asp

Sénat, legislative file
http://www.senat.fr/dossierleg/pjl05-315.html

L'Office parlementaire d'évaluation des choix scientifiques et technologiques (reports on waste ma,agement since 1990):
http://www.senat.fr/opecst/index.html

National commission on public debates
http://www.debatpublic.fr/

Specific commission on public debates on radwastes
http://www.debatpublic-dechets-radioactifs.org/

Le CLIS underground laboratory sitted in Bure
http://www.clis-bure.com/

Nuclear safety authority
http://www.asn.gouv.fr/

IRSN, Institute for nuclear safety and radioprotection :
http://www.irsn.fr/

Andra
www.andra.fr

Andra – National inventory (2006)
http://www.andra.fr/popup.php3?id_article=820

Andra ; 2005 file (reports on researches with many links)
http://www.andra.fr/interne.php3?id_rubrique=160

CEA ; Radwastes, reports on researches (with many links)
http://www.cea.fr/fr/sciences/dechets_radioactifs/

CEA – Marcoule (this site is particularly interesting for radwastes)
http://www-marcoule.cea.fr/

CEA – CLEFS n° 53 (Radwastes)
http://www.cea.fr/fr/Publications/clefs2.asp?id=53

CEA – Site for references
http://cat.inist.fr/

CNRS. PACE programme on back end electronuclear cycle
http://www.cnrs.fr/DEP/prg/pace.html

Le GDR FORPRO
http://www.forpro.org/

Le GDR MOMAS
https://mcs.univ-lyon1.fr/MOMAS

Site of NEA OCDE on radwaste management
http://www.nea.fr/html/rwm/welcome.html

AREVA – NC. Files on nuclear cycle and radwastes:
http://www.areva-nc.fr/servlet/ContentServer?pagename=cogema_fr/html_libre/html_libre_full_template&c=FreeHtml&cid=1032779988065

EDF. File on radwastes
http://www.edf.fr/70208i/Accueilfr/InfosNucleaire/Santeetenvironnement/Lesdechetsradioactifs.html

SOCODEI :
http://www.socodei.fr/

Association "Centre for evaluation on protection in nuclear concerns"
http://www.cepn.asso.fr/

« La radioactivité.com »
http://www.laradioactivite.com/

French society on nuclear energy
http://www.sfen.org/

National coordination against disposal of radwastes (many documents)
http://burestop.free.fr/

Local association (elected people from Meuse and Haute-Marne) against Bure laboratory.:
http://www.stopbure.com/

Network of "Phase out of nuclear energy"
http://www.sortirdunucleaire.org/

Radwaste and citizens – GRAINE Poitou-Charente :
http://dechetsradioactifs-citoyennete.org/

Study of future energy issues: UK situation

A. Duncan

3

1. General overview

1.1. Nuclear programme

The UK was involved in the earliest developments of nuclear technology in the 1940s and 1950s. It has a wide range of plant and equipment that has now served its purpose and needs to be decommissioned and dismantled. This includes R&D facilities for chemical processing, uranium and plutonium production, isotope separation, nuclear fuel fabrication, etc. as well as research reactors, critical assemblies, materials research reactors and various designs of experimental and demonstration reactors, including two sodium or sodium/potassium-cooled fast breeder reactors, a heavy water reactor and a high temperature reactor with special fuel. In addition, it has facilities associated specifically with nuclear weapons production and with naval nuclear propulsion systems. Consequently, and although individual facilities may be relatively small, this inventory of historic facilities gives rise to a complex range of nuclear wastes, whose management is complicated in some cases by the presence of non-radioactive, hazardous substances such as asbestos, and by the fact that some original documentation for older facilities is difficult to retrieve.

Commercial nuclear power generation started in 1956 with the first of a series of Magnox reactors. Initially, these were small dual-purpose plants, combining power generation with plutonium production for military purposes, but they were later modified to provide only power. Subsequent Magnox reactors, up to ten times larger, were optimised for continuous electricity production. They use natural uranium metal fuel in a magnesium alloy cladding, are graphite moderated and are cooled with carbon dioxide gas. In all, 26 Magnox units were built on 11 sites in the UK. The second generation of reactors is based on the Advanced Gas-cooled Reactor (AGR), a prototype of which started up at Windscale in 1962. A total of 14 such units were built on seven of the existing Magnox sites and started up between 1976 and 1989. They are also graphite moderated and carbon dioxide cooled, but use enriched uranium oxide fuel in stainless steel cladding. The third generation comprises a single large Westinghouse Pressurised Water Reactor (PWR), which started up in 1995.

There are currently 8 Magnox units remaining in operation, together with the 14 AGRs and the single PWR, i.e. 23 units in all, totalling 11,852 MWe generating capacity and accounting for 20% of UK electricity production in 2005. Of the 8 Magnox units, only 4,on two sites, will remain in operation after the end of 2006.

In addition, this commercial nuclear power programme is supported by a full range of fuel cycle facilities comprising uranium conversion, enrichment, fuel fabrication, spent fuel reprocessing and residues recovery, located in the north-west of England at Springfields, Capenhurst and Sellafield. These facilities also supply fuel cycle services to overseas customers.

1.2. Waste categorisation

The UK system of waste categorisation covers all of the radioactive wastes arising from the development and use of nuclear power to generate electricity, together with those from the nuclear weapons and nuclear-powered submarine programmes, and those arising from the use of radioactive substances in industry, research and medicine. The categories are as follows:

- ***High Level Wastes (HLW)***

Wastes in which the temperature may rise significantly as a result of their radioactivity, so that this factor has to be taken into account in the design of storage or disposal facilities.

HLW comprises the waste products from reprocessing spent nuclear fuels. These waste products arise in the form of highly radioactive nitric acid solutions, and are being converted into borosilicate glass contained in stainless steel canisters.

- ***Intermediate Level Wastes (ILW)***

Wastes exceeding the upper limits for Low Level Wastes, but which do not need their heat generation to be taken into account in the design of storage or disposal facilities.

The major components of ILW are metal items such as nuclear fuel cladding and nuclear reactor components, moderator graphite from reactor cores, and sludges from the treatment of radioactive effluents. Such non-heat generating waste is stored in tanks, vaults and drums. In time it will be retrieved, and packaged by immobilisation in cement-based materials within stainless steel drums or, for large items, in higher capacity steel or concrete boxes.

- ***Low Level Wastes (LLW)***

Wastes containing radioactive material other than those acceptable for disposal with ordinary refuse, but not exceeding 4 gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity. (The limits for disposal at the LLW disposal facility at Drigg, in Cumbria.)

Most LLW can be sent for disposal at the Drigg facility. Most of the LLW unsuitable for disposal at Drigg is reflector and shield graphite from reactor cores, which contains concentrations of carbon-14 above those acceptable in that disposal facility.

- ***Very Low Level Wastes (VLLW)***

Wastes which can be safely disposed of with ordinary refuse, each 0.1 cubic meters of material containing less than 400 kilobecquerels (kBq) of beta/gamma activity or single items containing less than 40 kBq of beta/gamma activity.

This category is intended for use in disposal of small quantities of waste that might fit into a dustbin, hence the commonly used term 'dustbin disposal'. It is not intended for the large quantities of lightly contaminated material that might arise from reactor dismantling or site clearance, for example.

- ***Surplus Plutonium, Uranium and Spent Fuel***

In addition to the above well-established categories of waste, consideration is currently being given to the implications for waste management if some or all of the UK accumulations of nuclear materials are declared as surplus to requirements, and classified as wastes. These materials include plutonium, uranium and spent fuel.

Plutonium is created as a by-product in nuclear reactors. It is separated from spent nuclear fuel by reprocessing. Separated plutonium can be used in fabrication of fresh nuclear fuel and in nuclear weapons. It is currently stored as an oxide powder.

Uranium is recovered during spent fuel reprocessing and can also be re-used in fresh nuclear fuel and in nuclear weapons. Depleted uranium (i.e. with less than the natural content of the isotope uranium-235.) has some commonplace uses, such as for counterweights in aircraft. Most of the uranium stockpile is stored either as gaseous uranium hexafluoride or as an oxide powder.

Spent nuclear fuel is nuclear fuel that has been irradiated in a nuclear reactor. It can be reprocessed to recover plutonium and "unburnt" uranium or managed in some other way. It is comprised mainly of uranium oxide, and contains the waste fission products and higher actinides created during its irradiation. Like HLW, spent nuclear fuel is intensely radioactive and generates heat.

1.3. Waste generation

A baseline inventory of radioactive wastes and potentially surplus materials has been established for the purpose of formulating recommendations for long-term waste management in the UK. It is based on the following main assumptions.

- All Magnox reactors are shut down by 2010; AGRs operate for up to 35 years, with the last shutdown in 2023; Sizewell B PWR operates for 40 years and is shut down in 2035; and no new nuclear power reactors are constructed.
- All Magnox spent fuel is reprocessed; AGR spent fuel and overseas Light Water Reactor spent fuel, covered by existing contracts, is reprocessed; and Pu, U and HLW arising from overseas fuel will be returned to customers, with an equivalent amount of HLW to substitute for their ILW and LLW, which will be retained in the UK.

- Surplus nuclear material declared as waste will include all of UK stockpiles of separated plutonium and uranium, AGR spent fuel not covered by existing reprocessing contracts, and all the Sizewell B PWR fuel.

The following table gives the volume and radioactivity of packaged waste. The volume estimates are based on assumptions as to how waste, including spent fuel, will be packaged for long-term management, including disposal. For certain types of wastes, such as the surplus nuclear materials, there are substantial uncertainties about the nature of the treatment and packaging processes, the degree of volume change and the type of container used. All these could affect the packaged volume, although the quantity of radioactivity will remain unchanged. These uncertainties are in addition to the obvious uncertainties arising from deviation from the main assumptions above, particularly as regards the future of nuclear power, and from decisions still to be made about nuclear plant decommissioning strategies, segregation and decay storage of waste, decontamination and recycling, etc. (For example, if it was decided to extend the UK nuclear power programme and to build a series of PWRs, it would be possible to utilize surplus Pu in Mixed Oxide Fuel.)

Category	Packaged Volume (Cubic metres)	Radioactivity (Terabequerels)
HLW	1,290	39,000,000
ILW	353,000	2,400,000
LLW (unsuitable for Drigg) *	37,200	< 100
Plutonium	3,270	4,000,000
Uranium	74,950	3,000
Spent Nuclear Fuel	8,150	33,000,000
Total	**477,860**	**78,000,000**

* Current plans for ordinary LLW disposal foresee construction of a further 700,000m^3 capacity by 2050, but current estimates suggest that this will still be insufficient to accommodate the LLW arising from decommissioning and clean-up activities. LLW management is the subject of a current government review.

1.4. Present situation and foresights

Power programme

There have been no new reactors built or planned in the UK since start-up of the Sizewell B PWR in 1995. Since then, the public and political climate has been consistently hostile to any consideration of new reactor construction, a factor which may have contributed indirectly to lack of progress on implementation of waste disposal. A government Energy Policy paper in 2003 did not foresee any such construction, but did not rule it out completely. An Energy Review, published in July 2006, however, examined the UK's progress against the medium and long-term goals of that 2003 policy paper, and considered options for further steps to achieve them. The Government's immediate response, in regard to nuclear power, is best described by the following extract from the associated Ministerial statement.

"Against a background where Britain's nuclear power stations are ageing, decisions will have to be taken on their replacement in the next few years. If we do nothing, the proportion of electricity generated by nuclear will fall from just under 20% today to just 6% in 15 years time. And nuclear has provided much of the electricity base-load, contributing to consistency of supply as well as security of supply.

Whilst some of that capacity can and should be replaced by renewables, it is more likely than not, that some of it will be replaced by gas which would increasingly have to be imported. The Government has concluded that new nuclear power stations could make a significant contribution to meeting our energy policy goals.

It will be for the private sector to initiate, fund, construct and operate new nuclear plants and cover the cost of decommissioning and their full share of long-term waste management costs."

A new Energy Policy paper will follow in due course, but it is expected that any reference to new nuclear construction will put the onus firmly on the private sector. It remains to be seen if the current obstacles, arising by way of the physical planning and licensing processes, will be eased by application of these processes to a 'class' of plant, as opposed to each plant individually. This, and other issues concerned with economic incentives for renewable sources of power, and difficulties with waste management, for example, will undoubtedly influence the views of the private sector. It may well be that further construction will only happen when Government takes a more pro-active role, perhaps under pressure from a public increasingly concerned about the cost and availability of electricity.

Waste management and decommissioning

The present-day situation is influenced most of all by the creation in recent years of the *Committee on Radioactive Waste Management (CoRWM)* and a new *National Decommissioning Authority (NDA).* Since 1982, until creation of the NDA, responsibility for developing and implementing new arrangements for disposal of ILW and LLW fell to the *Nuclear Industry Radioactive Waste Management Executive (Nirex).* The Government retained responsibility for developing arrangements for eventual disposal of HLW, but postponed substantive work on the basis of a policy intention to store it for at least 50 years for decay of its thermal power. Waste producers remained responsible for treatment, packaging and storage of their own wastes, but were required by regulators, in the case of ILW, to provide evidence of assurance from Nirex that their proposals were consistent with Nirex plans for its disposal. However, against a background of hostility from coalitions of local government, citizen protest movements, Non-Governmental Organisations (NGOs) and the media, various attempts by Nirex to obtain sites for ILW and LLW disposal failed. This culminated in 1997 in rejection of a physical planning application for a Rock Characterisation Facility (i.e. underground laboratory) near Sellafield in Cumbria.

In November 2003, after a period of reflection, the UK Government and the Devolved Administrations (in Scotland, Wales and Northern Ireland) set up the independent committee, the *Committee on Radioactive Waste Management*, to oversee a review of options for the long-term management of HLW and ILW in the UK. The Committee's remit was to review and recommend the best option, or combination of options, for the long-term management of the UK's higher activity wastes. The process of review was required to engage members of the UK public, and provide them with the opportunity to express their views. Other key stakeholder groups with interests in radioactive waste management were also provided with opportunity to participate. CoRWM published their report in July 2006 and the UK Government and the Devolved Administrations intend to respond to their recommendations later in 2006. The CoRWM considerations led to a set of interdependent proposals that recommend:

(1) Geological disposal as the end state;

(2) The vital role of interim storage; and

(3) A new approach to implementation based on the willingness of local communities to participate, partnership and enhanced well-being.

The Committee also suggested that these proposals form a basis for Government to act upon without delay. It remains to be seen how, and how quickly, the UK Government and Devolved Administrations will respond, and move towards implementation of the technical options, which are just as has been foreseen by the nuclear community, in the UK and elsewhere, for more than 20 years.

Most radioactive waste in the UK has been produced by the nuclear power station operators, British Nuclear Fuels plc (BNFL) and British Energy, (BE), and the fuel cycle establishments which serve them. A substantial amount arises from the nuclear research and development sites of the United Kingdom Atomic Energy Authority, (UKAEA), most of which are now in the decommissioning phase. Some comes from Ministry of Defence programmes and small amounts are produced by medical, industrial and educational establishments. Radioactive wastes from the civil nuclear facilities of BNFL and UKAEA, until recently, were owned and managed by the facilities themselves. The Government believed, however, that the scale and nature of the task required a much sharper and stronger strategic focus. This led to the establishment of the Nuclear Decommissioning Authority by way of the Energy Act 2004.

Ownership of the civil public sector nuclear sites now rests with the NDA. It became fully operational from 1 April 2005. It is responsible for the transfer, from BNFL and UKAEA, of the UK's public sector civil nuclear liabilities and their subsequent management. (i.e. excluding those of the Ministry of Defence, British Energy and other private sector bodies.) It is a public body, acting on behalf of Government, and works in partnership with site licensees (i.e. UKAEA and BNFL), and the safety, security and environmental regulators, for the most effective and safe means of discharging the liabilities. It is expected to provide the first ever UK-wide strategic focus on decommissioning and clean up of nuclear sites. It represents the biggest change to the structure of the UK nuclear industry in the last 35 years and has a current budget is around £2bn a year. As regards the future, the NDA is committed to delivering safe, cost-effective, accelerated and environmentally responsible decommissioning of the UK's civil nuclear legacy. This will be done in an open and transparent manner, with due regard to the socio-economic impacts on its communities and to securing best value for the taxpayer.

1.5. Nuclear power plant dismantling

A number of experimental or prototype power reactors have been in the process of dismantling in the UK for some years now. These include a prototype advanced gas cooled reactor at

Windscale in Cumbria, a prototype fast reactor at Dounreay in Scotland, and a heavy water reactor and a high-temperature, helium gas cooled reactor at Winfrith in Dorset. These are individual projects that have been used in part to develop and test decommissioning, dismantling and decontamination techniques but they are not in the mainstream of commercial NPP decommissioning and dismantling.

As regards the UK commercial NPPs, and as mentioned in the context of waste generation, it is assumed that the Sizewell B PWR will operate for 40 years and be shut down in 2035, that the AGRs will operate for up to 35 years, with the last shutdown in 2023, and that all Magnox reactors will be shut down by 2010. Currently, seven Magnox power stations, comprising 18 reactor units, are shut down and are at various stages of defuelling or decommissioning. The fuel from the reactors is sent to BNFL, Sellafield for reprocessing. Apart from dealing with operational ILW and the arrangements for the disposal of LLW, most of the remaining work is concerned with decontaminating and dismantling buildings and other structures in preparation for an extended period of care and maintenance.

The current strategy adopted by the NDA for decommissioning the Magnox reactor sites after defuelling involves:

- 20 to 25 years to reach the stage of care and maintenance;
- 80 to 100 years in care and maintenance; then,
- Dismantling and final site clearance.

One alternative to this strategy currently being considered is to reduce the time taken to reach the care and maintenance stage to as little as five years. However, it may also be possible to bring forward the dismantling stage and to achieve final site clearance within a much shorter overall timescale. It has been noted that EDF, the French nuclear power station operator, has adopted a 25 year overall timescale for the decommissioning of its gas-cooled reactors. Under this approach, the ILW from reactor dismantling would be stored until long-term waste management arrangements are available. The benefits foreseen from accelerating the decommissioning of Magnox, and indeed other, reactor sites include:

- Better use of the knowledgeable existing workforce, and associated socio-economic benefits for the local area;
- Not leaving final site clearance for future generations;
- Earlier availability of the site for other uses;
- Fewer ILW interim stores needed with consequential cost savings, e.g. if regional or national storage was selected;
- Visible signs of decommissioning and clean-up, including reductions in visual impact; and mitigation of the potential threat from coastal erosion and climate change at a number of sites.

However, to implement such an approach successfully in ways that protect people and the environment, a number of issues need to be addressed. These arise mainly from the reduced period available for radioactive decay before final decommissioning and include:

- Availability of agreed waste routes;
- Processing waste of higher activity with the potential to increase discharges;
- Handling larger quantities of radioactive waste in each activity category;
- The need for further controls to limit worker radiation exposure, including remote handling technologies.

In order to explore these issues further, NDA and EDF have a Mutual Cooperation Agreement for sharing know-how, R&D and technological developments.

2. Institutional framework

2.1. Legislation and policy

Legislation and overall policy for radioactive waste management in the UK is the responsibility of the Department for the Environment, Food and Rural Affairs, (Defra) and the Devolved Administrations. Defra, the Scottish Executive, the Welsh Assembly Government and the Department of Environment in Northern Ireland are responsible for legislation and policy relating to radioactive waste in England, Scotland, Wales and Northern Ireland, respectively. Environment Ministers are accountable to their respective Parliaments or Assembly for radioactive waste policy in their areas of the UK, except that the Secretaries of State for Trade and Industry and for Defence remain accountable for the management of radioactive wastes kept or stored at civil and defence-related nuclear licensed sites in England, Wales and Scotland.

Other Departments such as the Department of Health, and the Food Standards Agency also have a close interest, as does the Health and Safety Executive (HSE) and the Environment Agency (EA) for England and Wales, the Scottish Environment Protection Agency (SEPA) for Scotland and the Chief Radiochemical Inspector of the Environment and Heritage Service (EHS) for Northern Ireland.

2.2. Advisory bodies

Committee on Radioactive Waste Management (CoRWM) and the Radioactive waste Management Advisory Committee (RWMAC)

As noted above, CoRWM was set up in 2003 by the UK Government and the Devolved Administrations specifically to oversee a review of options for the long-term management of high and intermediate level radioactive solid wastes in the UK.

RWMAC operated until March 2004 and advised UK Government and the Devolved Administrations on a much wider range of issues concerned with radioactive waste management policy and its implementation. With the creation of CoRWM, RWMAC was put into abeyance. At that time, Government and the Devolved Administrations said that they would review the radioactive waste management advisory machinery when CoRWM had completed its work. CoRWM has now reported, the formal response is awaited and it remains to be seen whether RWMAC will be reinstated or some other body created.

Nuclear Safety Advisory Committee (NuSAC)

NuSAC is an independent advisory committee to the Health and Safety Executive (HSE). It advises HSE on matters which are referred to it or which it considers require attention regarding nuclear safety policy and its implementation at nuclear installations. These matters include the on-site management of nuclear waste and the balance of the HSE nuclear safety research programme.

Committee on Medical Aspects of Radiation in the Environment (COMARE)

COMARE was established in November 1985 to assess and advise Government and the Devolved Administrations on the health effects of natural and man-made radiation in the environment and to assess the adequacy of the available data and the need for further research.

Health Protection Agency's (HPA) Radiation Protection Division (Previously the National Radiological Protection Board)

In 2005, the National Radiological Protection Board merged with the HPA and formed a new Radiation Protection Division. Together with the Chemical Hazards and Poisons Division of HPA it forms the Agency's Centre for Radiation, Chemical and Environmental Hazards. The division undertakes research to advance knowledge about protection from the risks of ionising and non-ionising radiations; provides laboratory and technical services; runs training courses; provides expert information and has a significant advisory role in the UK.

Ionising Radiations Health and Safety Forum (IRHSF).

IRHSF provides a liaison mechanism between the Health and Safety Executive and stakeholders on matters concerning protection against exposure to ionising radiations that are relevant to the work of the Health and Safety Executive, and to identify significant issues for future action.

Nirex

Under new arrangements, Nirex has become independent of the nuclear industry. It is owned jointly by Defra and the Department for Trade and Industry, and is mainly funded by the NDA. Its several roles include:

- Advising the organisations and companies that produce radioactive waste on how they should package the waste.
- Advising on the standards for radioactive waste packaging.
- Producing, with Defra, an updated public record of the quantities and types of radioactive waste that exist in the UK.
- Continuing to develop its understanding of the options for dealing with radioactive waste.

2.3. Legal framework and enforcement

Radioactive Substances Act 1993 (RSA 93)

The Radioactive Substances Act 1993 (RSA93) is the main legislation governing the use of radioactive materials and radioactive waste management and disposal in the UK, except for on-site management of radioactive materials and waste on nuclear licensed sites. Under the RSA 93, disposal of radioactive waste including airborne and liquid discharges from any site, including licensed nuclear sites, requires an authorisation under this Act, unless exempted directly by the Act or by way of an Exemption Order. Control under the Act is exercised in England and Wales by the Environment Agency (EA), in Scotland by the Scottish Environment Protection Agency (SEPA) and in Northern Ireland by the Chief Radiochemical Inspector of the Environment and Heritage Service (EHS), in the Department of Environment.

Where an application is made for disposal of radioactive waste on or from a nuclear licensed site, the relevant Agency is required to consult the Food Standards Agency (FSA) and the Nuclear Installations Inspectorate of HSE before deciding whether to grant an authorisation and, if so, subject to what terms and conditions. EA, SEPA, EHS and the FSA conduct regular surveys of the UK terrestrial and marine environments to show that the radiological impacts of discharges are within the appropriate limits.

The Office for Civil Nuclear Security (OCNS), which is part of the Department of Trade and Industry (DTI), is responsible for regulating security arrangements at civil nuclear sites. This is primarily in order to protect against the threats of terrorism and nuclear proliferation. The Radioactive Materials Transport Division (RMTD) of the Department for Transport (DfT) regulates the transport of nuclear waste throughout Great Britain. It is responsible for regulating the packaging, labelling and vehicle marking standards for radioactive material carried by road. The Food Standards Agency (FSA) is a non-ministerial government department and reports to Parliament via Health Ministers on the food safety implications of discharges of radioactive waste.

Health and Safety at Work etc Act 1974 and Nuclear Installations Act 1965

The main legislation covering the health and safety of workers and the general public at nuclear installations in the UK is the Health and Safety at Work Act 1974 (HASAWA 74) and its Relevant Statutory Provisions, which include the Nuclear Installations Act 1965 (NIA65).

The HSE regulates spent fuel management and radioactive waste management, but not disposal, on all the nuclear licensed sites in the UK. The safety of operational nuclear facilities in the UK, including those for waste treatment and storage, is regulated by way of the Nuclear Installations Act 1965 (as amended) and general requirements of the HASAWA 1974. The HSE has regulatory responsibility in England, Scotland and Wales and has delegated the licensing authority for nuclear installations to its Nuclear Installations Inspectorate (NII). There are no nuclear sites in Northern Ireland. The NIA 65 requires organisations to obtain a nuclear site licence from the HSE before using a site for licensable activities. It also enables HSE to attach conditions to any license in the interests of safety and for handling nuclear matter. Before issuing such conditions, the NII is required, by way of Memoranda of Understanding, to consult the relevant environment agency on the radioactive waste management implications of any proposals for new plant or activities.

Monitoring arrangements

For nuclear sites, the environment agencies place statutory obligations on operators to carry out defined monitoring programmes, both for discharges and for environmental radioactivity. Site operators are required regularly to assess all radioactive discharges, ensure that the authorised discharge conditions are met, monitor the local environment and report the results to the relevant environment agency. These monitoring results are also published in separate company reports. In addition, the EA monitors radioactivity in the environment for England and Wales, SEPA monitors radioactivity in the environment for Scotland and the Chief Radiochemical Inspector monitors the impact of nuclear discharges into the Irish Sea on the Northern Ireland coastline.

The Food Standards Agency (FSA) has an aquatic and terrestrial radioactivity surveillance programme around nuclear licensed sites in England and Wales, to monitor radioactivity in food. The FSA programme is fully independent of all other government departments, local authorities and industry. The results of all regulatory monitoring of discharges and environmental radioactivity undertaken in the UK, are published in one report, 'Radioactivity in Food and the Environment' (RIFE). The RIFE monitoring programme is lead by the FSA.

Shipments of radioactive wastes and materials also have to comply with transport regulations, which entails monitoring before departure and on arrival. The consignor and recipient of the wastes are responsible for the goods and their safe carriage. The Radioactive Materials Transport Division (RMTD) of the Department for Transport (DfT) monitors the process.

3. LLW and ILW management

3.1. Low Level Waste (LLW) management

LLW represents about 90% by volume of radioactive waste from UK nuclear facilities. The major components are soil, metals and building materials. Laboratory equipment, clothing, paper towels and graphite, from gas-cooled reactors, are also present. There are smaller quantities of glass and ceramics and other miscellaneous inorganic materials. After incineration or compaction to reduce its volume, LLW is sent to a shallow repository at Drigg in Cumbria where most of the UK LLW is disposed. LLW that is not suitable for disposal at Drigg is kept in storage where it arises until the disposal policy for long-lived waste has been decided. There is also a disposal facility for LLW at Dounreay, in Scotland, which is owned by the United Kingdom Atomic Energy Authority (UKAEA), but this is now effectively full and a further facility is currently under consideration.

The Drigg disposal facility is owned by the Nuclear Decommissioning Authority (NDA) and is currently operated under contract, as a national LLW facility, by British Nuclear Group Sellafield Ltd. (One of the subsidiary companies held by BNFL.) It accepts waste, not only from nuclear sites, but also from hospitals, research and other facilities using radioactivity. LLW for disposal is usually packed in high-force compacted form into special ISO freight containers and emplaced in concrete-lined vaults. The plan is to cement waste in place when the vault is full and cover it with soil. The Environment Agency has recently amended the authorisation for disposals at the site, having regard to coastal erosion amongst other things, and after consultation with local residents. It is currently reviewing the remaining capacity of the facility.

As regards future availability, the NDA and site operators such as UKAEA, as well as advisory committees such as RWMAC and CoRWM, have already pointed out that a clear UK policy is required for the management of the very large quantities of solid LLW arising from decommissioning for example. Against this background, the UK Government and the Devolved Administrations are undertaking a review of LLW management policy.

3.2. Intermediate Level Waste (ILW) management

Much of the UK ILW arises from the dismantling and reprocessing of spent fuel and consists mainly of metals, with smaller quantities of organic materials, inorganic sludges, cement, graphite, glass and ceramics.

At present there is no facility in the UK for the long-term management of ILW. Specially designed, interim, surface or sub-surface facilities are currently used to ensure its safe storage pending the availability of a long-term management / disposal option. Most of it is stored at the site where it is produced, in water filled concrete tanks, or in a variety of steel containers or immobilised in standard packages and kept within dry, aboveground concrete stores. For most ILW currently arising, packaging consists of conditioning in cement-based materials within 500 litre stainless steel drums. Larger items are conditioned in higher capacity stainless steel or concrete boxes. There are a number of such conditioning plants operating, at Sellafield, Dounreay, Windscale and Trawsfynydd nuclear power station for example. Limited facilities for storing the small amounts of ILW from hospitals and industrial, educational and research establishments are also in operation.

Particular concern has focused on "historic" wastes because they are often poorly characterised, physically and chemically degraded, and held in old facilities subject to deterioration. In such cases considerable effort is needed to retrieve and condition these wastes for safer storage. In this context, the Environment Agency, Scottish Environment Protection Agency and the Health and Safety Executive have issued joint guidance to explain the regulatory process and provisions associated with conditioning of ILW on nuclear licensed sites in the UK. The NII has also published a guidance document on radioactive waste management for its inspectors. This is also publicly available and clarifies their expectations for the long-term, on-site storage of ILW in the UK.

As mentioned in Section 1.4, '*Present Situation and Foresights'*, CoRWM has now published its recommendations for the long-term management of higher activity wastes including ILW, and the official response is awaited.

4. Spent fuel and HLW management

4.1. Spent fuel management and reprocessing

The main types of UK spent fuel are those arising from Magnox, Advanced Gas Cooled Reactor (AGR) and Pressurised Water Reactor (PWR) power plants. Smaller amounts of spent nuclear fuel arise from prototype and research reactors and from nuclear submarines. Up to now spent fuel, together with the plutonium and uranium recovered by reprocessing, have not been regarded as wastes. UK policy has been that it is up to the owners of these materials to declare them as wastes or not. There is no such declaration at the present time but, with the formation of the new Nuclear Decommissioning Authority and changes in the structure of the UK nuclear industry, it is possible that some of these items may be categorised as radioactive wastes at some time in the future. In this event, of course, spent fuel would become a form of solid HLW.

There are two major plants for spent fuel reprocessing at BNFL, Sellafield. One is for reprocessing the uranium metal fuel from the older Magnox nuclear power plants and the other is for reprocessing uranium oxide fuel from the more modern Advanced Gas-Cooled and Light Water Reactors. The latter plant undertakes reprocessing of both UK and overseas spent fuel. Smaller plants were operated by UKAEA at Dounreay for reprocessing of fast reactor and materials test reactor fuel, but these are now shut down and in the process of decommissioning.

The current position on UK spent fuel management is as follows:

- All Magnox fuel (uranium metal/magnesium alloy cladding) is reprocessed, because the cladding is susceptible to corrosion by the water in which it is stored.

- BNFL has contracted with British Energy (BE) to reprocess or store all AGR lifetime fuel arisings. It has contracted to reprocess some 4700 tU, arising from the AGR stations up to about 2006/2007. BE retains the options of early reprocessing, or of storing, subsequent arisings of fuel from these stations, and the remaining lifetime arisings of AGR spent fuel will be sent for storage at Sellafield with the options to reprocess it or condition it for direct disposal.

- No decisions have yet been taken about the long-term management of spent fuel from the Sizewell B PWR station or about the spent fuel from nuclear submarines.

4.2. High Level Waste (HLW) management

HLW arises as a liquid waste stream from the reprocessing of spent nuclear fuel. Although small in volume, it contains over 95 per cent of the radioactivity in waste from nuclear facilities. HLW generates sufficient heat for it to be taken into account in the design of processing, storage and disposal facilities.

At Sellafield, liquid HLW is concentrated by evaporation and stored in double-walled stainless steel tanks inside thick concrete walls. Because the waste is still generating heat, the tanks are continuously cooled. It is the intention that all of this liquid HLW will be conditioned using a vitrification process, which immobilises the waste in a solid, stable, borosilicate glass product suitable for long-term management. A vitrification plant is operational at Sellafield and is producing glass blocks that are sealed into stainless steel canisters and then placed in a dry store. By 2015 all of it should be in this solid form. (Plant equipment from the vitrification process that has been contaminated with the HLW is also categorised as HLW.)

Since 1982, it has been the government policy that HLW should be stored above ground for at least 50 years. This would allow for radioactive decay and consequent reduction of the thermal power to a level where the waste could be safely disposed of in a manner similar to that previously contemplated for ILW. However, this situation may change following publication of the CoRWM report on the long-term management of higher activity wastes, including HLW. For the time being, all HLW continues to be stored at the Sellafield site until the Government decides on how to respond to the CoRWM recommendations.

4.3. R&D needs and generation of technology and Knowledge

UK Government policy is that each of the component parts of the nuclear industry, regulatory bodies and the Government itself should continue to be responsible for the research and development necessary to support their respective functions. A new scheme for co-ordinating this work nationally is being evolved.

The UK nuclear industry, and its confidence in the future of nuclear power in the UK, have changed over the last decade and it has carried out much less research than previously. Similarly, with the closure of a number of nuclear power reactors and the restructuring of the nuclear power industry, the emphasis on research by the regulators has changed. Most recently, however, CoRWM has recommended that "There should be a commitment to an intensified programme of research and development into the long-term safety of geological disposal aimed at reducing uncertainties at generic and site-specific levels, as well as into improved means for storing wastes in the longer term." It remains to be seen just what this will entail, or how much really needs to be done in addition to the extensive amount of work already carried out both domestically and internationally. In addition, the NDA, by way of its formal remit, is required to play a role in R&D related to cleanup and decommissioning programmes and it has recently created a Research Board to oversee R&D in these areas. Most of the current work is site-specific and concerns waste treatment and packaging, and improved techniques for dismantling and decontamination.

Currently, Defra has a small research programme relating to policy formulation covering control, handling and disposal of UK radioactive wastes, radioactivity in the general UK environment, and identification and remediation of radioactively contaminated land. Research by the EA on radioactive substances is limited and is concerned with improved understanding of the environmental consequences of radioactive waste management options, and development of risk assessment frameworks for humans and non-human species. The Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) identifies and manages environmental research on behalf of its members - the Scottish Environment Protection Agency, Environment and Heritage Service, the Scottish Executive, Scottish Natural Heritage and the Forestry Commission - and stakeholders. It aims to improve the environment of Scotland and Northern Ireland through research and forum activities.

UK bodies participate in the Euratom element of the EU R&D Framework Programmes, and the Government continues to issue information and advice about the EU programmes to those commissioning and undertaking research. The UK members of the Euratom Scientific and Technical Committee have supported the content and structure of these programmes, including Framework Programme 7. In particular, they recognise the importance of Generation IV Fission topics that address waste minimisation and management issues, and the work supporting geological disposal of long-lived wastes. They see the work on Partitioning and Transmutation (P&T) as a good vehicle for the training of new nuclear technologists, rather than as solution to the management of long-lived wastes. (This already widely held view is reflected in the CoRWM conclusion that P&T cannot realistically be considered to offer a long-term management solution for the UK's current stocks of radioactive waste, and those likely to arise in the future.) Hence, any future consideration of P&T is likely to be restricted to partitioning by way of spent fuel reprocessing, and transmutation of separated plutonium by incorporation in mixed oxide fuel for irradiation in future PWRs or, perhaps, even fast reactors.

As regards training in nuclear technology, and perhaps even generation of new knowledge, university courses have been re-established, e.g. at the University of Manchester. In addition, a new Nuclear Academy is being set up in Cumbria, near Sellafield. It is being created by a partnership involving the NDA, the British Nuclear Group and local bodies concerned with regional development and local investment. Its aim is to provide training and business support across the nuclear industry and it is scheduled to open in September 2008. Its customers will be nuclear industry employers in the UK and, presumably, from overseas.

5. Costs and financial aspects

5.1. Long-term management of UK wastes

The costs of long-term management of UK wastes have been studied in detail by CoRWM in their comparison of potential waste management options. In all, 14 options were analysed. Nine of them catered for the full range of potential wastes, i.e. Non-Drigg LLW and ILW, Vitrified HLW, Spent Fuel, Plutonium, and Depleted Uranium. A further 4 dealt only with disposal of reactor decommissioning waste. These were as follows:

1. Interim Stores, Above Ground, Current Locations, Unprotected. (As current design.)
2. Interim Store, Above Ground, Centralised, Unprotected.
3. Interim Stores, Above Ground, Current Locations, Protected. (Reinforced design.)
4. Interim Store, Above Ground, Centralised, Protected.
5. Interim Stores, Underground, Current Locations.
6. Interim Store, Underground, Centralised.
7. Deep Geological Disposal.
8. Deep Geological Boreholes.
9. Phased Deep Geological Disposal.

And for disposal of reactor decommissioning wastes only:

10. Near-Surface Vault, Current Locations, Protected.
11. Near-Surface Vaults, Centralised, Protected.

12. Mounded Over Reactors.

13. Shallow Vault Disposal, Centralised.

14. Shallow Vault Disposal, Current Locations.

The overall costs for each option were constructed from the costs of the various items involved, from initial R&D, through interim storage, to institutional control after completion. They were based on analogy with other projects, and used the 1999 Nuclear Energy Agency costing methodology to ensure a 'like for like' comparison, so far as possible. The major cost components and the detailed items are shown in the following table.

Cost Component	Cost Item
Development, including planning and licensing	Research and Development, including Site Selection. Regulation Application Stakeholder Consultation Public Relations Public Inquiry
Design and construction	Design Construction of Storage/Disposal Facility Construction of Supporting Facilities
Operation	Waste Characterisation Packaging and Conditioning Operation of Storage/Disposal Facility Operation of Supporting Facilities Operational Monitoring Store Refurbishment Interim Storage Transport
Decommissioning and completion, including post-closure monitoring	Decommissioning and Completion Post-Closure Monitoring Institutional Control

CoRWM recommended Deep Geological Disposal as the end-state for UK wastes. In their costing of this option they assumed timescales for the spend as shown in the following table.

Phase of Evolution	Dates
Development	2005 -2020
Design and Initial Construction	2020 - 2040
Operation	2040 - 2105
Decommissioning and Closure	2105 - 2205

For this Deep Geological Disposal option, the overall costs for the various combinations of waste streams were as shown in the following table.

Waste Combination	Cost (£M)
ILW/LLW only	7,070
HLW/spent fuel only	5,410
ILW/LLW + depleted U only	7,480
HLW/spent fuel +Pu + (Highly Enriched U) only	6,850
Co-location of ILW/LLW and HLW/spent fuel repositories	9,470
Co-location of repositories for all wastes	11,320

5.2. Costs of decommissioning the NDA liabilities

The NDA liabilities include all UK civil nuclear facilities other that the AGR and PWR nuclear power plants of British Energy. The total undiscounted cost of decommissioning these, based on a 2005 analysis is £62.7 billion at current prices, (£35.4 billion discounted at 2.2% per annum). However, there were other costs, not included in that analysis that will need to be funded. These include R&D directly funded by the NDA, the cost of any new LLW disposal facilities and the potential costs for long-term management of contaminated land. Including these items would add £7.5 billion to the cost of decommissioning and clean up. This higher figure still does not include costs associated with the long-term management arrangements for ILW or the treatment and disposition of plutonium and uranic materials, should they be reclassified as waste. Adding these would add some £billions to the above costs.

The NDA is funded directly by the Government. Its funds are a combination of general Government spending and revenue from continuing commercial activities on NDA sites, such as spent fuel storage and reprocessing at Sellafield.

5.3. Decommissioning of British Energy (BE) nuclear power plants

Following privatisation of the AGR and the PWR nuclear power plants, the nuclear liabilities inherited by BE, including provision for spent fuel reprocessing and storage and disposal of waste were about £14 billion at 1996 values. The Government imposed a requirement for a segregated fund to cover the costs of protecting the nation against the environmental impact that may result from these nuclear installations. To implement this, an independent Nuclear Decommissioning Fund Limited, the 'Nuclear Trust', was set up to receive funds and invest them to meet the long term decommissioning costs. However, the fund excludes those liabilities relating to defuelling and post operational clean out of BE's nuclear facilities, as well as their liabilities for HLW and ILW stored on other nuclear sites. These excluded activities are financed from BE's operational funds and provisions. Their decommissioning strategy, including the adequacy of funding arrangements are reviewed every five years by the Nuclear Installations Inspectorate.

6. Social, public opinion and communications aspects

6.1. General provisions in legislation for public participation and support

Under the Radioactive Substances Act 1993 (RSA93) there are substantial provisions for consultation with all stakeholders, including the public, before issue of an authorisation for disposal of radioactive waste from any nuclear site. The relevant environment agency is legally required to place the application on a public register, subject to protection of matters of commercial confidence or national security. It is also required to consult relevant local authorities, water undertakings and other public or local bodies as appropriate. When appropriate, it also invites comments from local interest groups and environmental organisations. The main vehicle for public consultation is a draft authorisation together with an explanatory document. In addition, public meetings may be held and, where the relevant Minister calls for it, a public inquiry may be held. The product of this lengthy process is an authorisation, together with a Decision Document explaining how the agency dealt with comments and arrived at its decision.

As regards operational waste management on nuclear sites, which is controlled by way of the Nuclear Installations Act.1965 (as amended), such matters are normally addressed at a public inquiry before the site is licensed but there are no arrangements for consultation with the public on subsequent changes to license conditions or to new operations. The public is kept informed by way of formal Local Liaison Committee meetings. As regards decommissioning, however, the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 require an Environmental Impact Assessment (EIA) to be carried out by the licensee before the Nuclear Installations Inspectorate (NII) considers granting consent for decommissioning of a nuclear reactor or nuclear power station. NII must ensure that an adequate EIA is carried out. It does this by consulting relevant bodies and the public on an Environmental Statement (ES) provided by the licensee. It then takes the results of such consultation into account when considering consent. NII may attach conditions to any consent to start the decommissioning project as may appear desirable in the interests of limiting the impact of a project on the environment.

The Energy Act 2004 requires the NDA to provide encouragement and other support to activities that benefit the social or economic lives of communities living near its sites. This recognises the significant shift of the civil nuclear industry from operations to decommissioning and clean up, and the potential for adverse impact on the social and economic well-being of local communities. This is because the sites are located predominantly in geographically remote areas and the NDA has become the dominant employer in the local area, inextricably linked to its wider social and economic well-being. In this context, the NDA has begun preparatory work with local stakeholders to generate a comprehensive picture of socio-economic need and it has commissioned several socio-economic studies of key locations in order to understand fully the impact of its activities on local communities. Their results will inform its strategic approach, ensuring that resources are directed appropriately, and they will be made available to the public.

6.2. Public involvement in policy development

Quite often, there are specific issues on which Government wishes to consult members of the public. This is usually done by way of publication of a consultation paper that is made widely available, e.g. by way of the relevant website. After a period of time, which depends on the complexity of the subject, the Government responds by way of a policy document which may be reflected, if necessary, in some form of legal instrument. A recent example of this is the consultation on policy for the long-term management of solid LLW in the UK. Two national stakeholder workshops took place in June and October 2005, and a consultation paper was published on 28 February 2006. Public consultation ended on 31 May 2006. As an indication of the typical level of stakeholder involvement, one hundred and fifty responses were received, coming from the following backgrounds:

- Nuclear industry, professional bodies and consultants – 27%
- Local authorities and associated bodies – 26%
- Non-nuclear sectors (i.e. education, research, pharmaceutical industry, medical sector and oil and gas industries) – 21%
- Individual members of the public – 10%
- Non-Governmental Organisations – 5%

Others came from a range of organisations, including central Government Departments, regulators, academic institutions and landfill and incinerator operators. The results of the review are currently awaited.

6.3. The Committee on Radioactive Waste Management (CoRWM) process

As described in the context of 'Present Situation and Foresights', CoRWM was asked to oversee a review of options for the long-term management of HLW and ILW and was required to engage members of the UK public, and provide them with the opportunity to express their views. Other key stakeholder groups with interests in radioactive waste management were also provided with opportunity to participate. The purpose of this was to inspire public confidence in the way that CoRWM worked, in order to secure confidence in its eventual recommendations. This was a step in the on-going process of developing Government policy, following a major public consultation on a paper entitled 'Managing Radioactive Waste Safely', in 2001.

CoRWM opted for a substantial programme of public engagement involving as wide a range of different views as possible, including intensive engagement with invited participants. Recognising the importance of ethical aspects and the need to inspire public confidence, the Committee believed that those with limited prior knowledge of radioactive waste issues would have an important role to play. Every effort was made not simply to consult, but to encourage debate and exchange of views between participants, and to enable the public and stakeholders to participate in key stages of CoRWM's assessment and decision-making processes. About 5000 people were involved in the process and CoRWM believes that, as a result of this substantial engagement, its recommendations can inspire public confidence. (The process is fully described in its report, published on 31 July 2006.) It remains to be seen how Government will respond to the CoRWM recommendations and how the public will react to Government proposals.

7. Sources of information

In order to ensure that the above information is both accurate and up-to-date, it has been taken directly from the websites of the relevant organizations as follows.

1) Department of Environment: (http://www.defra.gov.uk/), follow Environmental Protection, Radioactivity, Radioactive Waste, Radioactive Waste Policy Group and then 'National Framework' or 'Specific Policies'.

2) Committee on Radioactive Waste Management: (http://www.corwm.org.uk/), follow Information Centre, then 'Final Recommendations' for full report, or 'Document Vault'/ 'On-line Documents', for individual papers.)

3) Nuclear Decommissioning Authority: (http://www.nda.gov.uk/), follow 'Strategy' or 'Sites'.

4) Department of Trade and Industry: (http://www.dti.gov.uk/), follow 'Energy' and 'Energy Review' or 'Energy Sources'/'Nuclear Power'.

5) Health and Safety Executive, Nuclear Safety Division, (Nuclear Installations Inspectorate): (http://www.hse.gov.uk/nuclear/nsd1.htm) follow 'Information' and 'LLC Reports'.

7) Environment Agency: (http://www.environment-agency.gov.uk), follow 'Business and Industry', 'Business sectors', and 'Nuclear Industry'.

Radioactive waste management in Sweden

C. Thegerström

4

1. Nuclear energy in Sweden - a general overview

1.1. Policy overview 1970-1995

The construction of the first commercial nuclear reactor in Sweden was started in 1965. In 1972 when this unit was taken in operation an additional nine units were already under construction.

After the general election in 1976 a new government was formed with the leader of the (anti-nuclear) centre party as prime minister. The government introduced a new law which set forth new requirements in order to obtain permits to load nuclear fuel into power plants that were not yet in operation. Seven reactors had to meet the new requirements. The owners of the reactor(s) had two options, either 1) to show reprocessing contracts for the spent nuclear fuel from the new reactor(s) and also to show how the high level waste from reprocessing could be disposed of in an "absolutely safe way", or 2) to show how spent nuclear fuel from the reactor(s) could be disposed of in an "absolutely safe way" without reprocessing. The responsibility for spent fuel management was thus distinctly placed on the plant owners.

The nuclear power plant owners started the KBS-project, in order to demonstrate safe disposal options, and signed reprocessing contracts with the French firm Cogema during 1977. The KBS reports together with reprocessing contracts formed the bases for applications to load fuel in new units ready for start-up in the late 1970s. Supplementary geological investigations had also to be made before permits were granted for two new units.

In 1979 the accident at Three Mile Island 2 raised the feelings and debate about nuclear power to a new level. A national "advisory" referendum on the future of the nuclear power programme was held in March 1980. It resulted in an acceptance of completion of the twelve reactors that were in operation or under construction, but no additional units would be permitted. The twelve units would be gradually phased out before the end of 2010. This date was based on an assumed operational lifetime of 25 years for the last two units.

After the decisions in the Riksdag (Parliament) following the referendum the nuclear debate was quiet for many years. The Chernobyl accident in 1986, however, raised a strong opinion for beginning the phase out of the nuclear plants. In 1988 a statement was passed in the Riksdag that one unit should be closed in 1995 and another unit one year later.

The 1988 phase out plan was however set aside as part of an inter-party energy policy agreement in 1991. It was stated that the juncture at which the nuclear phase-out could begin and the rate at which it could proceed would depend upon the results of environmentally acceptable power production and the possibilities of maintaining internationally competitive electricity prices. This policy statement was supplemented by a decision about a five-year support programme for energy conservation and promotion of renewable energy sources. The 1980 position to phase out all nuclear power by 2010 was however not revised.

1.2. Energy policy 1995 - 2000

▶ *First phase-out*

An Energy Commission made up of parliamentary representatives was established in 1994 to review the bases for Sweden's energy policy. Late 1995, the Commission's reports indicated that an exact time limit setting out the year in which the last reactor was to be taken out of service should not be specified. On the other hand should the phase-out be started at an early stage to ease the adjustment process. The Commission found that it was possible to close one nuclear reactor by 1998 without adverse affects on the power balance.

The reports from the Energy Commission were followed by inter-party deliberations that resulted in an agreement between three parliamentary parties. The new energy policy guidelines were adopted by the Riksdag in June 1997. They singled out the Barsebäck plant with two 600 MWe units as the first to be phased out. The first unit at Barsebäck should be closed before the end of 1998 and the second unit 2-3 years later. One condition for the closure of the second reactor was that electricity production loss could be compensated by new production from renewable sources and reduced electricity consumption. The year 2010 was abolished as deadline for the phase-out of the remaining 10 nuclear units.

The government decided in February 1998 that the operating licence of Barsebäck Unit 1 was withdrawn from July 1. The close down was however delayed until 30 November 1999, due to an appeal to the Supreme Administrative Court. An agreement between the government, state-owned Vattenfall and Sydkraft (owner of Barsebäck) was later reached about compensation. It included a transfer of 25,8 % of the interest in Vattenfall's Ringhals nuclear plant to Sydkraft.

▶ *Electricity market deregulation*

During the 1990s a restructuring of the Swedish electricity market took place. It was mainly a consequence of a deregulation of the market which came in force in January 1996. Together with Norway Nord Pool was established, the world's first international electricity market which now also includes Denmark and Finland. The consumers were allowed to switch retailer. Each network company must publish tariffs for any retailer that wishes to use its grid. These tariffs are subject to the oversight of the Energy Markets Inspectorate.

The introduction of competition in production and supply of electricity involved new conditions for the efficient operation of the production units. Electricity production in Sweden has been more concentrated. Mergers have been frequent among various medium sized companies and have in Sweden resulted in that E.ON and Fortum each form about one-fifth of the industry, while Vattenfall has just under half of generation. These three large companies are the retailers for about 70 per cent of the Swedish customers. The opening up of the Nordic market, however, has lead to more major market players with more evenly distributed market shares, and this structure reduces the risks of the high level of concentration on the Swedish part of the market. The market restructure has also lead to an increased cross-ownership of the Swedish nuclear plants.

1.3. Energy policy 2001 - 2005

The 1997 energy policy decision included a number of policy instruments such as investment grants, norms for energy use, loans with interest subsidies and information drives. The aim was to increase energy efficiency and to promote district heating and electricity production based on renewable energy sources. In 2002 the Riksdag approved a new set of energy policy measures that in part is a prolongation of the 1997 program. An electricity certificate scheme was introduced in order to promote electricity production from renewable sources.

The closure of Barsebäck Unit 2 was discussed several times in the Riksdag. In 2001 the Riksdag decided that it should not be closed in 2002, which would have been in line with the 1997 agreement. Instead a review of Sweden's energy needs was initiated, and the closure date would then be set based on the outcome.

Meanwhile, the government initiated negotiations with the nuclear industry in order to reach an agreement about a long-term policy for the future restructuring of the energy system. A main objective for the government was to come to an agreement about a time-table for the use of and decommissioning of the nuclear reactors. The negotiations started in June 2002. In October 2004 the state negotiator broke off negotiations maintaining that it had been impossible to reach a conclusion.

Immediately after the negotiations broke, the parties behind the 1997 energy policy agreement announced their decision to close the second Barsebäck reactor. A new agreement was also made about the role of nuclear power in Sweden. This agreement was later submitted to the Parliament. In December 2004 the government decided that Barsebäck Unit 2 would be shut down at the end of May 2005.

The three-party agreement about the role of nuclear power in Sweden was submitted to and approved by the Riksdag in the spring of 2005. The closure of Barsebäck Unit 2 was confirmed. Regarding the future role of nuclear power in the Swedish energy system the agreement states that the objective is to secure a reliable supply of electricity and other forms of energy at internationally competitive prices, both in the short and the long term. Nuclear power must therefore be phased out in a planned and responsible manner and new electricity production must continuously be expanded. After the closure of Barsebäck Unit 2 the next step would be an examination of the oldest reactor(s). Such an examination should be made within a few years after the closure of Barsebäck.

The closure of Unit 2 was followed by negotiations about compensation. An agreement was reached in November 2005 on the basis of the same valuation principles that were applied in connection with the shutdown of Unit 1. According to the agreement E.ON's (formerly Sydkraft) interest in Ringhals NPP increased to 29,6 %.

1.4. Current energy policy

Following a regular parliamentary election in September 2006 a new four-party government based on the Moderate Party, the Center Party, the Liberal Party and the Christian Democrats took office. In its Statement of Government Policy the government announced that no political decisions on phasing out nuclear reactors will be taken during the electoral period (2006-2010). Nor will any renewed operating licences be issued to the two reactors that have already been closed. The prohibition against building new reactors will remain in place. The government also stated that it will consider power increase requests under the current legislation.

The new government also announced that it will invite the parties represented in the Riksdag to a broad and long-term energy agreement based on the four-party coalition's energy agreement.

1.5. The nuclear programme

The 1997 decision on energy policy removed the 2010 deadline for a phase-out of nuclear power in Sweden. Although the principles for the overall future of the nuclear power are uncertain, the nuclear power companies have prolonged the planning horizons for operation of the remaining 10 reactors. They are now calculating with 40-60 years operation time. Table 4.1 summarizes the current nuclear programme status.

Reactor	Net capacity MW	Start-up	Energy availability 2001 %	2002 %	2003 %	2004 %	2005 %	Generation 2001 TWh	2002 TWh	2003 TWh	2004 TWh	2005 TWh	Total generation from start-up to 2005 TWh
Barsebäck 1*	(600)												92.7
Barsebäck 2**	(600)	1977	88.4	77.2	45.4	91.1	99.6	4.4	3.9	2.2	4.6	1.9	111.5
Forsmark 1	1,018	1980	94.8	91.3	92.1	97.5	85.8	7.3	7.1	7.4	8.0	7.3	176.6
Forsmark 2	951	1981	92.3	90.1	89.2	97.0	94.9	7.4	6.8	7.3	8.0	7.8	172.0
Forsmark 3	1,190	1985	86.2	95.1	96.9	89.4	96.6	8.2	9.1	9.1	9.0	9.9	183.2
Oskarshamn 1	467	1972	83.7		75.7	87.6	79.8	3.1	0.0	3.1	3.5	3.3	81.9
Oskarshamn 2	602	1974	92.3	91.0	59.4	89.1	88.7	4.7	4.5	3.1	4.6	4.7	127.0
Oskarshamn 3	1,160	1985	92.6	92.0	77.9	93.0	86.5	9.1	8.9	7.7	9.3	8.6	178.6
Ringhals 1	873	1976	86.1	86.9	70.5	90.1	84.0	5.8	6.0	5.1	6.5	6.1	147.0
Ringhals 2	870	1975	87.0	92.3	92.4	90.4	78.3	6.3	6.5	6.8	6.8	5.8	160.4
Ringhals 3	920	1981	88.5	90.3	85.3	93.9	91.1	6.3	6.9	6.7	7.5	7.2	153.5
Ringhals 4	910	1983	88.2	80.2	89.1	92.0	91.3	6.6	5.9	7.0	7.2	7.1	147.2
Total	**8,961**		**89.1**	**89.2**	**82.0**	**92.3**	**88.4**	**69.2**	**65.6**	**65.5**	**75.0**	**69.5**	**1,731.5**

* Shut down 1999 ** Shut down 2005
Source: Swedenergy

Table 4.1. Nuclear power plants by energy availability and generation.

Table 4.2 below gives a record of the radioactive waste products from the nuclear power plants that shall be disposed of according to SKB's reference scenario, assuming 40 years operation time for the remaining 10 reactors.

Most of the spent fuel will be interim-stored in CLAB and then directly disposed of. In addition to the fuel from the 12 commercial reactors approximately 20 tonnes of fuel from Ågesta[1] and 23 tonnes of MOX fuel originating in Germany must also be dealt with. The latter fuel replaces 57 tonnes of Swedish fuel previously shipped to Cogema. In 1989, SKB transferred the right to reprocessing at Cogema to eight German companies. 140 tonnes of fuel have also been sent to BNFL for reprocessing, and Oskarshamn NPP will retrieve the plutonium and uranium in the form of MOX fuel.

Besides spent fuel, the Swedish nuclear power programme gives rise to low- and intermediate-level operational waste from the nuclear power plants and from CLAB and the encapsulation plant. SKB's programme also includes radioactive waste from Studsvik (research reactors, hot-cell and waste treatment facilities), the Westinghouse Electric Sweden AB fuel fabrication plant in Västerås, Ranstad (former uranium mining facility) and the Ågesta reactor. When the NPPs and treatment plants are decommissioned they give rise to decommissioning waste. The activity content of the different waste types varies greatly. The type of management and disposal required varies with the type of waste.

			According to reference scenario	
Product	**Principal origin**	**Unit**	**No. of units**	**Volume in final repos. m³**
Spent fuel		spent fuel canisters	4 500	18 800
Alpha-contaminated waste	LILW from Studsvik	drums and moulds	4 500	1 800
Core components	Reactor internals	long moulds	1 400	9 700
LILW	Operational waste from NPPs and treatment plants	drums and moulds	34 800	54 600
Decommissioning waste	From decommissioning of NPPs and treatment plants and Studsvik	ISO containers	12 000	178 700
Total quantity, approximately			**57 200**	**263 600**

* Shut down 1999 ** Shut down 2005
Source: Swedenergy

Table 4.2. Main types of radioactive waste products to be disposed of.

[1] Ågesta Nuclear CHP was situated close to the Stockholm suburb Farsta and generated a thermal power of 65 MW of which 10 MW was used for electricity generation and 55 MW for district heating. The plant was in operation from 1964 to 1974, when it was permanently shut down after 52,000 hours of operation.

With prolonged operational times all the three remaining nuclear power plants plan to modernize their facilities and to increase the thermal power. In conjunction they have to upgrade the plants to meet the requirements in the new safety regulations issued by SKI. The increase of thermal power means also a new licensing process and a new permit from the government.

Ringhals NPP was the first to apply for increased thermal power of 377 MW for unit 3 and of 40 MW for unit 1. SKI and the government has approved the increases. The application was also a part of the environmental review by the Environmental Court which issued its final decision in March 2006. Ringhals has filed an appeal concerning the conditions that the Environmental Court intends to carry into effect after five years. According to Ringhals should no conditions be imposed besides those that are or will be issued by the regulatory authorities.

Ringhals is now awaiting the final conditions for the power increase from the SKI. The decision will probably be taken early 2007.

The Oskarshamn NPP, OKG, has applied for increased thermal power in unit 3 with 600 MW. SKI and the government has approved the increases. The Environmental Court issued in August 2006 the final decision together with operational conditions. OKG has lodged an appeal with the The Environmental Court of Appeal concerning some of the conditions. Regarding unit 2 OKG has started an investigation regarding the possibilities to increase the thermal power rate to 2300 MW from the 1800 MW today.

In September 2005 Forsmark NPP filed an application for increased power in all three of its reactors. The applications were for a thermal power increase of 120 MW in each of unit 1 and unit 2, and an increase of 170 MW in unit 3. A preliminary hearing is expected late in 2006.

1.6. Decomissioning

A timetable for decommissioning of the Swedish nuclear power plants has not been finalized. The power companies estimate that the operating time of the reactors could end up being 60 years or more. SKB's current planning and cost estimates are based on the assumption that the power plants are operated for about 40 years and then decommissioned as soon as possible. The final planning for construction, operation and decommissioning of SKB's facilities is based on the planning at the NPPs.

Owners of nuclear installations are obliged to ensure that the installations are decontaminated and dismantled to a sufficient extent when they have been taken out of service. There are no specific regulations governing this today; judgements are made by the regulatory authorities (SSI and SKI) from case to case. There have not yet been any large-scale decommissioning projects in Sweden. As of the closure of Barsebäck NPP, however, planning for a future decommissioning has assumed more concrete forms

The division of responsibility between SKB and its owner companies is such that SKB carries out general decommissioning studies and ensures that the necessary technology and competence exists and that the costs are estimated correctly. The nuclear power utilities take responsibility for the planning, licensing and execution of decommissioning of their own facilities. Management of the waste is coordinated with SKB.

The experience we have of decommissioning in Sweden today is limited to small research plants that have been decommissioned. The biggest one is the R1 research reactor on the Royal

Institute of Technology in Stockholm. Decontamination and dismantling of the ACL (Active Central Laboratory) in Studsvik has recently been completed, and SKB has learned from this experience

The design and licensing process for disposal of the radioactive waste from decommissioning requires planning on the national level. This planning must be done in cooperation between the power companies and SKB. Such planning offers advantages with regard to access to special equipment and specially trained personnel, as well as an opportunity for experience feedback. The point of departure for planning is that no unit is decommissioned as long as a nearby unit is still operating. Taken together, this means that the first decommissioning will not be commenced until some time after 2015. If the operating time of the NPPs is extended, or if the power companies decide to allow the radiation from the reactor to decay for a period, dismantling will begin at a later time.

The greatest quantity of waste obtained during decommissioning of a nuclear power plant consists of conventional building material that is not radioactive.

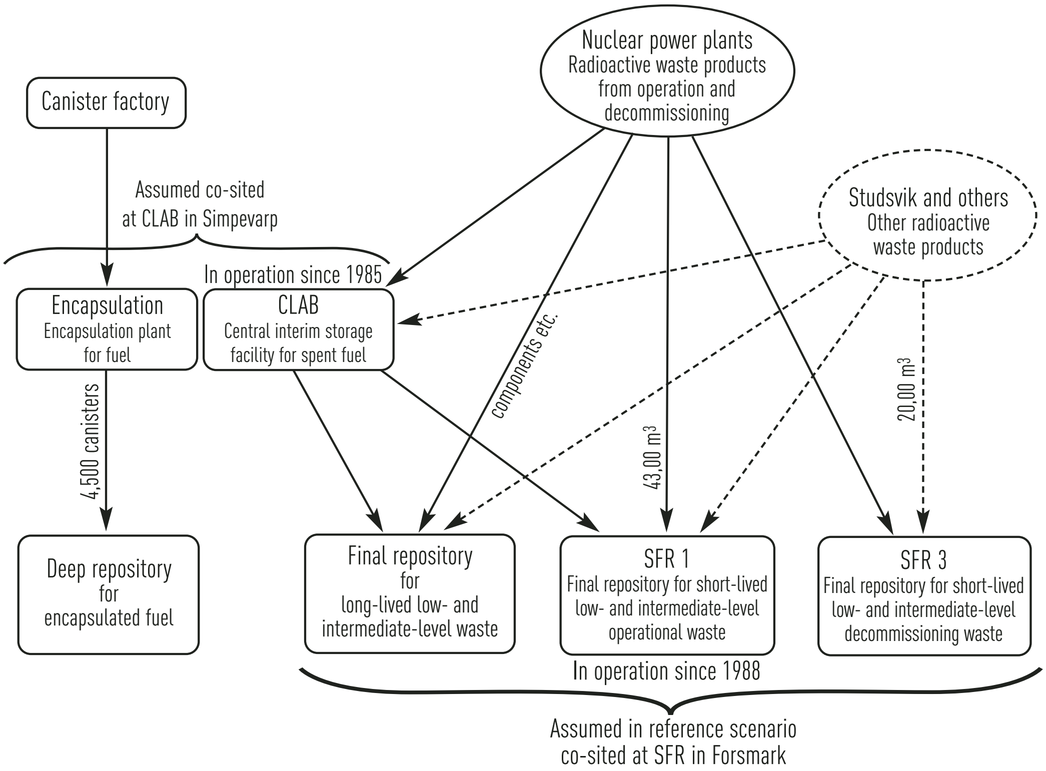
Of the radioactive material, a large portion is very low-level. Following decontamination and/or melting, quite a bit will be able to be reused. How much depends partly on how reliable the available measurement methods are and partly on what rules for free release are applied.

The waste that is not released for unrestricted use will be disposed of in special repositories. The short-lived decommissioning waste is planned to be disposed of in an extension of SFR. This extension must be built so that the first phase is finished when dismantling of the NPPs begins. A final repository for the short-lived waste will not be needed until 2020 at the earliest. Long-lived waste from decommissioning consists primarily of the reactor internals, which were exposed to considerable neutron irradiation during operation. They comprise a small volume (when packaged, less than 1,000 m3 for an NPP), but need to be managed separately. They are highly radioactive and therefore require extra shielding, and they contain large quantities of long-lived radionuclides, which means that they should be disposed of at greater depth than the short-lived waste. SKB plans to keep this waste in interim storage until most of the NPPs have been decommissioned. The waste will then be emplaced in a special repository, which is planned to be built e.g. at SFR but at greater depth. The long-lived waste from research etc that is packaged and kept in interim storage at Studsvik will also be disposed of here.

1.7. The nuclear waste management system

The Swedish nuclear waste management system has evolved over the past 30 years in consensus between the nuclear power utilities and political interests. During the 1970s, politicians and scientists gathered to lay the foundation of a national programme. In the 1980s the industry built the first facilities for management of Sweden's radioactive waste: Clab and SFR. In the 1990s additional R&D facilities were built: the Äspö HRL and the Canister Laboratory. These new resources have given SKB greater knowledge and expertise regarding the entire system.

An important part of this progress has been a clear division of roles. The nuclear power utilities – the producers – are responsible for management of the waste. SKB, which is owned jointly by the nuclear power utilities, plans and executes the work. Section 2 below describes the institutional framework and the role division.



Note: Rounded-off waste data apply to reference scenario with reactor operation for 40 years.

Figure 4.1. Block diagram with transport flows showing management of the waste products from nuclear power.

The block diagram in figure 4.1 shows how the waste products are planned to pass through the storage and treatment facilities before being deposited in various final repositories. Some of these facilities exist and are operating. Others are planned to start operation later on. Sections 3 and 4 below describe the complete system.

2. Institutional framework

2.1. Legal framework

The provisions of the Nuclear Activities Act, the Environmental Code and the Radiation Protection Act provide the general principles of the regulatory regime. In addition building permits under the Planning and Building Act are needed to build a facility. These acts are supplemented by a number of ordinances and other secondary legislation containing more detailed provisions for particular aspects of the regime. Operation of a nuclear facility can only be conducted in accordance with a licence issued under the Nuclear Activities Act and a licence issued under the Environmental Code. Thus, operation of a nuclear facility requires two separate licences.

- The Nuclear Activities Act /SFS 1984:3/ describes the rules governing the construction and operation of nuclear facilities, among them facilities for the management and final disposal of spent nuclear fuel. Applications under the Nuclear Activities Act are submitted to the government, which delegates authority to the Swedish Nuclear Power Inspectorate (SKI).

- The Environmental Code /SFS 1998:808/, stipulates the rules for application for and licensing of environmenttally harmful activities as well as the requirements on the environmental impact statement (EIS) that shall be appended to the application for a permit to start construction. A permit may be associated with conditions and demand for safety measures. Applications under the Environmental Code is considered by an Environmental Court. For a nuclear facility a specific permissible decision by the government is also required before the Environmental Court can issue a permit and lay down operational conditions.

- The Radiation Protection Act /SFS 1988:220/ imposes obligations on people engaged in activities involving ionising radiation. It also provides that manufacturers and importers are required to provide radiation protection information about their products (by means of labelling, etc.) and to ensure that the products are fitted with appropriate radiation protection equipment.

- The Planning and Building Act /SFS 1987:10/concerns building permits and planning of the area. Applications are processed and decided by the municipality.

The financing legislation document is the Act on the Financing of Future Expenses for Spent Nuclear Fuel etc. /SFS 1992:1537/, often referred to as the Financing Act. It contains provisions for the future costs of spent fuel disposal, decommissioning of reactors and research in the field of nuclear waste. A new Financing Act /SFS 2006:647/ has been approved by the Riksdag and will come into force in 2007.

The Studsvik Act /1988:597/ on financing the management of certain types of nuclear waste, etc. regulates fees and reimbursement for actions taken to phase out operations in Studsvik, the Ågesta reactor and the facility in Ranstad. It is also replaced by the new Financing Act in 2007.

2.2. Institutional organisation

A clear division of roles between the main actors I n the nuclear waste sector was established already in the early 1980s.

The companies operating nuclear power plants are obliged under the Nuclear Activities Act to implement and finance all activities necessary to decommission the plants and to safely manage all wastes until final disposal arising from the operation and from the decommissioning of nuclear power plants and all facilities in the waste management system. This responsibility also includes on-site processing, conditioning, packaging etc and interim storage of the waste. The Swedish Nuclear Fuel and Waste Management Company, SKB, is jointly owned by the power producing companies. SKB has been charged with responsibility for nuclear waste management from the time the waste leaves the nuclear power plants, up to final repository, including transport of radioactive material. For more information, see sections 3 and 4.

The Swedish Nuclear Power Inspectorate, SKI, is responsible for overseeing safety both in the operation of the nuclear power stations and in waste management. Another task is reviewing the SKB RD&D programmes and submitting statements of comment to the Swedish government.

The National Radiation Protection Institute, SSI, is responsible for co-ordinating the radiation protection policy for individuals and the environment. Another responsibility is the supervision of SKB's activities in accordance with the Radiation Protection Act. SSI issues specific regulations concerning radiation protection and is also an important reviewing body in SKI's reviewing process.

Permits to handle and transport nuclear materials or nuclear waste are issued by SKI and SSI. Another task under SKI and SSI is the organising of public information on safety issues and radiation protection issues. Shipments of radioactive material (handled by SKB) are subject to permits from the SKI, SSI and the National Maritime Administration.

The Ministry of Sustainable Development has overall responsibility for issues concerning safety management and radiation protection at the nuclear facilities.

The Swedish National Council for Nuclear Waste, KASAM, is an advisory scientific committee to the government. One of its tasks is to submit a report to the government every third year with their assessment of the state of knowledge in the field of nuclear waste management.

2.3. SKB

The Nuclear Activities Act clearly states, based on the Polluter Pays Principle, that the power industry has full responsibility to take whatever measures are necessary to dispose of Swedish nuclear waste in a safe manner. There are four nuclear power utilities in Sweden (three in operation and one appointed for decommissioning): Forsmarks Kraftgrupp, OKG Aktiebolag, Vattenfall AB and E.ON Sverige AB. These companies are required by law to manage and dispose of the radioactive waste. For this purpose they have formed a joint company, Svensk Kärnbränslehantering AB, SKB (the Swedish Nuclear Fuel and Waste Management Company). SKB is a common interest company, owned jointly by:

Forsmarks Kraftgrupp (36%)

OKG Aktiebolag (30%)

Vattenfall AB (22%)

E.ON Sverige AB (12%)

SKB is responsible for ensuring that the waste from nuclear power (as well as radioactive waste from medical care, industry and research) is managed and disposed of in a safe manner and without harming the environment.

SKB conducts extensive research, development and demonstration work on spent fuel and other radioactive waste. Every three years a report on SKB's RD&D (Research, Development and Demonstration) programme is submitted to the Swedish Nuclear Power Inspectorate (SKI), which forwards the programme and their review report to the Government for its decision on the adequacy of SKB's further work.

SKB plans, builds, owns and operates systems and facilities for management and disposal of the radioactive waste.

SKB's operation is based on the principle of putting a qualified in-house staff in charge of getting the work done, and engaging the services and cooperation of outside experts on a large scale. The number of employees are currently about 240 people. In addition to these, about 500 external consultants work full-time on the Swedish programme.

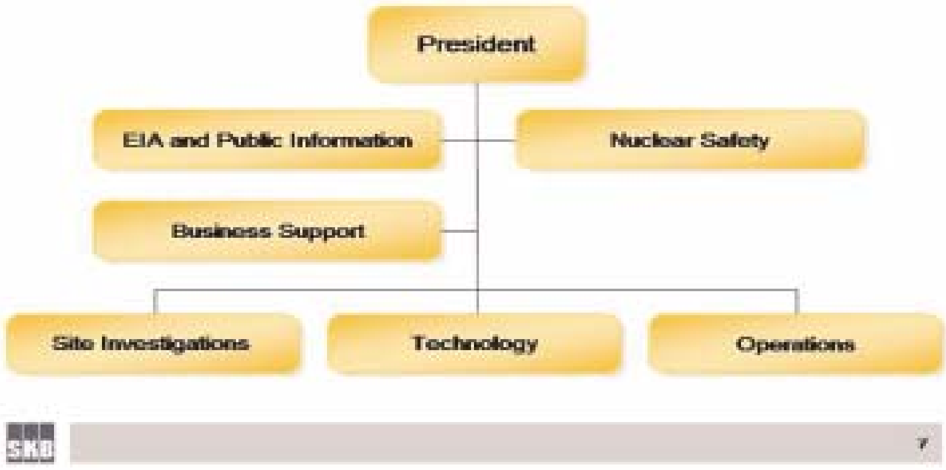


Figure 4.2. SKB Organizational Chart.

The President of SKB is Claes Thegerström.

A brief description of the SKB organization:

- The department EIA and Public Information consists of two units, Communications and EIA(Environmental Impact Assessment). The Communications unit is in charge of internal and external communications, media, business intelligence and events. The EIA unit is in charge of SKB's central resources and competence within EIA. The unit shall ensure that statutory consultation is carried out prior to upcoming permit and licence applications and that SKB's EIA work is well coordinated and organized.

- The Business Support department offers management and administrative support to all SKB employees.

- Activities in the Nuclear Safety department include safety review, development of nuclear safety, HFE (Human Factors Engineering), physical protection and overall responsibility for SKB's management system.

- The department of Site Investigations consists of five units:
    - Analysis
    - Projecting
    - Site Unit Forsmark
    - Site Unit Oskarshamn
    - Site Investigation Technology

The department gather site-specific data to support applications for permits to site and build the final repository for spent nuclear fuel. The department is also responsible for the data needed to implement the construction and detailed characterization phase.

- The Technology department works with development, demonstration and rationalization of the remaining parts of the system for encapsulation and final disposal of spent nuclear fuel and for the LILW management.

  The department consists of five units:
    - Repository Technology
    - Encapsulation Technology
    - Äspö HRL
    - Encapsulation plant
    - Safety & Science

- The Operations department is in charge of planning, control, follow-up and development of operations at SKB's nuclear facilities, i.e. SFR, Clab and the transportation system. Day-to-day operation of the facilities and the ship m/s Sigyn are performed by contractors. Activities also include obtaining the necessary permits and licences and ensuring that stipulated conditions are fulfilled for all types of waste. 1 January 2007, the operations department will grow significantly when SKB is taking over the management of the Central Interim Storage for Spent Fuel, Clab, which is presently operated by the Oskarshamn NPP.

SKB International Consultants AB is SKB's commercial consulting arm (100% subsidiary of SKB) providing support to nuclear waste management programmes and projects in other countries.

3. L & ILW management

3.1. Final repository for radioactive operational waste, SFR

A final repository for short-lived operational waste from the nuclear power plants called SFR (Final repository for radioactive operational waste) has been in operation since 1988 adjacent to the Forsmark NPP.

The repository is located beneath the Baltic Sea, covered by about 60 metres of rock. It consists of four 160 m long rock vaults and one 70 m high cylindrical rock cavern containing a concrete silo. The waste containing most of the radioactive substances is placed in the silo. Two 1 km long parallel access tunnels lead from the harbour in Forsmark out to the repository area.

Radioactive waste from Clab and similar radioactive waste from non-electricityproducing activities, including Studsvik, is also disposed of in SFR. The facility has the capacity to accommodate 63,000 cubic metres of waste and can be expanded if needed. So far about 31,000 cubic metres of the space has been utilized. Just under 1,000 cubic metres of waste is added every year.

Operation of SFR has from the beginning proceeded according to plan. Both radiation doses and release levels have lain far below the limit values that apply to the activities.

SFR is owned by SKB, but operated by Forsmark NPP. Altogether, operation and maintenance of SFR requires about 12 full-time persons working in the facility.

The waste in the silo consists primarily of solidified filter resins used for purification of water from the reactors. The filter resins are classified as intermediate-level waste and contain most of the radioactivity in the facility. The space between the silo and the rock wall has been filled with bentonite clay. The clay prevents groundwater from entering the silo. All handling of waste in the silo is automated and remote-controlled.

One rock vault contains intermediate-level waste packages which are emplaced in shafts. When the shafts have been filled they are sealed with concrete lids. The waste in this vault is handled with a remote-controlled overhead crane.

Low-level waste from the nuclear power plants is deposited in one of the four rock vaults. It consists of such items as used protective clothing. The waste is transported to SFR in standard freight containers. Then the unopened containers are driven directly into the rock vault by an ordinary forklift truck. The radioactivity is so low that the waste can be handled without any radiation shielding.

The remaining rock vaults are used to dispose of the intermediate level waste. The radioactivity is so high that the radiation shielding is required. Dewatered filter resins in concrete tanks are kept in two of the vaults. These waste packages are handled by a radiation-shielded forklift truck.

The waste has not been transported to SFR at the pace originally assumed when the facility was built. The main reason for this is that the technology for treating and compacting the waste at the nuclear power plants is constantly being improved, reducing the waste volumes.

3.2. The waste transportation system

A sea-born transportation system is used for LILW as well as spent fuel. Se section 4.2.2 below.

3.3. Final repository for radioactive waste from decommissioning, SFR 3

The short-lived decommissioning waste from the NPPs and from Studsvik and Ågesta, about 170,000 cubic metres of low- and intermediate-level decommissioning waste, is planned to be deposited in a repository called SFR 3. This repository is planned to be located adjacent to SFR 1. It will consist of rock vaults of a type similar to those in SFR 1.

Prior to decommissioning of the nuclear power plants, SKB will apply for a permit to expand SFR and dispose of decommissioning waste there. According to SKB's and the NPP's plans, this expansion will be finished around 2020.

Core components and reactor internals from decommissioning of the NPPs are planned to be deposited in the final repository for long-lived LILW (see 3.3 below).

The operating time at SFR 3 will be determined by the timetable for decommissioning of the reactor plants. Closure of the repository will take place jointly with other repositories at SFR.

3.4. Final repository for long-lived low- and intermediate-level waste

The final repository for long-lived LILW is mainly intended to contain core components and reactor internals, plus long-lived LILW from Studsvik. The short-lived decommissioning waste from Clab and the encapsulation plant is also supposed to be deposited in this repository.

The site of the repository has not been decided and will not have to be decided for a long time to come. It is assumed that the waste will be interim-stored in radiation-shielded casks, which will be simpler to handle after their radiation has decayed. Interim storage can be arranged in different ways, for instance in SFR.

The final repository for longlived LILW may then later be co-sited with one of the other final repositories. The repository will consist of rock vaults in which the waste is stacked in concrete cells, which are then backfilled with porous concrete. After backfilling, the cells are covered with concrete planks and sealed. All handling is done by remote-controlled overhead crane. Finally, the space between the concrete cells and the rock is filled with crushed rock and the openings of the rock cavern are sealed with concrete plugs. This takes place later in conjunction with sealing and closure of the repository.

4. Spent fuel management

4.1. Objectives and strategies

High-level waste (HLW) consists primarily of spent nuclear fuel, which must be both cooled and radiation-shielded. Certain internal parts of the reactor, such as the control rods, are also high-level, but do not require cooling.

Spent nuclear fuel comprises a small fraction of the total waste volume, but contains by far most of the total radioactivity, both short- and long-lived. The decay (disintegration) of the radionuclides causes them to emit radiation and generate heat. Eventually, as the short-lived substances decay, the radioactivity in the spent fuel will be dominated by the long-lived substances. Spent nuclear fuel requires radiation shielding in conjunction with all handling, storage and final disposal. The decay heat requires cooling to prevent the fuel from overheating. The content of long-lived radionuclides determines the layout of a final repository. The presence of fissionable material requires measures to prevent criticality and keep the fuel from falling into the wrong hands.

All spent nuclear fuel from the Swedish nuclear program is now interim-stored in water pools in a central interim storage facility (Clab) at the nuclear power plant in Oskarshamn.

SKB's reference method for disposal of spent nuclear fuel is called the KBS-3 Method, where the abbreviation KBS stands for kärnbränslesäkerhet = Nuclear Fuel Safety. The method involves encapsulating the fuel in copper canisters which are then deposited, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system at a depth of approximately 400–700 metres in crystalline bedrock.

The purpose of the three barriers (canister, buffer and rock) is to isolate the radionuclides in the fuel from the surrounding environment. Only if the radionuclides are brought up to the surface by the moving groundwater do they become harmful to man and the environment. In the deep repository it is primarily the canister that provides the isolating function. If radionuclides should escape from a leaky canister, their transport must be retarded. All barriers contribute to the retarding function. A partially damaged copper canister can effectively contribute to retardation by impeding inflow and outflow of water. The bentonite buffer has the capacity to retain many of the long-lived radionuclides, since they adhere to the surfaces of the clay particles. The rock contributes to the retardation by virtue of the low water flux at such great depth. Furthermore, radionuclides can adhere to fracture surfaces or penetrate into microfractures containing stagnant water.

The KBS-3 method has been under development since the early 1970s. The method was first described in a report in 1983 as a basis for the decision to commission the most recently built nuclear power reactors. It has since served as a basis for SKB's programmes for research and development, at the same time as other methods have been studied in general terms.

Site investigations are now undertaken in two municipalities in Sweden. The principal aim of the investigations is to provide the basis for applications to build and operate a final repository at one of the two investigated sites. The applications are planned to be submitted in 2009.

In the following sections are both existing and planned facilities in the SF management program described. The existing facilities include both operational facilities and laboratories, i.e. facilities for research, development and demonstration. Finally is SKB:s plans for licensing of new facilities described.

4.2. Facilities in operation

Central interim storage facility, Clab

The spent nuclear fuel is interim-stored in water pools in a central interim storage facility (Clab) at the nuclear power plant in Oskarshamn. The facility was put into service in 1985.

Clab consists of a receiving section at ground level where transport casks with the spent fuel are received and the fuel is unloaded under water.

The actual storage chamber consists of two rock caverns whose roofs are 25–30 metres below the ground surface. Each rock cavern is approximately 120 metres long and contains five pools. The water in the pools serves both as a radiation shield and a cooling medium. The top end of the fuel is eight metres below the water surface. The radiation level at the edge of the pool is so low that the personnel can stand there for an unlimited time.

Operation of Clab has from the beginning proceeded according to plan. The release levels lie far below the limit values set by the authorities, and the radiation doses to personnel and contractors have also been very low.

Clab has been expanded in recent years. The second rock cavern was completed at mid-year 2004 and is scheduled to be taken into service during 2007.

At year-end 2005 there was a total of more than 4,200 tonnes of spent nuclear fuel (counted as uranium) in the facility. Clab received approximately 256 tonnes of spent nuclear fuel from the Swedish nuclear power plants during 2005. The total storage capacity is 8,000 tonnes of fuel: 5,000 tonnes in the original pools and 3,000 in the new ones.

The waste transportation system

In Sweden, nuclear waste shipments go by sea, since all nuclear power plants and nuclear waste facilities are situated along the coast. The transportation system consists of the ship m/s Sigyn, a number of transport containers/casks and vehicles for loading and unloading. The system has been gradually built out and augmented since the start of operation in 1982.

The transportation system is used for LILW as well as spent fuel. Low-level waste does not need any radiation shielding. It can therefore be transported in ordinary freight containers. Intermediate-level waste, on the other hand, requires radiation shielding and is embedded in concrete at the nuclear power plants. The waste then is shipped in transport containers with 7–20 centimetre thick walls of steel, depending on how radioactive it is. The spent fuel is shipped in transport casks with approximately 30 centimetre thick steel walls. These casks are also equipped with cooling fins to dissipate the decay heat.

Normally m/s Sigyn makes between 30 and 40 trips per years between the nuclear power plants and Clab or SFR. The ship is also chartered out for other heavy shipments.

4.3. Facilities for research, development and demonstration

Much of the research and development for encapsulation and final disposal of spent nuclear fuel needs to be done on a full scale and in a realistic setting. SKB has therefore built two laboratories – the Äspö HRL (Hard Rock Laboratory) and the Canister Laboratory – to carry out different research and development projects. The results of these projects will provide a basis for designing the deep repository and the encapsulation plant, as well as for safety analyses.

Äspö HRL

The Äspö Hard Rock Laboratory, which was built during the period 1990–1995, is situated on the island Äspö north of the Oskarshamn Nuclear Power Plant. The purpose of the HRL is to enable research, development and demonstration to be done in a realistic and undisturbed rock environment down to repository depth. The underground laboratory consists of a tunnel from the NPP site (the Simpevarp Peninsula) to the southern part of the island of Äspö, where the tunnel runs in a spiral down to a depth of 460 metres. The total length of the tunnel is 3,600 metres. At ground level there are office buildings, workshops, laboratories and premises for information activities that have gradually been built out.

The role of the Äspö HRL has changed in recent years from developing methods for rock investigations to developing methods for construction and operation of the deep repository. The first goal of the activities at the laboratory has thereby been achieved. The next step is to carry out the following tasks:

- Develop and demonstrate methods for construction and operation of the deep repository.
- Test alternative technology that can improve and simplify the design of the deep repository without compromising its high quality and safety.
- Improve our scientific understanding of the deep repository's safety margins and gather data for assessments of long-term safety.
- Train personnel for execution of various parts of the deep repository project.
- Provide information on technology and methods that are being developed for the deep repository.

The activities at the Äspö HRL, which are largely being pursued in collaboration with other countries, are planned to continue until the initial operation of the deep repository is concluded. The evaluation of the results of initial operation and of ongoing experiments in the Äspö HRL will serve as a basis for an application for a licence for regular operation of the deep repository. An important role for the Äspö HRL in this perspective is therefore to conduct long-term experiments where different aspects of the function of the deep repository are tested over a long period of time, in some cases 15–20 years.

Activities are being conducted within the following areas:

- Natural barriers (mechanical, hydrological and chemical properties of the rock).
- Engineered barriers (buffer and backfill).
- Deep repository technology (rock extraction, design, handling technology).

For more information about the experiments and development projects being pursued in the Äspö HRL, please contact the SKB webb site http://www.skb.se

The Canister Laboratory

The Canister Laboratory, situated in the harbour area at Oskarshamn, was built during the period 1996–1998. One of the old welding halls, which was used for shipbuilding, has been converted for the development of sealing technology for the copper canisters. It is used mainly for the development of equipment for welding of copper lids and bottoms and for nondestructive testing of the welds. Equipment and systems for handling of fuel and canisters in the future encapsulation plant are also tested and developed in the Canister Laboratory. Another purpose of the activities is to train personnel for commissioning of the encapsulation plant. The Canister Laboratory is therefore intended to remain in use until the encapsulation plant is put into operation.

There are stations in the Canister Laboratory for testing different welding techniques and different methods for nondestructive testing. The goal is to develop methods that meet the stipulated quality requirements and have sufficiently high reliability to be used in the encapsulation plant. The most important items of equipment in the laboratory are an electron beam welder, a friction stir welding and an ultrasonic testing machine.

SKB has developed two welding methods in parallel: electron beam welding (EBW) and friction stir welding (FSW). The different methods differ in terms of the properties and quality of the welds. The nondestructive testing methods must therefore be adapted depending on whether the welds were made by EBW or FSW. FSW is the reference method at the encapsulation plant.

4.4. Planned facilities

With Clab, SFR and the transportation system, SKB can already manage the radioactive waste from the nuclear power plants today. The additional facilities that are needed for disposal of the spent nuclear fuel in a manner that is safe even in a long-term perspective are an encapsulation plant for encapsulating the fuel in copper canisters and a deep repository where the encapsulated fuel can be permanently emplaced. A transportation system designed to serve these facilities is also needed.

Encapsulation plant

The work of planning and designing the encapsulation plant has been going on since the end of the 1980s. Fabrication of the copper canisters is separate from the encapsulation plant. In the encapsulation plant, the spent nuclear fuel is placed in copper canisters. The facility is designed for sealing of up to 200 canisters per year.

The encapsulation process begins with lifting of the fuel from the pools in the encapsulation plant to a radiation-shielded handling cell. There it is dried and placed in the canister. When the canister is full, a copper lid is welded on. Then the quality of the weld is checked by nondestructive testing. If the weld is not approved, either it is redone or the fuel assemblies are transferred to a new canister.

After the filled and sealed canister has been approved, it is examined externally to make sure it is clean. If the canister should be contaminated with radioactivity, it is washed and re-examined. When the canister has been approved, it is placed in a transport cask and taken to the deep repository to be deposited.

Siting

SKB's main alternative is to build the encapsulation plant adjacent to Clab so that it can be coordinated with existing activities. The spent fuel can then be transferred directly from the storage pools in Clab to the pools in the encapsulation plant. At Clab there are also personnel with expertise in and experience from radiological work.

On 8 November 2006 SKB applied according to the Nuclear Activities Act for a licence to build and operate the encapsulation plant adjacent to Clab. Further application according to the Nuclear Activities Act for the final repository and the application according to the Environmental Code for both the encapsulation plant and the final repository is planned to year 2009. An EIS is appended to the applications. The licences, according to both laws, is planned to be received earliest in year 2011.

Final repository

The final repository consists of two parts: a surface facility and an underground facility. The surface facility is a medium-sized industrial complex. Besides offices and personnel quarters there is also a factory for fabricating the bentonite blocks that will be used to line the deposition holes and a receiving section for transport casks with copper canisters.

In its basic configuration, the underground repository consists of a descent tunnel, shaft, central area and a number of deposition tunnels. Each deposition tunnel contains a number of vertical holes in which the copper canisters with the spent nuclear fuel will be emplaced. The location of the deposition tunnels, as well as the spacing between the deposition holes, is determined above all by the consideration that the temperature on the canister surface may not exceed 100°C.

The canisters with the spent nuclear fuel are brought to the deep repository in transport casks, which also act as radiation shields. They also protect the canisters in the event of an accident. The transport casks are driven underground by electric trucks.

There the canisters are transferred to a deposition machine. The machine, which is remotecontrolled and radiation-shielded, drives up to the hole where the canister is to be deposited and lowers it into the hole. The deposition hole has first been lined with rings of bentonite clay. When all the holes in a deposition tunnel are full, the tunnel is backfilled with a mixture of bentonite clay and crushed rock. The main access tunnel is also backfilled when all fuel has been deposited.

An alternative layout of the KBS-3 repository, which has been a part of the picture since the early 1990s, is horizontal deposition. In this case the canisters are emplaced in long horizontal holes instead of short vertical holes. The volume of extracted rock and backfill in the deep repository would then be greatly reduced, since deposition tunnels are not needed. Development of rock drilling technology has now come so far that this layout is an interesting alternative to vertical deposition. Development of horizontal deposition, KBS-

3H, will therefore be conducted in parallel with the work on vertical deposition, KBS-3V, for the next few years.

Siting

The work of finding a suitable site for the repository goes on. In 2002, site investigations were commenced in the municipalities of Östhammar and Oskarshamn. The selected sites are situated near the Forsmark and Oskarshamn nuclear power plants.

The site investigations are carried out in two stages. In the first stage limited efforts are made to determine whether a site is still considered suitable when data from great depth are available. This first stage was finished in 2005, and preliminary safety evaluations have been made on the basis of the available data. These are followed by complete site investigations. They will provide the data needed for site specific repository design and safety assessment. During the investigation phase, descriptive models are devised for geology, groundwater flow and biosphere on each site. These models serve as a basis for assessing the long-term safety of the deep repository. The investigations are expected to be finished in 2008.

The principal aim of the site investigation is to provide the basis for applications to build and operate a final repository at one of the two investigated sites. The applications are planned to be submitted in 2009 (see below).

SKB's goal for the site investigation phase is to obtain the permits that are needed to site and build the deep repository and the encapsulation plant. For the deep repository, the construction phase will then be able to be commenced on the selected site. A primary task for SKB is now to assemble supporting material for the applications, carry out consultations and prepare environmental impact statements (EISs) in compliance with the requirements of the law. Permit or permissibility review takes place primarily under the Nuclear Activities Act, the Environmental Code and the Planning and Building Act. An EIS will be appended to the applications. This document shall identify and describe the direct and indirect effects which the planned activity may have on man, the environment and society. The scope of the EIS is arrived at within the framework of the consultations that are held.

4.5. Restrictions and uncertainties

There are a number of risks connected with spent nuclear fuel programme, risks that if they are realized would delay or even stop the project. The most important risks are briefly described below.

Prolonged processing time for applications

SKB applied on 8 November 2006 according to the Nuclear Activities Act for a license to build and operate the encapsulation plant adjacent to Clab, the central interim storage facility for spent nuclear fuel. Further applications, according to the Nuclear Activities Act for the final repository and according to the Environmental Code for both the encapsulateion plant and the final repository, is planned to year 2009.

The licences, according to both laws, are planned to be received earliest in year 2011. The application procedure for this type of facilities is however entirely untested. This is especially so as a principally new legislation involving the new Environmental Code was introduced during the 1990s.

The examination of all application documents may require more time than expected today, the court proceedings may take long time as they are also open for the public. Finally, given that licences will be decided there may be an extensive scope for appeals against the decisions.

There are accordingly many possibilities that the processing time for applications will be longer than expected.

▶ *Extended RD&D requirements*

SKB's permit submissions 2006 and 2009 is the result of about 30 years research and development. During this period a large number of questions have been examined and clarified. One major development stage was reached earlier this year when it was been confirmed that the copper canister welding method works as intended and that the canister can withstand the powerful pressures that may arise during future ice ages. SKB is confident that it is now time to conclude the development process.

Also during the last few days, however, research fields have been identified that may increase the safety margins for the final repository. These include e.g. the effect of the heat from the spent nuclear fuel on the rock, and the long-term function of the bentonite clay surrounding the canisters. A number of important research efforts have to be undertaken during the next years. It is then important that they can be finalised within time and with a clear result.

▶ *Loss of public confidence*

SKB has now been working in the site investigation regions for more than 10 years. We feel that the residents generally have trust in our work. SKB has occasionally commissioned opinion polls on people's attitudes towards a deep repository. One of the clearest tendencies is that people with the most knowledge about SKB and the deep disposal method are the ones who are the most positive. This is particulary clear in the municipalities where we have performed feasibility studies and where the issue has been discussed for a long time. Around two thirds of the people in Oskarshamn and Östhammar are in favour of building a deep repository if a suitable site will be found in their municipality. This is a confidence in our project that must be maintained.

One challenge is that we have to maintain a positive public interest in our project during the whole, extended consultation period. We have to continue to keep up the public interest in our project. The residents in the site investigation municipalities must look upon SKB as a natural and obvious part of the community.

It is necessary for us to inform and educate people constantly about the nuclear waste project. There will be two regular elections to the Parliament and to the municipal councils during this period. Before our applications are filed and decided on, many of the politicians, officials and other decision-makers who have been working with the project will withdraw. They resign, move from the region or take up positions in other fields. New and not so well-informed people replace them. We must inform and educate the newcomers.

The same is true for many of the residents in the site investigation municipalities. For example, the schoolchildren, who are now attending secondary schools, may belong to the electorate, if a local referendum about a deep repository is arranged around year 2010.

We cannot afford to lose public participation in the project. If we do, we will be back to square one when we finally submit our applications.

There is, today, insignificant opposition against our project. We know, however, that the potential for conflict can flare up. The Environmental Code provides the opportunity for all concerned to question our EIA work formally, and we know for a fact that when it is time to hand over our permit applications, the project will be in the spotlight again.

Several environmental organisations are opposing the nuclear waste program and are actively campaigning against it. This is to a large extent related to their views on nuclear power, and they are using the radioactive waste as an argument against the use of it.

Certain environmental organisations have the possibility to apply for economic support to their participation in the consultations concerning the encapsulation plant and the final repository. They are driving a strong campaign towards the people in the site investigation regions, aiming to call the repository project in question.

4.6. R&D

The goal of the research being conducted by SKB on longterm safety is to understand the processes that occur in a final repository. Many research projects are being conducted in the Äspö HRL. Others are being carried out in cooperation with organizations, universities and colleges in Sweden and abroad.

There is a constant interplay between safety assessment, research and technology development. The primary purpose of the safety assessment is to find out whether the deep repository satisfies the safety requirements of the regulatory authorities in the long term. But the results of the assessment also help us to formulate requirements on the bedrock where the deep repository will be built, to design the engineered barriers and – last but not least – to prioritize among our research activities.

At the end of September, SKB submitted the most recent programme for research, development and demonstration, RD&D 2004, to SKI. An account is given of the activities that are required for us to dispose of the radioactive waste in a safe manner. The programme focuses on spent nuclear fuel and the emphasis is on development of technology in preparation for the applications for permits to build the encapsulation plant and the final repository. The most important research areas are enumerated below.

- *Fuel dissolution.* In parallel with the model for fuel dissolution that is used in the interim safety assessment (SR-Can), a less conservative model is being developed.

- *Canister strength.* Experiments are being conducted with creep in copper.

- *Corrosion of copper and iron.* Corrosion of copper and cast iron continue to be priority areas. The importance of surface films on copper is being studied and experiments are being conducted to see how bentonite influences iron corrosion.

- *Model for damaged canister.* Demonstration experiments are being conducted on Äspö to confirm that the evolution of a damaged canister takes place in the predicted direction.

- *Resaturation of buffer and backfill.* Results from experiments on Äspö and laboratory experiments are being used to test resaturation models.

- *Composition of buffer and backfill.* Naturally swelling clay is currently a main alternative for backfilling. It has better properties than the previous solution involving a mixture of bentonite and crushed rock.

- *Gas transport through the buffer.* Lasgit (Large Scale Gas Injection Test) is being carried out at Äspö.

- *Groundwater flow.* Together with Finnish Posiva, SKB has started a project with the goal of developing a new model for calculating the transport of radionuclides in rock.

- *Rock movements.* Work is continuing on determining whether rock fractures at different places in the repository can be accepted considering the possibility of earthquakes.

- *Geochemical stability.* The consequences of the changed geochemical conditions during a glaciation are currently being studied.

- *Future climate.* Models that describe ice sheet movements, shoreline displacement and permafrost evolution are being tested for later use in determining how the conditions caused by climate variations can affect the barriers and safety of the final repository.

- *Biosphere model.* New computer codes will be used for calculations using data from the sites.

4.7. Safety and licensing

As is already mentioned above has SKB in November 2006 applied according to the Nuclear Activities Act for a licence to build and operate the encapsulation plant adjacent to Clab. In 2009 SKB plans to make a further application according to the Nuclear Activities Act for the final repository and an application according to the Environmental Code for both the encapsulation plant and the final repository. An EIS will be appended to the applications.

A safety assessment will also accompany the permit applications for the final repository in 2009. It will be a very important decision base. The long-term safety of the repository is examined and evaluated by means of the safety assessment. The first step is to describe the initial state of the repository, after which possible long-term changes are explored, and finally the consequences for man and the environment are described. Knowledge regarding long-term changes is obtained from the research, whose purpose is to support the safety assessment and furnish it with the necessary models and data. Input data for the safety assessment are also obtained from the investigations of possible repository sites and the details of the technical systems. Conversely, the needs of the safety assessment drive the need for research in the field and are essential for both design studies and site investigations.

The safety assessment utilizes models that are developed in the research work and devises special modelling tools for integrated modelling. The repository's evolution is simulated by system models. Transport of released radionuclides is calculated using both numerical and analytical models.

An interim safety report was presented in the autumn of 2006 together with the permit application for the encapsulation plant. It is the first safety assessment that is based on data from the site investigations. The project is called SR-Can and will later be followed by SR-Site, aimed at the deep repository application in 2009.

5. Costs and financial aspects

5.1. Financing system

Already from the start of nuclear power production in Sweden, the licensees set aside means for waste management in internal funds. In the early 1980's, the Riksdag resolved to implement a special financing system for the future expense s for the safe management of spent nuclear fuel and for the decommissioning and dismantling of nuclear reactors. In accordance with the financing system, nuclear power utilities pay a special fee to the Swedish state. The size of the fee is based on a certain amount per kWh of electricity delivered by the nuclear power plants. The nuclear power utilities are entitled to reimbursement, on a continuous basis, for any expenses which they have already incurred for measures to achieve the safe handling and disposal of spent nuclear fuel. The remainder of the funds are accumulated for future needs.

According to the Financing Act (1992:1537) shall a reactor owner, in consultation with other reactor owners, calculate the costs for disposal of the spent fuel and radioactive waste and for decommissioning and dismantling of the reactor plant. The reactor owner shall annually submit to the regulatory authority the cost data that are required for calculation of the fees to be imposed on electricity production during the ensuing year and of the guarantees that must be given as security for costs not covered by paid-in fees. The reactor owners have jointly commissioned SKB to calculate and compile these costs. The estimates of future cost are based on SKB's current planning regarding the design of the system, including the timetable for its execution.

The fees vary from owner to owner. During 2006 the fee varies between 0,6 and 1.2 öre per nuclear kWh produced, depending on how long the reactors at the different power plants have been in operation.[2]

Paid-in fees are transferred to the *Nuclear Waste Fund*, whose assets are deposited in an interest-bearing account at the National Debt Office or invested in treasury bills. The reactor owner is entitled to obtain compensation from the fund for waste disposal and certain other costs stipulated in the Financing Act.

During 2005, about SEK 689.1 million was paid into the Fund. Costs during the year amounted to about SEK 1,013.4 million, most of which comprised reimburse ment to the reactor owners. As of the time that both fi nancing systems entered into force and up to 2005, about SEK 26,264.9 million was paid in to the Fund. At the same time, other income (mainly financial

[2] 100 öre= 1swedish Krona. For caomparison, 1 EUR= 9.07 SEK (1 december 2006).

income in the form of interest and capital gains with a deduction for capital losses) amounted to about SEK 26,716.3 million. The expenses, largely in the form of reimbursement to the reactor owners, amounted to about SEK 18,164.3 million during the same period.

The capital of the Nuclear Waste Fund (the book value) amounted to about SEK 34,816.3 million at yearend 2005. In addition to this, unrealized gains on financial fixed assets amounted to about SEK 4,236.3 million. The market value of the Fund at year-end was therefore estimated at SEK 39,052.6 million. Of this amount, about SEK 784.0 million in provisions were made for the future expenses of the management of the waste from Studsvik.

5.2. Estimated costs

The plan drawn up by SKB for the management system, which gives different investment and operating phases as well as design-basis data for the facilities, is based on historical production data and currently prevailing conditions as well as forecasts of future events. The forecasts are based essentially on the reactor owners' planning for future reactor operation.

Two cases have been put forth by SKB and SKI in recent years as a basis for fees. They are here called case A and case B and are based in the following assumptions.

Case A refers to a decommissioning plan for the reactor plants that relates to a mean operating time of 40 years and where variation analyses are performed with respect to this operating time. The condition pertains solely to the scheduling of the decommissioning date for the reactor plants and does not influence the so-called "earning time" stipulated in the Financing Act,

Case B refers to a decommissioning plan for the reactor plants that relates to a foreseen shutdown coinciding with the expiry of the so-called earning time of 25 years as defined in the Financing Act. No variation analyses are performed of the shutdown dates (fixed premise).

Cases A and B represent two different cost levels for decommissioning and for the final repository for the decommissioning waste. The amounts are shown in Table 5-1.

Since it is only the decommissioning timetable that distinguishes the two cases, the quantity of fuel and radioactive waste to be disposed of is the same. The other costs for the facilities are therefore the same in both cases.

The Fionancing Act is currently under revision. The new legislation will probably agree more with Case A above.

6. Public opinion and communication

SKB's task to manage and dispose of the radioactive waste from the Swedish nuclear power plants also includes keeping people informed about what we are doing today and what plans we have for the future. Information activities are of course particularly intense in Oskarshamn and Östhammar municipalities where site investigations are being conducted. SKB's information officers there have regular contact with both permanent and part-time residents in the investigation areas. Other municipal inhabitants are reached via outreach activities, open house evenings and written information. The statutory consultation meetings are additional forums for communication.

To reach a wider public with information, SKB also produce a large number of reports and information publications. They can be requisitioned via our website at www.skb.se

Object and cost category	Future costs acc. to reference scenariowith operation of reactors for 40 years MSEK	MSEK	Basis for fees acc. to Financing Act[1]) MSEK
SKB adm. and RD&D	4,880	4,880[2)]	4,920
Transport		2,430[2)]	1,590
investment	1,280		
operation and maintenance	1,150		
Decommissioning NPPs		14,860	14,840 (A)
operation at shutdown reactor units	1,700		16,680 (B)
decommissioning	13,160		
Clab		4,370[2)]	4,370
investment	1,090		
operation and maintenance	2,820		
decommissioning	460		
Encapsulation plant		8,010[2)]	7,590
investment	2,040		
operation and maintenance	5,780		
decommissioning	190		
Deep repository – off-site facilities		260[2)]	280
investment and operation	260		
Deep repository – siting, site investigations	700	700[2)]	810
Deep repository – operating areas			
(above-ground fac.)		5,350[2)]	5,010
investment	1,850		
operation and maintenance	3,390		
decommissioning	110		
Deep repository – spent fuel		9,280[2)]	7,570
investment	4,940		
operation and maintenance	1,190		
decommissioning and backfilling	3,150		
Final repository for long-lived LILW		670[2)]	890 (A)
investment	420		880 (B)
operation and maintenance	140		
decommissioning and backfilling	110		
Final repository for reactor waste – SFR 1		470[2)]	0[3)]
investment			
operation and maintenance	470		
decommissioning and backfilling			
Final repository for decomm. waste – SFR 3		990[2)]	1,060 (A)
investment	560		1,000 (B)
operation and maintenance	210		
decommissioning and backfilling	220		
Total		49,600 47,700 (B)	46,500 (A)

1) The quantity of spent fuel and radioactive waste is limited to the amount which is estimated to arise through 2004 or at least during 25 years of operating time for each reactor. An allowance for uncertainties is also included.
2) Also includes costs financed outside the Financing Act.
3) Decommissioning costs for SFR 1 are included in SFR 3, other costs for SFR 1 are assigned to operation of Clab.
(A) Alternative where the decommissioning date is controlled by the reference scenario's operation of the reactors for 40 years.
(B) Alternative where the decommissioning date is controlled by a shutdown of the reactors coinciding with the end of the earning time given in the Financing Act (25 years).

Also the regulatory agencies, SKI and SSI, are providing information about the nuclear waste management program in public meetings and in information publications.

6.1. The siting programme

A conclusion from the first years of siting work was that the strong political power of municipalities in Sweden concerning local issues and the special character of the nuclear waste issue implies a need for clear local understanding and support if SKB would be able to site and operate a repository. To obtain such understanding it was judged necessary to create a participatory and voluntary process. This approach was strongly supported by almost all stakeholders and also by the government.

With time a siting process encompassing three steps has been agreed on in the stakeholder discussions. It has also been approved by the government. The first step includes general siting studies. These studies was carried out to help identify areas which are of interest for more detailed investigations in order to locate a site for the disposal of nuclear waste.

The second step, feasibility studies in 5 – 10 municipalities, aims to determine whether areas may exist in the municipalities that are of interest for further studies. Finally, in the third step is site investigations made in at least two municipalities. This step involves a more detailed technical investigation of the bedrock.

It is not until after site investigations and prior to detailed characterisation on the main candidate site that the main decision on siting of the deep repository is made.

6.2. Feasibility studies

Actual siting work on the deep repository began in 1993, when the first feasibility study was started in Storuman. It was soon followed by a study in Malå. Both municipalities are located in the north of Sweden.

In the feasibility studies all experiences gained from the earlier studies were used and developed. One very important contribution to the process was that the local municipalities set up formal review teams with the explicit task of following and assessing SKB's work and proposals. The review teams were appointed by the municipal boards, which thereby assumed the responsibility of representing their residents and serving as counterparts to SKB in the discussions.

A neutral, trusted player was thereby introduced in each municipality, and the role division became clearer. The municipal review teams were given the mandate to question SKB's work and to request supplementary studies and investigations.
After completion of the first two feasibility studies, local referenda were held on the possible continuation of the siting studies. About 70 % of the Storuman votes in 1995 were against continuation, as were about 54 % of the votes in Malå in 1997. SKB immediately discontinued the siting work in the two municipalities.

When the feasibility studies in northern Sweden were completed SKB turned south and initiated discussions with a number of municipalities with nuclear installations or with such installations in the vicinity. The discussions led to the commencement of three feasibility studies in

Östhammar, Nyköping and Oskarshamn. They were later supplemented by feasibility studies in Tierp, Hultsfred and Älvkarleby. The results of all six feasibility studies were published at the end of 2000.

Based on a comprehensive analysis of the reports from the feasibility studies and other studies, SKB at the end of 2000 proposed further site studies scheduled to begin 2002 in three of the municipalities (Oskarshamn, Östhammar and Tierp). The proposal was thoroughly examined by government organisations and other key players, and the government subsequently approved it. In accordance with the volunteer principle, however, an approval from the proposed municipalities was also asked for. The municipal boards of Oskarshamn and Östhammar decided with strong majorities to approve the planned site investigations, while the Tierp board decided to withdraw from further investigations.

6.3. Site investigations and statutory consultations

In 2002, SKB started site investigations at Simpevarp in Oskarshamn municipality and Forsmark in Östhammar municipality. The investigations are extensive and concern for instance the properties of the rock by means of measurements from the surface and in 1,000-metre deep boreholes. A safety assessment will be performed based on these data. An inventory is also conducted of natural and cultural values in these areas, as well as studies how a final repository will affect the community. Furthermore, a hypothetical facility is being tailored specifically to the particular site as regards bedrock, groundwater, environment and the viewpoints expressed in consultations with affected parties (see below).

The site investigations are carried out in two stages. In the first stage limited efforts are made to determine whether a site is still considered suitable when data from great depth are available. This first stage was finished in 2005, and preliminary safety evaluations have been made on the basis of the available data. These are followed by complete site investigations. These will provide the data needed for site specific repository design and safety assessment. The investigations are expected to be finished in 2008.

SKB has worked for many years with information and dialogue in the areas where we operate, and we are continuing and intensified these efforts during the site investigations.

Both the Nuclear Activities Act and the Environmental Code stipulate requirements on environmental impact assessment, EIA, for the two facilities as well as a consultation process where everyone who may be affected by the future activities has an opportunity to say what they think.

The consultation procedure, for applications under both the Environmental Code and the Nuclear Activities Act, is regulated by Chapter 6 of the Environmental Code. In the case of an activity that requires a permit pursuant to the Environmental Code, consultations shall be held with the County Administrative Board, the supervisory authority and any individuals who are likely to be affected.

In the case of certain types of activities, for example nuclear activities, consultations shall also be held with other national authorities, local authorities, private citizens and organizations that are likely to be affected. The further along we come in the site investigations, the more parties are invited into the process.

The result of the EIA process, an environmental impact statement (EIS), is supposed to describe what consequences the planned activities may have for human beings and the environment. It is also supposed to explain how these consequences can be prevented or mitigated. According to the Environmental Code, the consultations shall cover the siting, scope, design and environmental impact of the planned activity, as well as the form and content of the EIS.

The consultation process commenced in 2002 and will continue until the permit applications are submitted. About 35 consultation meetings were held during 2002-2005. Detailed descriptions of the consultations during 2003 – 2005 is given in the report Consultations according to the Environmental Code. Compilation 2005, which can be downloaded from the SKB website at www.skb.se

The consultation meetings for both the encapsulation plant and the final repository will continue up to the applications in 2009. One or two public meeting per year will be held in Oskarshamn as well as in Forsmark. In addition, one "summer meeting" will be held at each place once per year. Next public meeting is planned in late spring 2007.

Both the so-called Oskarshamn EIA Forum and Forsmark Consultation and EIA group plan to have 3 - 4 meetings per year. These groups include representatives from SKB, SKI, SSI and the relevant County Administrative Board and municipality.

In the work with the environmental impact assessment, assessments are constantly being made of what environmental consequences the construction and operation of a final repository may have on human health and the environment. These assessments should allow greater consideration to be given to the environment in the final repository project.

The actual construction work can give rise to noise, traffic and air pollution. In a broader perspective we are also looking at how nature and the environment around the final repository may be affected and whether human use of the landscape may be changed.
The assessments are important inputs for the consultations. The results are discussed and further investigations and clarifications are often requested from the public.

It is also clear that the final repository can have effects on the community at large. SKB is therefore conducting a societal programme which is focusing on the importance of the final repository for the local population, the district and the region. The societal programme includes both studies and independent research projects.

The social science research is presented in a special yearbook that can be downloaded from SKB's website, www.skb.se

6.4. Local information

The site investigations for the final repository require a close dialogue with everyone who is in any way affected by the activities. SKB have regular contact with the landowners where the investigations are conducted. In addition, different types of nearby resident meetings are arranged for the purpose of information and goodwill, along with field visits to present and obtain viewpoints on suggested locations of the final repository's above-ground facilities. A SKB newsletter is sent regularly to everyone who lives in Misterhult parish in Oskarshamn, as well as to nearby and part-time residents in the Forsmark area, with information about the site investigation, the field activities and current events.

SKB also tries to meet with other municipal residents as often as possible in other contexts (for example at municipal workplaces, schools, businesses and private associations) to provide information on and discuss the nuclear waste programme and ongoing site investigations.
The contact with nearby residents is important. In Oskarshamn, for example, SKB held a meeting in 2005 with the municipal Misterhult Group dealing with private wells. Personnel from Oskarshamn NPP also participated at this meeting. They talked about the tests of agricultural and fishery products that are performed regularly in accordance with SSI's guidelines. The local road network has been discussed in various contexts. SKB has conducted a conceptual study with a focus on the road's use today and in the future. The results were presented to the residents of Misterhult.

In Forsmark, nearby residents are invited to information get-togethers where questions concerning the ongoing site investigations are brought up. These gatherings are well-attended, which we greatly appreciate since our day-to-day work goes smoother if many people know what we are working on and why.

Four issues of SKB's information magazine Lagerbladet are published during a year. It is distributed to all households in the concerned municipalities and other interested persons can subscribe to it free of charge. The magazine discusses activities and subjects that are of current interest, directly or indirectly and particularly on the local level in the site investigation municipalities.

Websites for Oskarshamn and Forsmark can be accessed via SKB's website. They are updated regularly with information on SKB's activities and on past and planned events in the different municipalities.

During 2005, SKB's facilities were visited by more than 20,000 people altogether. In Forsmark, SFR and the visitor drilling site had nearly 9,000 visitors. Others, more than 11,000 persons, visited one or more of SKB's facilities in Oskarshamn (the Äspö HRL, Clab, the Äspö Path, the Canister Laboratory, the visitor drilling site and the field exhibition on Hålö).

The largest visitor category is school children; more than 6,000 pupils during the year. Approximately 5,000 of the visitors live or work in the municipalities of Oskarshamn or Östhammar. Many international visitors also come to the SKB facilities; the number in 2005 was 1,100.

Radioactive waste management in USA

J.Reig

5

1. Introduction. General overview

1.1. Nuclear energy programme

The U.S. includes two distinct lines regarding nuclear energy uses. One is resulting from Government activities, both military and research activities, and the other is the commercial uses of nuclear energy by private companies.

Regarding Government activities, the U.S. has a legacy of radioactive waste from past government activities and events spanning nearly five decades. A total of 114 sites covering more than two million acres of land are used by the U.S. Government for nuclear research and development and nuclear weapons production activities. Most of the land at these sites is not contaminated. Within the boundaries of these 114 sites are numerous radiological-controlled areas with thousands of individual facilities, encompassing 10,400 discrete contaminated locations.

The U.S. nuclear power industry comprises 4 reactor vendors (1 BWR vendor and 3 PWR vendors), 27 licensees, 80 different designs, and 65 sites. 104 commercial nuclear power reactors are licensed to operate in 31 States. The operating reactors have accumulated about 2,600 reactor-years of experience; permanently shutdown reactors have accumulated 385 additional reactor-years. Key programs and processes comprise a well-established licensing process, which includes power uprates and license renewal.

Requests for power uprates range from small increases to large increases in the range of 15 to 20 percent. The NRC has approved more than 100 power uprates, which have added approximately 4,179 megawatts electric — the equivalent of about four large nuclear power plants — to the Nation's electric generating capacity.

With the improved economic conditions for operating nuclear power plants, the Commission has seen sustained strong interest in license renewal, which allows plants to operate up to 20 years beyond their original 40-year operating licenses The original 40-year term was established in the Atomic Energy Act and was based on financial and antitrust considerations, rather than technical limitations.The NRC has issued renewed licenses for 15 sites, totaling 26 units, and is currently reviewing applications to renew the licenses for an additional nine sites (totaling 18 units). Judging by statements from industry representatives, the Commission expects virtually all sites to apply for license renewal.

1.2. Waste categorization

Spent fuel

In the U.S., spent fuel is fuel withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been chemically separated by reprocessing. DOE allows test specimens of fissionable material irradiated for research and development only, and not production of power or plutonium, to be classified as waste, and managed in accordance with DOE Order 435.1, when it is technically infeasible, cost prohibitive, or would increase worker exposure to separate the remaining test specimens from contaminated material.

Radioactive waste

The U.S. radioactive waste classification system has two separate subsystems. One classification subsystem applies to commercial waste and is defined in NRC regulations. The other classification subsystem applies to DOE waste.

The NRC regulations classified LLW in the commercial sector as Class A, Class B, Class C and Greater-than-Class C (GTCC) LLW. These classes are defined based on potential LLW hazards and disposal and waste form requirements. Class A LLW contains lower concentrations of radioactive material than Class B LLW, which has lower concentrations than Class C LLW. Table 5.1 compares the commercial waste classification structure to IAEA proposed waste classes.

Radioactive waste from DOE nuclear operations is classified as HLW, TRU waste, LLW, or mill tailings. Waste may also contain hazardous waste constituents. Waste with both radioactive and hazardous constituents in the U.S. is called "mixed" waste, e.g., mixed LLW or mixed TRU waste.

DOE manages waste from its operations using procedures and requirements comparable to those used by NRC for commercial waste. Both NRC and DOE approaches apply similar performance objectives. DOE does not use the NRC LLW classification system for its near surface disposal systems, however. DOE requires each LLW facility operator to conduct a performance analysis considering waste forms and characteristics, site conditions, and facility design. This analysis leads to specific waste acceptance criteria tailored to each of its LLW facilities. Table 5.2 compares DOE disposal classification to IAEA proposed waste classes. DOE uses the TRU waste class for long-lived, alpha emitting waste. Similar NRC regulated commercial waste falls in the GTCC LLW category.

U.S. radioactive waste has many designations for its hazards and the circumstances and processes in which it is created. Uranium mill tailings, the final byproduct of the uranium ore extraction process, are considered radioactive wastes. The day-to-day rubbish generated in medical laboratories and hospitals, contaminated by medical radioisotopes, is also designated radioactive waste. Tailings from industrial extraction of metals and minerals of value (such as molybdenum or vanadium) are not routinely considered radioactive waste, but the processor of tailings having elevated levels of natural radionuclides may be licensed by NRC. The laws also specify which chemical and physical forms are regulated and controlled, and also by which Federal or state entity.

Waste Class	U.S. Definition	IAEA HLW	IAEA LILW-LL	IAEA LILW-SL
HLW	The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste containing fission products in sufficient concentrations and other highly radioactive material that requires permanent isolation.	100%	0%	0%
Greater Than Class C (GTCC) LLW	Waste not generally acceptable for near-surface disposal is waste from which form and disposal methods must be different, and in general more stringent, than those specified in Class C waste. Such waste must be disposed of in a geologic repository.	0%	100%	0%
Class C LLW	Waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. Must meet both the minimum and stability requirements.	0%	25%	75%
Class B LLW	Waste that must meet more rigorous requirements on waste form to ensure stability. The physical form and characteristics must meet both the minimum and stability requirements. Concentration limits of certain short-lived radionuclides are higher than limits .	0%	0%	100%
Class A LLW	The physical form and characteristics must meet the minimum requirements. Concentration is limited in short-lived radionuclides or longlived radionuclides.	0%	0%	100%
Byproduct Material	Tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.	0%	0%	0%

Table 5.1. U.S. Commercial Radioactive Waste Classification Compared with the IAEA Proposed Classification for Disposal.

Waste Class	U.S. Definition	IAEA HLW	IAEA LILW-LL	IAEA LILW-SL
HLW	High-level waste is the highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste containing fission products in sufficient concentrations; and other highly radioactive material that require permanent isolation.	100%	0%	0%
TRU	Radioactive waste containing more than 3,700 becquerels (100 nanocuries) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20-years.	0%	100%	0%
LLW	Radioactive waste that is not HLW, spent fuel, TRU waste, byproduct material or naturally occurring radioactive material.	0%	0,5%	99,5%
Byproduct Material	The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed y for its source material content.	0%	0%	0%

Table 5.2. DOE Radioactive Waste Classification Compared with the IAEA Proposed Classification for Disposal.

1.3. Waste production: Current status and forecast

Radioactive waste treatment and storage

In the U.S. radioactive wastes are treated primarily to produce a structurally stable final waste form and minimize the release of radioactive and hazardous components. The U.S. does not commonly make a differentiation between the terms treatment and conditioning. Conditioning is defined in the international community as an operation producing a waste package suitable for handling, such as conversion of a liquid to a solid, enclosure of the waste in containers, or overpacking. Treatment is defined as operations intended to improve the safety and/or economy by changing the characteristics of the waste through volume reduction, removal of radionuclides, and change in composition. U.S. terminology covering both conditioning and treatment is generally referred to as treatment or processing.

Sector	Function	Waste/Material Type	Number	Inventory
Government	Storage/Treatment	HLW TRU LLW By product	8 16 25 2	356,000 m^3 136,000 m^3 104,000 m^3 206,000 m^3
Commercial	Treatment/Processing	LLW	44	Small volumes for collection

Table 5.3. Radioactive Waste Storage and Treatment Facilities.

Table 5.3 summarizes the U.S. radioactive waste treatment and storage facilities and the inventory in storage as of September 30, 2003.

Radioactive High Level Waste Disposal

DOE is preparing a license application for submission to receive authorization to begin construction of a repository at Yucca Mountain. The license application review by NRC is expected to take about three to four years. DOE will then begin construction of the repository and then apply to NRC for a license amendment to allow receipt and possession of waste (given adequate funding and successful completion of the licensing process). Spent fuel shipments could then begin arriving at the repository.

NRC continues to authorize licensees to store spent fuel in dry casks using NRC approved dry cask designs. Even when a geological repository becomes available, using ISFSIs for interim storage of spent fuel in the U.S will continue.

The U.S. HLW is planned to be disposed, along with spent fuel, in the planned geologic repository. The cumulative inventory of disposed radioactive waste September 30, 2004 is shown in table 5.4.

Sector	Facility Type	Waste Type	Number	Inventory
Government/ Commercial	Planned Geologic Repository (Yucca Mountain)	HLW (also Spent Fuel)	1	0
Government	Geologic Repository (WIPP)	TRU	1	24,000 m^3
	Closed Greater Confinement Disposal (boreholes)	TRU	1	200 m^3
	Near Surface Disposal	LLW	19	5,800,000 m^3
Commercial	Operating Near Surface Disposal	LLW (Class A, B, C)	3	2,660,000 m^3
		By product	1	1,010,000 m^3
	Closed Near Surface Disposal	LLW	4	438,000 m^3
Government/ Commercial	Title I UMTRCA Disposal	Residual Radioactive Material (tailings)	20	163,000,000 Metric Tons
	Title II UMTRCA Disposal	By product	39	
Government Commercial	Other Closed Disposal Cells (Weldon Spring Site and Monticello)	Residual Radioactive Material (tailings)	2	3,120,000 m^3

Table 5.4. Radioactive Waste Disposal Facilities.

Commercial low-level waste disposal

The commercial low-level waste management system in the U.S. provides adequate disposal capacity to waste generators. There remains uncertainty in the availability of disposal for Class B and C LLW after 2008, when the Atlantic Compact (South Carolina, New Jersey and Connecticut) plans to limit access to the Barnwell, South Carolina, site to generators outside the compact. Efforts by regional compacts to site new disposal facilities have been unsuccessful. The State of Texas received an application from Waste Control Specialists in 2004 for a new LLW disposal facility, near Andrews, Texas, for the Texas Compact (Texas and Vermont). Review of the application for this facility is continuing with the issuance of a license or denial projected for December 2007. Plans call for disposal of Class A, B, and C LLW in one cell, and possible disposal of DOE LLW in another cell. The U.S. Congress and government agencies continue to monitor the availability of commercial LLW disposal facilities to meet future needs, although opposition to new disposal sites for LLW waste makes it difficult to site new facilities.

Transuranic waste disposal

The Waste Isolation Pilot Plant (WIPP) is a geologic repository to safely and permanently dispose of TRU radioactive waste left from the research and production of nuclear weapons. WIPP began operations on March 26, 1999, after more than 20 years of scientific study, public input, and regulatory review.

WIPP is located in the remote Chihuahuan Desert of southeastern New Mexico, about 80 kilometers (50 miles) from Carlsbad, New Mexico. The repository consists of disposal rooms mined 655 meters (2,150 feet) underground in a 600 meter-thick (2,000 feet) salt formation. This formation has been stable for more than 200 million years. The TRU waste currently stored at 23 locations nationwide will be shipped to and disposed of at WIPP over the next 35 years. WIPP is expected to receive about 170,000 cubic meters of waste in 37,000 shipments. About 24,000 cubic meters of contact-handled TRU waste were disposed at WIPP as of September 30, 2004.

1.4. Decommissioning and remedial action program

Government sites with decommissioning/remediation projects

The U.S. Government continues to safeguard its nuclear materials, dispose of waste, remediate extensive surface and ground water contamination, and deactivate and decommission thousands of excess contaminated facilities. The Fernald Environmental Management Project, Fernald, Ohio, a former defense uranium processing plant, is now undergoing decommissioning and includes an on-site waste disposal cell. Some of the large decommissioning projects now in progress are:

- Brookhaven Graphite Research Reactor,
- Rocky Flats
- Plutonium Finishing Plant at the Hanford Site,
- Fast Flux Test Facility at the Hanford Site,

- East Tennessee Technology Park (formerly the Oak Ridge Gaseous Diffusion Plant), and
- Alpha-4 Building at Oak Ridge Y-12 Complex.

Work was performed at sites throughout the U.S. during the 1940s, 1950s, and 1960s as part of the nation's early atomic energy program. Some sites' activities can be traced back as far as World War II and the Manhattan Engineering District (MED). Other sites were involved in peacetime activities under the AEC. Most sites contaminated during the early atomic energy program were cleaned up under the guidelines in effect at the time. Those cleanup guidelines were generally not as strict as today's, so trace amounts of radioactive materials remained at some of the sites. Contamination was then spread to other locations, either by demolition of buildings, intentional movement of materials, or by natural processes.

DOE established the Formerly Utilized Sites Remedial Action Program (FUSRAP) in 1974 to study these sites and take appropriate cleanup action. When contamination is suspected at a site, old records are reviewed and the site is surveyed. Additional cleanup is authorized under FUSRAP if contamination connected to a MED or AEC activity is found. The Energy and Water Development Appropriations Act (1998) transferred responsibility of FUSRAP from DOE to the U.S. Army Corps of Engineers (COE). The contaminants at FUSRAP sites are primarily low levels of uranium, thorium, and radium, with their associated decay products. None of these sites pose an immediate threat to human health or the environment.

NRC developed a Site Decommissioning Management Plan (SDMP) in 1990 for timely cleanup of certain unusual and difficult sites, particularly those with high soil contamination or with old, contaminated buildings. The SDMP was originally created to develop a comprehensive strategy for achieving timely closure of decommissioning issues and to develop a list of contaminated sites ("SDMP sites") in order of cleanup priority. Forty-nine sites were originally identified as SDMP sites.

This comprehensive decommissioning program includes routine decommissioning sites, formerly licensed sites, SDMP sites, non-routine/complex sites, fuel cycle sites, and test/research and power reactors. There are now 39 complex decommissioning materials sites. NRC is committed to terminating one site each year from the list of complex material sites under decommissioning.

Commercial sites

NRC has regulatory project management responsibility for decommissioning 16 power reactors. NRC also provides project management and inspection oversight for the decommissioning of 20 research and test reactors. Currently, 13 research and test reactors have been issued decommissioning orders or amendments by NRC. Three research and test reactors are in "possession-only" status, either waiting for shutdown of another research or test reactor at the site or removal of the spent fuel from the site by DOE. One research and test reactor is preparing to submit a decommissioning amendment request, and one of the three research and test reactors in possession-only status still has fuel in storage at the reactor.

NRC provides project management and technical review for decommissioning and reclamation of facilities, including conventional uranium mills and in-situ leach (ISL) facilities and NRC-licensed [Uranium Mill Tailings Radiation Control Act (UMTRCA) Title II] sites in decommissioning.

NRC also provides licensing oversight and decommissioning project management for fuel cycle facilities, including conversion plants, enrichment plants, and fuel manufacturing plants. NRC continues to work closely with the states and EPA to regulate remediation of unused portions of fuel cycle facilities. One conversion facility (Honeywell) and two fuel manufacturers (Framatome Richland and General Atomics) continued some decommissioning in 2004, although all are still operating.

Sector	Type	Number
Government	DOE Nuclear/Radioactive Facilities for which Decommissioning is Ongoing or Pending	1186
Government/Commercial	Formerly Utilized Sites Remedial Action Program Sites (FUSRAP)	27
	Decommissioning Materials Sites	39
Commercial	Nuclear Power Plants	16
	Other Non-Power Reactor Facilities	20

Table 5.5. Summary of Decommissioning Activities in Progress.

2. Instituional framework

The Atomic Energy Commission (AEC) was the predecessor of current U.S. Government agencies governing nuclear activities.

The Atomic Energy Act of 1954 assigned AEC the functions of both encouraging the use of nuclear power and regulating its safety. AEC regulatory programs sought to ensure public health and safety from the hazards of nuclear power without imposing excessive requirements inhibiting the growth of the industry. The Atomic Energy Act of 1954 made development of commercial nuclear power in the private sector possible. The U.S. Government has actively promoted the development of commercial nuclear power and ensured its safe use ever since.

The U.S. Congress passed the Energy Reorganization Act of 1974 and redistributed the functions performed by the AEC to two new agencies. It created the Nuclear Regulatory Commission (NRC) as an independent agency to regulate private sector and non-military governmental nuclear power, and the Energy Research and Development Administration (ERDA) to promote energy and nuclear power development. ERDA was also responsible for defense nuclear activities. NRC was established as an independent authority governed by a five-member Commission to regulate the possession and use of nuclear materials as well as siting, construction, and operation of nuclear facilities. ERDA was established to ensure development of all energy sources, increase efficiency and reliability of energy resource use. It was also responsible for AEC military and production activities and general basic

research activities. Supporters and critics of nuclear power agreed promotional and regulatory duties of AEC for commercial activities should be assigned to different agencies.
NRC began regulatory operations in 1975. It performs its mission by issuing regulations, licensing commercial nuclear reactor construction and operation, licensing the possession of and use of nuclear materials and wastes, safeguarding nuclear materials and facilities from theft and radiological sabotage, inspecting nuclear facilities, and enforcing regulations. NRC regulates commercial nuclear fuel cycle materials and facilities, commercial sealed sources, including disused sealed sources. NRC is also responsible for licensing commercial nuclear waste management facilities, independent spent fuel management facilities, and the planned Yucca Mountain repository for disposal of high-level waste (HLW) and spent fuel. NRC also oversees certain state programs where NRC has relinquished limited regulatory authority to the individual states.

The Department of Energy Organization Act brought a number of the Federal government's agencies and programs, including ERDA, into a single agency, Department of Energy (DOE), which was made responsible for nuclear energy technology and nuclear weapons programs. DOE has added new nuclear-related activities for environmental clean up of contaminated sites and surplus facilities. DOE retains authority under the Atomic Energy Act of 1954 for regulation of its nuclear activities other than certain specifically designated facilities, such as the repository at Yucca Mountain. DOE is responsible for developing the planned Yucca Mountain site as a repository.

DOE is responsible for regulating the management of its radioactive waste and spent fuel, other than the disposal of HLW and spent fuel. DOE spent fuel and radioactive waste management receive oversight from DOE Office of Environment, Safety and Health (DOE-EH) and Office of Security and Safety Performance Assurance (DOE-OA).

DOE-EH performs independent technical reviews of facility nuclear safety authorization basis documents and the implementation process to ensure the establishment and maintenance of an adequate safety margin and the control of hazards resulting from DOE activities during routine and upset conditions for all facility life cycles. It also performs facility reviews, walk-downs, and personnel interviews to ensure actual facility conditions (including operations, where appropriate) are consistent with the authorization basis.

The Environmental Protection Agency (EPA) was created in 1970 to address a growing public demand in the U.S. for cleaner water, air, and land. EPA was assigned the daunting task of repairing the damage already done to the environment and established new criteria for a cleaner environment. Under its general authority, EPA establishes generally applicable environmental standards for the protection of the general environment from radioactive material. This authority establishes standards for cleanup of active and inactive uranium mill tailing sites, environmental standards for the uranium fuel cycle, and environmental radiation protection standards for management and disposal of spent fuel (SF), HLW, and transuranic (TRU) waste. EPA standards are implemented and enforced by other government agencies. EPA also regulates disposition of hazardous chemical wastes. EPA promulgates standards for and certifies compliance at the Waste Isolation Pilot Plant (WIPP) repository for the disposal of defense-related TRU waste. EPA standards limit airborne emissions of radionuclides from DOE sites managing defense-related spent fuel and radioactive waste under the Clean Air Act.

The Advisory Committee on Nuclear Waste (ACNW) was established in June 1988 to provide independent technical advice to NRC Commissioners on agency activities, programs, and key technical issues on NRC regulation, management, and safe disposal of radioactive waste.

The ACNW interacts with NRC, the Advisory Committee on Reactor Safeguards, other Federal, State, and local agencies, Indian tribes, the public, and other stakeholders to fulfill its responsibilities. The bases for the Committee's advice include the regulations for high-level waste disposal, LLW disposal, and other regulations and legislative mandates. The ACNW examines and reports on areas of concern as requested by NRC Commissioners and may undertake studies and activities on its own initiative, as appropriate.

The ACNW is independent of NRC and reports directly to the Commissioners who appoint its members. Advisory committees are structured to provide a forum where experts representing many technical perspectives can provide independent advice factored into the Commissioners' decision-making process. Most advisory committee meetings are open to the public and any person may request an opportunity to make an oral statement during the committee meeting.

Currently the individual States in the U.S. usually regulate the sources of radiation that NRC does not regulate. For example, naturally occurring radioactive materials (NORM) such as radium and radon, and radioactive materials produced in particle accelerators, such as cobalt-57, are regulated by the states rather than NRC. Radiation producing machines, such as particle accelerators and x-ray machines (both medical and industrial) are also regulated by the states.

The Office of Surface Mining of the U.S. Department of Interior and the individual states regulate mining of uranium ore. Other extraction mining and refinement operations for metals, phosphates, etc. may concentrate naturally occurring radionuclides in these tailings materials. Some mineral extraction processes (not for nuclear content) are specifically licensed by NRC, because they incidentally result from the use, or concentration, of material above 0.05 percent by weight source material. Identified processors are required to obtain a NRC license.

The U.S. Congress created the U.S. Nuclear Waste Technical Review Board (NWTRB) in 1987 to review DOE scientific and technical activities for management and disposal of the nation's spent fuel and HLW. NWTRB evaluates the characterization of Yucca Mountain, Nevada, as a potential repository site, as well as the packaging and transportation of commercial spent fuel and defense HLW.

The Nuclear Waste Policy Amendments Act authorized a board of 11 part-time members who are eminent in a field of science or engineering, including environmental, and social sciences, and selected solely on the basis of distinguished service. The National Academy of Sciences recommends candidates, and the President makes the appointments.

NWTRB makes scientific and technical recommendations to DOE to ensure a technically defensible site suitability decision and disposal program.

3. Management of low and intermediate level waste

Low activity waste

Management and disposal of "low-activity waste" (LAW) is receiving increased attention. The U.S. has no official legal definition for the term, "lowactivity waste," but it is a term frequently used by organizations involved in radioactive waste management. The National Research Council of the National Academies defined it as including all types of conventional low-level radioactive waste produced by generators in the nuclear fuel cycle, discrete sources, slightly contaminated solid materials, uranium and thorium ore processing wastes, and wastes containing technologically enhanced naturally occurring radioactive materials (TENORM).

EPA has been considering a rule that would permit disposal of certain types of "low-activity" wastes in the hazardous waste facilities it regulates. EPA has also discussed LAW in the broad context of radioactive wastes containing radionuclides in small enough concentrations to allow them to be managed in ways that do not require all of the radiation protection measures necessary for higher-activity materials.

One of the primary reasons LAW has become a focus of attention is the unusually large volumes to be managed in comparison to conventional LLW from the ongoing operations of nuclear facilities. DOE's cleanup program includes 75 million cubic meters of contaminated soil, and 20,000 buildings and structures. NRC reports more than a billion metric tons of TENORM waste are produced each year. Some of this waste contains very low levels of radioactivity and may not need special attention. Other TENORM waste streams require measures to manage their risks.

Hazardous waste facilities and municipal or industrial solid waste landfills are now used by U.S. generators for some LAW disposal.

LAW from remediation of sites and decommissioning is also affected by risk management decisions for the release of sites. LAW from contaminated sites may be allowed to remain onsite under certain circumstances, often after the more highly radioactive materials have been removed. DOE plans to leave residual radioactivity in place at many sites, and will require long term management (institutional controls) to ensure future use of the land is safe and barriers are functioning as intended.

Low level waste

Low-level waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, soil, debris, luminous dials, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissues. Radioactivity can range from just above background to very high levels, such as parts from inside the reactor vessel in a nuclear power plant. The U.S. has a comprehensive management system for most LLW. Commercial and government facilities exist for LLW processing, including treatment, conditioning, and disposal. Generators prepare LLW for shipment to licensed disposal.

LLW disposal volumes and radioactivity vary from year to year based on the types and quantities generated. The volume of operational commercial LLW has been decreasing over the years due to significant advances in volume reduction techniques to offset the high cost of disposal. Large volumes of LLW have been generated in recent years from facility decommissioning and site remediation. LLW specific activity has thus increased.

Commercial LLW disposal facilities are designed, constructed, and operated under licenses issued by either NRC or an Agreement State based on NRC health and safety requirements. NRC regulations restrict the waste disposal quantities, forms, and activity levels in commercial LLW facilities.

DOE operates disposal facilities for LLW generated in the government sector under authority of the Atomic Energy Act. DOE also uses commercial LLW disposal sites in certain circumstances.

LLW (Class A, B and C) is currently disposed in near surface facilities. A key factor in the LLW disposal requirements and waste classification system is protecting people during operations and later from their inadvertent intrusion. The design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls are removed. GTCC LLW is stored until an adequate method of disposal is established.

There are currently three active, licensed commercial LLW disposal sites; however, none can accept GTCC LLW. A license application for a fourth facility is pending:

- GTS-Duratek/Chem-Nuclear (Barnwell, South Carolina) -Access is currently authorized for LLW generators not limited or bound by compact rules, but plans to close to waste outside of the Atlantic Compact (South Carolina, Connecticut, and New Jersey) in 2008. Barnwell disposes of Class A, B and C LLW.

- U.S. Ecology (on DOE's Hanford Site near Richland, Washington) - restricted access to only the Northwest and Rocky Mountain Compacts. U.S. Ecology disposes of Class A, B and C LLW.

- Envirocare of Utah (Clive, Utah) - accepts Class A LLW and mixed LLW for LLW generators not limited or bound by compact rules.

- A license application is under review by the State of Texas for a new commercial LLW disposal site at Waste Control Specialists near Andrews, Texas. The proposed site includes a facility to dispose of LLW for the Texas compact and a facility to dispose of Federal mixed LLW and LLW. A licensing decision is not expected before December 2007.

Commercial LLW sites now closed are: Beatty, Nevada (closed 1993); Maxey Flats, Kentucky (closed 1977); Sheffield, Illinois (closed 1978), and West Valley, New York (closed 1975).

Table 5.6 provides a breakdown of LLW commercially disposed in 2004, a representative year. About 55 percent of the LLW commercially disposed is from government sources, including Federal, state and local governments. No commercial LLW is disposed in DOE (government) facilities, but DOE does dispose of LLW at both government and commercial facilities, when economical. Industry, including waste brokers and processors, accounts for 30 percent of the volume of LLW disposed commercially. Nuclear power plant operations generate 15 percent of the volume of waste disposed commercially, and about 0.1 percent is from academic and medical sources.

Source	Class A	Class B	Class C	Total
Academic	28	0	1.5	29
Government (from DOE)	258,000	0	0	258,000
Government (non-DOE)	17,613	20	26	17,659
Industry	35,491	7	15	35,513
Medical	1.6	0	0.7	2
Utility	55,391	385	447	56,223
Government Mixed LLW (from DOE)	8,900	0	0	8,900
All other Mixed LLW	273	0	0	273
Total	**376,000**	**412**	**490**	**377,000**

Table 5.6. Low-Level Waste Received at Commercial Disposal Sites in 2004 (volume in cubic meters)

Over 99 percent of the LLW volume disposed of at commercial sites was Class A LLW, most of which was disposed of at the Clive, Utah site, with the remaining volume split between the Barnwell, South Carolina, and U.S. Ecology, Richland, Washington, sites. Over 97 percent of Class B LLW and over 99 percent of Class C waste was disposed at the Barnwell site, with the remainder disposed at Richland.

DOE operates disposal facilities for LLW at: Hanford, Washington; Idaho National Laboratory, Idaho; Los Alamos National Laboratory (LANL), New Mexico; Nevada Test Site, Nevada; and Savannah River Site, South Carolina. DOE also operates LLW disposal facilities for waste from cleanup projects (generally large volumes with low concentrations) at Fernald, Ohio; Hanford, Idaho National Laboratory, and Oak Ridge, Tennessee.

There are also closed disposal facilities managed by DOE. One such facility is greater confinement disposal (boreholes) used to dispose of certain transuranic and other defense waste at the Nevada Test Site. There are closed burial grounds for LLW used decades ago for disposal of wastes resulting from defense activities, e.g., at Hanford, Oak Ridge, and Savannah River. Hydrofracture was once used at Oak Ridge, Tennessee, for disposal of waste in slate formations beneath the site.

In addition to the LLW facilities discussed above, U.S. waste generators also may use hazardous waste disposal facilities for disposal of waste with very low-levels of radioactive constituents. These facilities are designed to isolate hazardous waste substances from the environment, but are also effective in isolating radioactive constituents and may offer cost and efficiency benefits. Some sites are used for disposal of naturally occurring radioactive materials, and therefore already have procedures and features for ensuring safety of disposal of low activity radioactive waste. Waste originating in the nuclear fuel cycle, if appropriate, is disposed in these facilities under specifically authorized limits, after a safety analysis is performed.

Transuranic waste

Classification as "TRU waste" exists only within DOE government (non-commercial) sector. TRU waste generally consists of protective clothing, tools, glassware, equipment, soils, and sludge contaminated with manmade radioisotopes heavier than uranium. TRU elements are beyond or "heavier" than uranium on the periodic table of the elements. These elements include plutonium, neptunium, americium, curium, and californium. TRU waste is produced during nuclear fuel research and development; during nuclear weapons research, production, and cleanup; and from reprocessing spent fuel. TRU waste is itself divided into two categories, contact-handled and remote-handled, based on its surface dose rate. The maximum radiation dose at the surface of a contact-handled TRU waste container is 2 mSv per hour (200 mrem per hour). Remote-handled TRU waste emits more radiation than contact-handled TRU waste and must be both handled and transported in shielded casks. Surface radiation levels of unshielded containers of remote-handled TRU waste exceed 2 mSv per hour (200 mrem per hour).

Uranium recovery

Uranium recovery is the extraction or concentration of uranium from any ore processed primarily for its source material content. This results in waste from uranium solution extraction processes. These wastes usually have relatively low concentrations of radioactive materials with long half-lives.

NRC is responsible for planning and implementing regulatory programs under UMTRCA. Title I (of UMTRCA) involves managing, coordinating, and conducting the safety and environmental reviews of remediation activities, and reviewing and concurring in documents related to the cleanup and licensing of abandoned uranium mill tailings sites.

UMTRCA charged EPA to issue generally applicable standards for control of uranium mill tailings. EPA issued standards for both Title I and Title II sites in 1983. The Title I program established a joint Federal/state funded program for remedial action at abandoned mill tailings sites, with final Federal ownership under license from NRC. NRC, under Title I, must evaluate DOE designs and concur that DOE actions meet standards set by EPA. The Atlas site (Moab, Utah) was recently designated a Title I site and will undergo surface remedial action. Only reviews for the ground water remedial action program for all other title I sites remain, as all surface remedial action was completed in fiscal year 1999. NRC and DOE have a memorandum of understanding to clarify their roles and responsibilities, e.g., to minimize or eliminate duplication of effort between the two agencies.

Four types of uranium recovery operations are regulated by NRC:

1. Milling of uranium or thorium ore involving conventional processes of excavation and extraction,
2. Solution or "in situ" leach mining involving chemical removal of uranium from subsurface layers by pumping fluids through the formation by a series of injection and recovery wells and is subsequently sent to a processing facility to selectively concentrate the uranium,
3. Heap leach recovery, similar to (2), but generally performed at the earth's surface by placing dissolution fluids on ore or tailings material piles and collecting the uranium bearing liquid infiltrating through the tailings, and

4. Processing of radioactive waste as an "alternate feed material" through conventional mills to extract the uranium from the waste.

4. Management of high level waste and spent fuel

4.1. Strategies, objectives and main milestones of management programme

The Nuclear Waste Policy Act (NWPA) of 1982 provides for siting, construction, and operation of a deep geologic repository for the disposal of spent fuel and HLW. NWPA also assigns responsibilities for the disposal of spent fuel and HLW to three Federal agencies:

- DOE for developing permanent disposal capability for spent fuel and HLW;
- EPA for developing public health and safety standards; and
- NRC for developing regulations to implement EPA standards, deciding whether or not to license construction, operation, decommissioning and closure of the repository, and certifying packages used to transport spent fuel and HLW to the repository, if it is licensed.

The NWPA, as amended in 1987, directed DOE to characterize a site at Yucca Mountain, Nevada, for its potential use as a geologic repository. DOE is pursuing licensing and construction of a geologic repository for spent fuel and HLW at Yucca Mountain, Nevada. The planned geologic repository will provide permanent disposal of spent fuel and HLW from commercial and government facilities.

HLW resulting from commercial reprocessing activities was vitrified and is stored at the former reprocessing plant in West Valley, New York. Defense HLW is stored, managed and treated at three DOE sites.

DOE is responsible for and performs most of the spent fuel and radioactive waste management activities for government-owned and generated waste and materials located, for the most part, on government-owned sites. These activities include management of spent fuel remaining from decades of defense reactor operations, primarily at the Hanford Site, Washington, and Savannah River Site, South Carolina. These operations ceased in the early 1990s. Reprocessing of spent fuel from defense reactors ceased in 1992. DOE has safely stored the remaining defense spent fuel and spent fuel generated in a number of research and test reactors since then. DOE also provides safe storage for the core of the decommissioned Fort St. Vrain gas-cooled reactor and the core of the Three-Mile-Island Unit 2 reactor damaged in an accident in 1979.

The U.S. has an aggressive program for the return of "foreign" research reactor fuel originally enriched or supplied by the U.S. This spent fuel is being returned by other nations for safe keeping in the U.S.

DOE is planning to dispose of its inventory of surplus weapons-grade plutonium to address nonproliferation goals with Russia, as well as facilitate closure of former weapons complex sites. A disposition path for surplus weapons-grade plutonium will be fabricating the plutonium into Mixed Oxide (MOX) fuel and then irradiating it in commercial reactors. The irradiated plutonium remaining in the spent fuel cannot be easily re-used in nuclear weapons. Spent MOX fuel would be disposed in the planned geologic repository. Other radioactive waste generated during fabrication will be disposed of in DOE facilities.

4.2. Facilities (in operation and planned)

Spent fuel storage

The need for alternative storage began to grow in the late 1970s and early 1980s when pools at many commercial nuclear reactors began to fill with stored spent fuel. Dry cask storage allows spent fuel already cooled in the spent fuel pool for at least one year to be surrounded by inert gas inside a container called a canister. The canisters are typically steel cylinders either welded or bolted closed. The steel cylinder provides a leak-tight containment of the spent fuel. Additional steel, concrete, or other material surrounds each cylinder to provide radiation shielding to workers and the public. Some cask designs can be used for both storage and transportation.

Various dry cask storage systems are in use. In some designs, canisters containing the fuel are placed vertically or horizontally in a concrete vault to provide radiation shielding. In other designs the canister is placed vertically on a concrete pad and both metal and concrete outer cylinders are used for radiation shielding.

U.S. spent fuel has been produced in commercial nuclear power plants, research reactors, and defense reactors. All operating nuclear power reactors are storing spent fuel in NRC licensed on-site spent fuel pools (SFPs) or independent spent fuel storage installations (ISFSIs). Nuclear power plants being decommissioned may have spent fuel stored on site. NRC amended its regulations allowing licensees to store spent fuel in NRC-certified dry storage casks, at approved reactor sites.

In 1990, NRC updated an earlier generic determination, finding spent fuel generated in any reactor can be stored safely and without significant environmental impacts for at least 30 years beyond its licensed life. Sufficient repository capacity will be available within 30 years beyond its licensed life for operation of any reactor to dispose of the commercial high-level waste and spent fuel generated by commercial reactors up to that time. Spent fuel from a reactor can either be stored in an SFP or ISFSI, either on site or off site until a permanent disposal facility is licensed. NRC expects sufficient capacity for such storage to be available for at least 30 years beyond the licensed operating life of existing U.S. reactors.

The U.S. currently has 33 licensed dry cask storage facilities (ISFSIs), one licensed wet spent fuel storage facility, 18 spent fuel storage facilities at government-owned sites, and one planned spent fuel geologic repository. Table 5.7 summarizes the types and numbers of U.S. spent fuel storage facilities.

The U.S. commercial nuclear power industry had generated about 47,000 metric tons heavy metal (MTHM) of spent fuel as of the end of 2002. About 4,200 MTHM of this spent fuel were in dry cask storage at 30 commercial nuclear power plants. About 2,450 MTHM of spent fuel is stored at government facilities. Table 7 summarizes spent fuel storage facilities and inventories.

Sector	Function	Number of Facilities	Inventory (MTHM)
Government	Pool Storage	2	51
	Dry Cask Storage	7	2,399
	Research and Test Reactors	6	< 1
Commercial	University Research Reactors	30	1
	Other Research and Test Reactors	5	< 1
	At-Reactor Storage Pools	99	42,000
	Independent Spent Fuel Storage Facilities (Dry Cask)	33	4,200
	Independent Spent Fuel Storage Facilities (Pool)	1	700

Table 5.7. Spent Fuel Storage Facilities.

Spent fuel from both domestic and foreign research reactors, in addition to limited quantities of commercial spent fuel, is stored at DOE and other research reactor facilities throughout the country. DOE also stores spent fuel from former defense production reactors. Storage of radioactive waste at DOE sites is managed consistent with regulatory guidelines used at commercial nuclear facilities.

About 13 percent of all commercial spent fuel assemblies were stored in dry casks at ISFSIs as of December 2004. This percentage is expected to increase as more commercial utility spent fuel pools reach capacity, because they are required to maintain full core reserve capacity.

These reactors were not designed to store all the spent fuel generated during their operational lives, and they contribute between 1,800 and 2,200 MTHM annually to the growing inventory of spent fuel. Projected spent fuel discharges (taking into account plant life extensions) could bring the total to 129,000 MTHM by the year 2055.

Spent fuel disposal

The Nuclear Waste Policy Act of 1982, as amended, provides for the siting, construction, and operation of a deep geologic repository for disposal of spent fuel and high-level radioactive waste. Any such repository would be licensed by NRC.

The Congress on 2002 designated the Yucca Mountain site to be developed as a geologic repository based on the results of more than 20 years of intensive science and engineering work. DOE is preparing a license application for submission to NRC for authorization to begin construction of a repository at Yucca Mountain. NRC will review this application pursuant to 10 CFR Part 63. NRC's decision whether or not to grant the application will be based on the results of a comprehensive safety review and of a full and fair public hearing.

Yucca Mountain is located about 160 kilometers northwest of Las Vegas, Nevada, on unpopulated desert land owned by the Federal government. The long-term average precipitation has been about 30 centimeters per year. Yucca Mountain itself is a ridge of tilted layers of volcanic rock, called tuff that was deposited by a series of eruptions about 11 to 14 million years ago. Geological mapping of the surface and other studies show faults are present in the vicinity of Yucca Mountain. The host rock proposed for the planned repository is a welded tuff unit located about 300 meters below the surface and 300 meters above the water table.

DOE is responsible for transporting spent fuel and HLW from storage locations to the NRC-licensed geologic repository. Spent fuel and HLW would be transported by truck and rail in shipping casks certified by NRC. The material would then be transferred into robust corrosion resistant waste packages for disposal. NWPA limits the emplacement of waste at the first geologic repository to 70,000 MTHM until a second repository is in operation. DOE will provide a report to the U.S. Congress between 2007 and 2010 on the need for a second repository. Spent fuel and HLW disposed at Yucca Mountain are expected to include about 63,000 MTHM of commercial spent fuel, and 7,000 MTHM from defense related activities (about 2,400 MTHM of DOE spent fuel, and the equivalent of about 4,600 MTHM of DOE HLW).

HLW storage and treatment

U.S. HLW remains in storage at 4 sites where it was generated from reprocessing of spent fuel. All 2,270 cubic meters (600,000 gallons) of HLW generated from reprocessing at the former commercial reprocessing plant at West Valley, New York, between 1966 and 1972 was vitrified into 275 canisters awaiting disposal in the planned geologic repository. The vitrification plant at West Valley is now being decommissioned.

HLW from reprocessing of defense materials at the Savannah River Site resulted in both solid and liquid forms: insoluble solid chemicals and water soluble salts. The insoluble solids settle and accumulate on the bottom of storage tanks as "sludge." Liquid above the sludge is concentrated by evaporation to reduce its volume. The concentrate left behind is a damp "salt cake." About 378,000 cubic meters (100 million gallons) of high-level waste was concentrated by evaporation to a volume of about 140,000 cubic meters. The waste is stored at in steel tanks within concrete vaults until it is treated. The sludge remaining in the waste tanks (which contains most of the radioactivity), along with the radioactive cesium from the salt solution, are transferred to the site's Defense Waste Processing Facility for immobilization in borosilicate glass. The Defense Waste Processing Facility began radioactive operations on March 12, 1996, and will continue operations until all HLW is processed. There were 1,712 canisters of vitrified HLW stored at Savannah River Site in the Glass Waste Storage Building as of September, 2004 awaiting disposal in the planned geologic repository.

Reprocessing of defense materials at the Hanford Site, began in 1944 and ended nearly 50 years later resulting in 207,000 cubic meters (53 million gallons) of radioactive waste stored underground in 177 tanks. The waste consists of sludge, supernate, and salt cake. The tanks are old. Sixty-seven tanks are believed to have leaked waste into the soil. Continued leakage could threaten the Columbia River, located between 7 and 10 miles away. The waste must be removed and processed to a form suitable for disposal, and the tanks stabilized to protect the Columbia River. DOE plans to process tank waste and dispose the high-level portion (vitrified HLW) at the planned geologic repository. The interim stabilization of all single-shell tanks has been completed (all pumpable liquids removed), and waste is being retrieved from these tanks in preparation for interim closure. Waste in one tank has been fully retrieved. Design and construction of the Waste Treatment Plant, which includes a pretreatment facility, low-activity waste treatment facility, high-level waste facility, and analytical laboratory is progressing. This project is one of the largest construction projects in the U.S. Treatment of Hanford HLW is planned to begin in 2011 and end in 2027.

Radioactive waste from for more than 50 years of defense spent fuel reprocessing at the Idaho Nuclear Technology and Engineering Center, Idaho National Laboratory, has been stored in tanks and treated for disposal in a geologic repository. The tank farm includes eleven 300,000-gallon underground storage tanks and four 30,000 gallon underground storage tanks. As of February 28, 2005, seven of the eleven 300,000-gallon storage tanks and all four 30,000-gallon tanks were emptied, with a remaining 3,300 cubic meters (873,700 gallons) in the remaining 3 tanks. Much of the waste was previously treated and is now stored as calcine (4,400 cubic meters) in bins. The remaining liquid HLW contains a high concentration of sodium. DOE has selected four technologies: calcination, steam reforming, cesium ion exchange and direct evaporation for further evaluation in treating the sodium-bearing waste. Treatment of all waste is expected to finish by the end of 2012. A decision on further treatment of calcine HLW is expected in 2009.

4.3. Main restrictions and uncertainties

Regarding low level waste, there remains uncertainty in the availability of disposal for Class B and C LLW after 2008, when the Atlantic Compact (South Carolina, New Jersey and Connecticut) plans to limit access to the Barnwell, South Carolina, site to generators outside the compact. Efforts by regional compacts to site new disposal facilities have been unsuccessful. The State of Texas received an application from Waste Control Specialists in 2004 for a new LLW disposal facility for the Texas Compact (Texas and Vermont). Review of the application for this facility is continuing with the issuance of a license or denial projected for December 2007. The U.S. Congress and government agencies continue to monitor the availability of commercial LLW disposal facilities to meet future needs, although opposition to new disposal sites for LLW waste makes it difficult to site new facilities.

Regarding spent fuel and high level waste, there remains the uncertainty of the outcome of the licensing process of the Yucca Mountain disposal facility. Without this facility the U.S. would not be able to meet future high level waste disposal needs.

Regarding site remediation program, the large size and complexity of the program is becoming very expensive and difficult to manage technically and politically. New initiatives introducing risk considerations may help to make the program more efficient and focus on activities that will have greater impact on public health.

4.4. R&D needs. Knowledge and technology development

The Office of Science and Technology and International (OST&I), which is part of the Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM). The Science and Technology (S&T) Program provides a range of science and technology resources and capabilities, from targeted applied research through technology development and demonstration, needed to deliver scientific and technological enhancements to enhance our understanding, and to optimize performance, of the proposed Yucca Mountain repository.

The S&T Program mission is to provide advanced science and technology to continually enhance the understanding of the repository system and to reduce the cost and schedule for the OCRWM mission without sacrificing safety. The S&T effort complements the proposed repository design, performance assessment, and other baseline engineering and scientific studies. As such, the S&T Program works in close collaboration to assure timely transfer of research results.

The S&T Program is divided into five sections that correspond to the major research programs:

- ource Term
- Materials Performance
- Radionuclide Getters
- Natural Barriers
- Advanced Technologies

The goal of the **Source Term** program is to enhance the understanding of the performance of nuclear waste forms (mainly spent nuclear fuel (SNF) and nuclear waste glass) and to quantify the release of radionuclides in the evolving near-field environment expected at the proposed nuclear waste repository at Yucca Mountain, Nevada. The behavior of the source term, mainly SNF and vitrified waste, limits radionuclide releases, both initially and over the long term. Interactions of the source term with the near-field environment, such as corroded waste packages, place additional constraints on the longterm behavior, including retention and mobility of important radionuclides.

This program is directed at developing a basic understanding of the fundamental mechanisms of radionuclide release and a quantification of the release as repository conditions evolve over time. The research programs address four critical areas:

- SNF Dissolution Mechanisms and Rates
- Formation and Properties of U6+ Secondary Phases
- Waste Form–Waste Package Interactions in the Near Field
- Integration of In-Package Chemical and Physical Processes

The goal of the **Materials Performance** program is to further enhance the understanding of the role of engineered barriers in waste isolation. In addition, it will explore technical enhancements and seek to offer improvements in materials cost and reliability.

The program comprises directed technical goals and thrusts. A team of leading scientists/engineers from major universities, national laboratories, and other participants is working together to meet the program objectives. This group brings expertise and specialized facilities in important disciplines, including corrosion science, materials science, electrochemistry, physical chemistry, and geochemistry. The team is organized among collaborative technical thrusts focused on important topics:

- Long-term behavior of protective, passive films
- Composition and properties of moisture in contact with metal surfaces
- Rate of penetration and extent of corrosion damage over extremely long times

The goal of **Radionuclide Getters** program is to prescribe a recipe and placement recommendation for getters that could enhance radionuclide containment within the proposed repository. Among the major radionuclides contributing to potential dose are neptunium (Np), technetium (Tc), and iodine (I). These three radionuclides are highly mobile in the environment. Sequestering these radionuclides within the proposed repository horizon is a priority for the Yucca Mountain Project (YMP). Developing radionuclide sorbents, or "getters," is the focus of this area.

The **Natural Barriers** program has the following objectives:

1. To demonstrate that the natural barriers can make large contributions to repository performance, supporting the multiple-barrier concept for geological disposal of high-level radioactive waste.

2. To strengthen the natural barriers analysis for periods up to and beyond the expected occurrence of peak dose, when the extrapolation of engineered performance may not be relied upon.

3. To reduce the overall cost of repository development by elimination of unnecessary engineered components, given the demonstrated natural barriers performance.

From the repository drifts to the accessible environment, the basic elements of the Natural Barriers program are:

1. Drift Seepage

2. In-drift Environment

3. Drift Shadow

4. Unsaturated Zone (UZ) Flow and Transport

5. Saturated Zone (SZ) Flow and Transport

The purpose of the **Advanced Technologies** program is to:

- Identify/develop technologies and processes.
- Reduce the cost of proposed repository development, construction, and operation with the application of these new technologies and processes.
- Provide the data necessary to demonstrate feasibility of new technologies and processes.

There are 11 projects included in this program, addressing:

- The Evaluation of Improved Waste Package Materials and Fabrication Processes
- Advanced Approaches for Improved Waste Package Closure Welds
- Advanced Tunneling Technology
- Improved Understanding of Extreme Ground Motions Predicted Using Probabilistic Seismic Hazard Analysis.

All of these areas have great potential for improving the safety performance of the proposed Yucca Mountain repository. Thus, rather modest effort in the S&T Program could lead to large savings in the lifetime repository total cost and significantly enhanced understanding of the behavior of the proposed Yucca Mountain repository, without safety being compromised, and in some instances being enhanced.

An overall strength of the S&T Program is the significant amount of integration that has already been achieved after two years of research. During 2005, each program areas assembled a team of external experts to conduct an independent review of their respective projects, research directions, and emphasis. In addition, the S&T Program as a whole was independently reviewed by the S&T Programmatic Evaluation Panel.

4.5. Safety and licensing

The national policy on regulatory control of radioactive waste management in the U.S. has evolved through a series of laws establishing the Federal government agencies responsible for the safety of radioactive materials. Federal legislation is enacted by the U. S. Congress and signed into law by the President. Laws of the nation apply to all 50 states and territories.

The U.S. Congress passed legislation in 1954, for the first time permitting the wide peaceful use of atomic energy. The 1954 Atomic Energy Act (AEA) redefined the atomic energy program by ending the government monopoly on technical data and making the growth of a private commercial nuclear industry an urgent national goal.

Three types of commercial nuclear materials are regulated:

- Special nuclear material - uranium-233 or uranium-235, enriched uranium, or plutonium
- Source material - natural uranium or thorium, or depleted uranium not suitable for use as reactor fuel, and
- Byproduct material - generally nuclear material (other than special nuclear material) produced or made radioactive in a nuclear reactor. Also the tailings and waste produced by extraction or concentration of uranium or thorium from an ore processed primarily for its source material content.

The 1954 Act assigned AEC three major roles: to continue its weapons program, to promote the private use of atomic energy for peaceful applications, and to protect public health and safety from the hazards of commercial nuclear power.

Congress passed the National Environmental Policy Act (NEPA) in 1969, among other things, establishing a national policy for the environment. EPA was created in 1970 and given authority for setting generally applicable standards for radioactivity in the environment outside the boundaries of AEC-owned facilities. EPA also has responsibility for regulating and enforcing the levels of radioactivity in air emissions and in drinking water. EPA can determine soil cleanup values and other residual radioactivity limits at contaminated sites where there are releases or potential for releases of hazardous substances into the environment under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). EPA also has authority to provide Federal guidance on radiation protection matters affecting public health.

Congress passed the Energy Reorganization Act in 1974, separating the AEC into NRC and ERDA, predecessor of DOE. Additional legislation further defined the roles of NRC and DOE and introduced a role for the states through the Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) and the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA). This legislation assigned to the states, rather than the U.S. Government, the responsibility to provide additional disposal capacity for commercial LLW.

The NWPA and the NWPAA provide for siting, construction, and operation of a deep geologic repository to dispose of spent fuel and HLW. Any such repository would be licensed by NRC. The Secretary of Energy, the President, and the U.S. Congress have now acted to designate Yucca Mountain as the site of the first such repository. DOE is preparing a license application to submit to NRC for authorization to begin construction of a repository at Yucca Mountain.

Congress amended NWPA through NWPAA in 1997 to:

- Create a Nuclear Waste Technical Review Board (NWTRB) as an independent review body;
- Establish a Nuclear Waste Negotiator;
- Direct DOE to study (characterize) only the Yucca Mountain site;
- Require a report to Congress between 2007 and 2010 on the need for a second repository; and

The Energy Policy Act (EnPA) of 1992 mandated a new and different process for EPA to develop the HLW disposal standards for a repository at Yucca Mountain. The U.S. Congress directed the National Academy of Sciences (NAS) to evaluate the scientific basis for a Yucca Mountain standard, and directed EPA to promulgate new public health and safety standards based on and consistent with the findings and recommendations of the NAS. Once the final standards were promulgated, EnPA directed NRC to modify its technical requirements to conform to the new EPA standards.

EPA issued its radiation protection standards in 2001. These standards are designed to protect public health and safety by establishing a maximum dose level for the first 10,000 years. EPA proposed revised standards for the period beyond 10,000 years, and up to one million years after disposal.

NRC's role is to implement the public health and safety standards established by EPA in any licensing process conducted for a repository at Yucca Mountain. NRC finalized its licensing in 2001, incorporating EPA standards.

DOE's role is to characterize the Yucca Mountain site and determine whether it should be recommended to the President for development as a repository. DOE issued its final repository site suitability guidelines. DOE used the guidelines to determine whether the planned Yucca Mountain site is suitable for development as a repository. DOE will submit a license application for the planned repository construction to NRC.

The general regulations for the three Federal Agencies responsible for radioactive waste regulation are contained in Title 10 (for NRC and DOE) and Title 40 (for EPA) of the U.S. Code of Federal Regulations (CFR). A compendium of these regulations is published annually, but regulations are frequently revised and in force before the next annual compendium. U.S. Government regulations are developed through an open process, including the opportunity for public comment. New regulations are published daily in the Federal Register, in proposed or final forms.

HLW regulation

The responsibility of regulatory agencies for disposal of HLW and spent fuel is described in the Nuclear Waste Policy Act. NRC is the U.S. regulator for disposal of HLW, including:

- Preparing to review a DOE license application for a HLW repository at a pace consistent with the national program.
- Implementing EPA's site-specific HLW radiation safety standards, using site-specific, performance (assessment)-based regulation, both of which were developed in open, public rulemaking processes.
- Conducting pre-licensing consultation and beginning regulatory activity when the application for the Yucca Mountain repository is received.
- Certifying transportation casks.

The design objectives of the repository are to: (1) protect the health and safety of both the workers and the public during the period of repository operations; (2) minimize the amount of radioactive material that may eventually reach the accessible environment; and (3) minimize life cycle costs. The design of the repository will permit it to be kept open, with only routine maintenance, for at least 50 years from the start of waste emplacement. Keeping the repository open means the underground storage areas can be directly inspected and the waste packages readily removed, if necessary. DOE's license application to NRC will describe systems, methods and procedures to enable safe inspection and removal during the operating period. This flexibility will enable repository operations to meet future societal needs. The geologic repository operations area (GROA) must be designed so any or all of the emplaced waste could be retrieved on a reasonable schedule at any time up to 50 years after waste emplacement operations begin, unless a different time period is approved or specified by NRC.

EPA issued final standards for Yucca Mountain in 2001, and the NRC published conforming licensing regulations also in 2001. These standards and regulations withstood multiple legal challenges except for the part of the EPA regulation governing the period of time after disposal for which compliance must be demonstrated. In July 2004, the Court of Appeals for the D.C. Circuit vacated the 10,000-year compliance period established in EPA standards and incorporated in NRC regulations. EPA's August 2005 proposal to revise its regulations retains the 10,000-year compliance period with a maximum dose level, and adds a compliance period for the time period after 10,000 years and up to one million years after disposal with a separate maximum dose level based on natural background radiation levels for people currently living within the United States. The proposed standards for the period after 10,000 years incorporates specific direction on analyzing features, events and processes (e.g., earthquakes, volcanoes, increased water flow due to climate changes) that may affect performance. NRC will amend its regulations as necessary to be consistent with the final changes to EPA standards for Yucca Mountain.

The following is a summary and explanation of these proposed standards:

For the first 10,000 years:

- Retain the original 0.15 mSv (15 mrem) per year individual protection standard.
- This standard ensures that people living near Yucca Mountain are protected to the same level as those living near the Waste Isolation Pilot Plant in Carlsbad, New Mexico , currently the only operational deep geologic radioactive waste disposal facility in the U.S.

From 10,000 years up to 1 million years:

- Add a limit of 3.5 mSv (350 mrem) per year.
- This standard limits the maximum radiation from the facility so people living close to Yucca Mountain during the 1 million-year time frame will not receive total radiation any higher than natural levels experienced by people currently living in other areas of the country.

The standards further protect public health by requiring DOE to conduct analyses covering a 1 million-year time frame to assess the potential effects of natural processes or disruptive events affecting how well Yucca Mountain contains the waste. These include:

- Earthquakes, affecting the facility tunnels and breakdown of the waste containers.
- Volcanic activity, affecting the waste containers directly or cause releases of radionuclides to the environment.
- Climate change, causing increased water flow through the facility, resulting in the release of radionuclides to the environment.
- Corrosion processes, causing breakdown of the waste containers.

The proposal also extends the time DOE must assess events and processes affecting the safety of Yucca Mountain from 10,000 to 1 million years.

The proposal also includes requirements for:

- Use by DOE of the middle, or median, value in calculating radiation dose. This ensures compliance is judged using the most likely performance of the disposal facility, and not against either very optimistic or pessimistic projections of its behavior.

- Use of updated scientific factors to calculate radiation dose. These represent the most recent international consensus and guidance on estimating the health effects of radiation.

In addition, EPA has a 0.04 mSv/year (4 mrem/year) ground-water protection standard and associated requirements for determining compliance with the standard over 10,000 years after closure.

NRC's regulatory program for HLW disposal is now focused on its transition from prelicensing to licensing activities as NRC prepares for receipt of a license application. NRC's prelicensing activities with DOE have been conducted under a formal prelicensing agreement, and have been open to participation by the states, Indian tribes, local governments, industry, and other stakeholders.

LLW regulation

EPA has several regulatory functions associated with low level radioactive waste. EPA enforces its radiation standards and provides oversight of DOE WIPP disposal facility for transuranic radioactive waste. The Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA), requires EPA to issue final regulations for disposal of spent fuel, HLW, and TRU waste. It also gave EPA the authority to develop the criteria implementing final WIPP radioactive waste disposal standards. EPA must also determine every five years whether or not the WIPP facility continues to be in compliance with regulations. The WIPP LWA required EPA to determine whether WIPP complies with other Federal environmental and public health and safety regulations.

EPA issued final amendments to its radioactive waste disposal standards in 1993. The amendments address the individual and ground water protection requirements of the original standards which had been remanded by the U.S. Court of Appeals. The other portions of the standards were not remanded. The final individual protection standards require disposal systems to limit the amount of radiation an individual can be exposed for 10,000 years, rather than for 1,000 years as was required in the original standard. The final ground water protection standards require disposal systems to be designed, for 10,000 years after waste disposal, contamination in off-site underground sources of drinking water will not exceed the maximum contaminant level for radionuclides established by EPA under the Safe Drinking Water Act.

EPA issued final compliance criteria in 1996 for certification and recertification of WIPP compliance with the final radioactive waste disposal standards. DOE submitted a Compliance Certification Application to EPA in 1996, to demonstrate WIPP complies with the criteria. EPA published a Notice of Proposed Rulemaking in 1997, announcing the proposed certification the WIPP will comply with EPA disposal standards. The EPA Final Rulemaking Notice on the certification decision was announced in 1998. DOE submitted an application for recertification of WIPP in March 2004, which by statute is required every five years. EPA is reviewing the application and will respond through the rulemaking process.

DOE LLW disposal facilities are sited, designed, operated, maintained, and closed so there is a reasonable expectation the following performance objectives are met for waste disposed of:

- Dose to representative members of the public does not exceed 0.25 mSv (25 mrem) in a year from all exposure pathways, excluding the dose from radon and its progeny in air;

- Dose to representative members of the public via the air pathway does not exceed 0.10 mSv (10 mrem) in a year total effective dose equivalent, excluding the dose from radon and its progeny; and

- Release of radon is less than an average flux of 0.74 Bq/m2/s (20 pCi/m2/s) at the surface of the disposal facility; alternatively, a limit of 0.0185 Bq/l (0.5 pCi/l) in air may be applied at the boundary of the facility.

The performance assessment includes calculations for a 1,000-year period after closure of potential doses to representative future members of the public and potential releases from the facility to provide a reasonable expectation the performance objectives above are not exceeded as a result of operation and closure of the facility.

Closure of a DOE LLW disposal facility occurs within a five-year period after it is filled to capacity, or after determining the facility is no longer needed. The final inventory of the LLW disposed in the facility is prepared and incorporated in the performance assessment and composite analysis, which is updated to support the closure of the facility prior to closure. A final closure plan is prepared and implemented based on the final inventory of waste disposed in the facility. An updated performance assessment and composite analysis are prepared in support of the facility closure.

The plan includes, at a minimum, the following elements:

- Identification of the closure standards/performance objectives;

- A strategy for allocating waste disposal facility performance objectives from the closure standards identified in the closure plan among the facilities/units to be closed at the site;

- An assessment of the projected performance of each unit to be closed compared to the performance objectives allocated to each unit under the closure plan;

- An assessment of the projected composite performance of all units to be closed at the site compared to the performance objectives and closure standards identified in the closure plan; and

- Any other relevant closure controls including a monitoring plan, institutional controls, and land use limitations to be maintained in the closure activity.

Institutional control measures are integrated into land use and stewardship plans and programs, and continue until the facility can be released.

DOE will use active institutional controls for at least 100 years following closure at the WIPP repository for disposal of TRU waste. Active controls, such as fences, roadways, signs, and periodic surveillance, prevent human intrusion during this period. Ground water monitoring will continue for at least 30 years after closure, and subsidence monitoring will continue for at least 100 years. Passive institutional controls are required to inform and warn future generations about the location and purpose of this repository after the active institutional control period.

Regulations require that the TRU waste disposal site use markers and controls. These passive controls are expected to communicate the location, design, and contents of the disposal system for at least 10,000 years. Planned components include: a large earthen berm, perimeter monuments, buried warning markers, magnets and metal radiation symbols, an information center using graphics and various languages, and information storage rooms. Archives will be stored in various locations around the world. A summary report is planned, and will be written in multiple languages on archival-quality paper to preserve it.

5. Financial provisions

Both commercial (NRC-regulated) and government (DOE) sectors have requirements to ensure human and financial resources are sustained for spent fuel and radioactive waste management activities.

Licensees in the commercial sector must meet NRC requirements for financial surety. Spent fuel and radioactive waste management activities in the government sector (DOE facilities) have the financial assurance of the U.S. Government. Annual appropriations are made by the U.S. Congress. Special considerations are discussed below for the planned Yucca Mountain repository, where disposal of both government and commercial spent fuel and high-level waste are proposed.

Commercial LLW management facilities

The financial information must be sufficient to demonstrate the financial qualifications of the applicant are adequate to carry out the activities for which the license is sought and meet other financial assurance requirements. Each applicant must show it either possesses the necessary funds or has reasonable assurance of obtaining the necessary funds, or a combination of the two, to cover the estimated costs of conducting all licensed activities over the planned operating life of the project, including costs of construction and disposal.

Waste processors are subject to NRC regulations requiring sufficient financial assurance to enable an independent third party, including a governmental custodian of a site, to assume and carry out responsibilities for any necessary control and maintenance of the site where the license is terminated with restrictions on future site use. The financial assurance mechanism and amount are reviewed and approved by NRC before the license is terminated. No post-closure activities or institutional controls are needed for sites released after closure without restrictions on future site use.

The licensee's surety mechanism for commercial disposal facilities is reviewed annually by NRC to assure sufficient funds are available for completion of the closure plan, assuming the work has to be performed by an independent contractor. NRC regulations (10 CFR 61.62) require funding for disposal site closure and stabilization of commercial waste disposal sites. The applicant must provide assurance sufficient funds are available to carry out disposal site closure and stabilization, including: (1) decontamination or dismantlement of land disposal facility structures; and (2) closure and stabilization of the disposal site so that following transfer of the disposal site to the site owner, the need for ongoing active maintenance is eliminated to the extent practicable and only minor custodial care, surveillance, and monitoring are required. The applicant's cost estimates must take into account total capital costs incurred if an independent contractor were hired to perform the closure and stabilization work.

NRC accepts financial sureties consolidated with earmarked financial or surety arrangements established to meet requirements of other Federal or state agencies and/or local governing bodies for such decontamination, closure and stabilization to avoid unnecessary duplication and expense. NRC accepts this arrangement only if it is adequate to satisfy these requirements and the portion of the surety, covering the closure of the disposal site, is clearly identified and committed for use for these activities.

The amount of surety changes with the predicted cost of future closure and stabilization. Factors affecting closure and stabilization cost estimates include: inflation; increases in the amount of disturbed land; changes in engineering plans; closure and stabilization already accomplished and other conditions affecting costs. This yields a surety at least sufficient at all times to cover the costs of closure of the disposal units expected to be used before the next license renewal. The term of the surety mechanism is open-ended unless it can be demonstrated another arrangement would provide an equivalent level of assurance.

Financial surety arrangements generally acceptable to NRC include: surety bonds, cash deposits, certificates of deposits, deposits of government securities, escrow accounts, irrevocable letters or lines of credit, trust funds, and combinations of the above or other arrangements approved by NRC. Self-insurance, or any arrangement, constituting pledging the assets of the licensee, does not satisfy the surety requirement for private sector applicants since this provides no additional assurance other than through license requirements.

Spent fuel and HLW management facilities

The policy of the U.S., as implemented through the Nuclear Waste Policy Act (NWPA), requires utility customers who receive benefits of electricity generated by nuclear power to pay costs for site characterization and development of geologic repositories to dispose of spent nuclear fuel and high-level radioactive wastes. These consumers currently pay a fee of $0.001 per kilowatt-hour of nuclear generated power used. The fee is periodically analyzed to determine adequacy in meeting the estimated life cycle costs for disposal. It is collected by utilities and deposited into the Nuclear Waste Fund (NWF). The U.S. Congress appropriates funds annually for the development of Yucca Mountain and attendant management costs. The U.S. Congress also provides an annual appropriation from the General Fund of the Treasury to pay for costs for disposal of defense-related high-level radioactive waste. Financial and technical assistance funds from the NWF are also provided to the State of Nevada, local counties (nine in Nevada and one in California), and educational institutions conducting oversight and monitoring activities as required under a 1987 amendment to the NWPA.

Financial assurance for the storage of spent fuel is required under provisions in 10 CFR Part 72 to ensure funds are available to store spent fuel in ISFSIs and for future decommissioning of nuclear reactor facilities. Financial mechanisms used include surety/insurance or other guarantee method, external sinking funds, government statement of intent, or contractual obligations on the part of the firm's customers.

Uranium recovery waste management facilities

Financial surety arrangements must be established by each mill operator prior to the start of operations to assure sufficient funds will be available to carry out the decontamination and decommissioning of the mill and site and for the reclamation of any tailings or waste disposal areas. This may be accomplished by a third party. The amount of funds to be guaranteed by such surety arrangements must be based on NRC-approved cost estimates in an NRC-approved plan for:

- Decontamination and decommissioning of mill buildings and the milling site to levels allowing unrestricted use of these areas upon decommissioning, and
- Reclamation of tailings and/or waste areas in accordance with technical criteria.

The licensee must submit this plan in conjunction with an environmental report addressing the expected environmental impacts of the milling operation, decommissioning and tailings reclamation, and evaluates alternatives for mitigating these impacts. The surety must also cover payment of the charge for long-term surveillance and control. The licensee's surety mechanism is reviewed annually by NRC to recognize any increases or decreases resulting from inflation, changes in engineering plans, activities performed, and any other conditions affecting costs.

This process will yield a surety at least sufficient at all times to cover the costs of decommissioning and reclamation of the areas expected to be disturbed before the next license renewal. Financial surety arrangements generally acceptable to NRC are: surety bonds, cash deposits, certificates of deposits, deposits of government securities, irrevocable letters or lines of credit, and combinations of the above or other arrangements approved by NRC.

A variance in funding requirements may be specified by NRC if site surveillance or control requirements at a particular site are determined, on the basis of a site-specific evaluation, to be significantly greater than annual site inspections. Eventual ownership of the uranium mill disposal site will be to an agency of the U.S. Government (DOE) or an appropriate state agency for perpetuity.

A minimum charge of $250,000 (1978 U.S. dollars) to cover the costs of long-term surveillance is paid by each mill operator to the General Treasury of the United States or to an appropriate state agency prior to the termination of a uranium or thorium mill license.

Complex material sites decommissioning

Many of the existing NRC regulated decommissioning sites are complex and difficult to decommission for a variety of financial, technical, or programmatic reasons. These sites can be thought of as NRC "legacy" sites — those sites where past financial or operational events have created the existing problems that must now be overcome, to conduct sufficient cleanup and ultimately complete decommissioning and license termination. NRC evaluated the lessons from these existing legacy sites and plans on changes to financial assurance and licensee operational requirements to minimize or prevent future legacy sites.

A number of sites licensed before the financial assurance regulations were issued in 1988 now find that the full cost of decommissioning exceeds their projections and fund balances.

Furthermore, NRC experience applying the financial assurance regulations has resulted in many lessons that can be applied to improve the regulations and reduce the risks to decommissioning financial assurance. Based on this experience, NRC identified specific risks possibly causing shortfalls in decommissioning funding including: 1) underestimation of decommissioning costs caused by a restricted release assumption; 2) operational indicators of increasing costs; 3) unavailability of funds in bankruptcy; 4) inadequate financial disclosure; 5) reaching assets after corporate reorganization; 6) investment losses reducing trust account balances; and 7) increased decommissioning cost because of accidental release.

6. Social public opinion and communication aspects

U.S. policy to dispose of spent fuel and radioactive waste is aimed at not placing undue burdens on future generations. Performance requirements on disposal sites mandate the level of isolation to ensure that there are no undue burdens on future generations. The WIPP geologic repository for TRU waste and the planned Yucca Mountain repository demonstrate the U.S. is addressing the burden/impacts on future generations as national policy.

Members of the NCRP work directly with their counterparts in the international community. A panel of the National Academy of Public Administration has studied the issues involved and issued a report addressing these issues. The NAS Board of Radioactive Waste Management considers the public policy, sociological, and ethical aspects of radioactive waste management, for example, long-term societal commitments, societal acceptability of waste management practices, and institutional capabilities to effectively and efficiently manage radioactive wastes.

The U.S. recognizes the many benefits derived from public participation in its program activities including spent fuel and radioactive waste management. Public participation is open, ongoing, two way communication - both formal and informal - between government officials and stakeholders. Public participation provides a means for the government to gather the most diverse collection of opinions, perspectives, and values from the broadest spectrum of the public, enabling the government to make better, more informed decisions. Public participation benefits stakeholders by creating an opportunity to provide input and influence decisions.

Many DOE sites have formed formal panels made up of interested citizens to advise the government on planned ongoing activities under the Federal Advisory Committee Act. Site-Specific Advisory Boards (SSABs) provide consensus advice and recommendations to DOE spent fuel and waste management activities at most locations where spent fuel and radioactive waste is stored. The boards, which are voluntary and not required by law, provide advice and offer recommendations on DOE activities. When established (as one is at Hanford for example), the SSABs are subject to the Federal Advisory Committee Act of 1972. In addition, there are other panels formed to advice DOE at the program and secretarial office level, e.g. the Environmental Management Advisory Board and the Secretary of Energy Advisory Board. These groups review broader agency actions and policies, providing advice and guidance to senior governmental officials.

EPA and NRC conduct public hearings and public meetings, accept written and electronic comment on proposed actions, participate in stakeholder meetings, and provide internet sites. The NRC internet website provides a full description of the agency's public information process and meeting calendar.

DOE has multilateral agreements with national waste management organizations and international organizations, e.g., IAEA and Nuclear Energy Agency (NEA). The EPA Office of International Affairs and NRC Office of International Programs participate in international organizations (NEA, IAEA, ICRP, etc.) and bilateral activities with neighbors countries, such as Canada.

NRC views nuclear regulation as the public's business, and as such, identifies openness in its regulatory process as an explicit goal of the Agency. NRC recognizes it must inform the public about the regulatory process, and offer a reasonable opportunity for meaningful participation in that process. NRC long ago established mechanisms and procedures to afford the public access to major regulatory decisions. NRC has recently examined ways to enhance public involvement and foster confidence in NRC's actions as an effective and independent regulator. NRC is seeking to expand opportunities for public access to clear and understandable process and risk information. NRC has developed fact sheets and brochures as part of its public outreach strategy. These documents provide information to members of the public about different topics, including decommissioning, spent fuel, and radioactive waste. NRC sought to improve its efforts to inform and involve the public in NRC's decision-making process on rulemaking when developing new, site-specific regulations for the planned geologic repository at Yucca Mountain. Major changes were made to the way technical staff members prepare for speaking to general audiences. The format used for public meetings was modified to encourage dialogue with participants. Handout and presentation materials explaining NRC's role and technical topics of concern, in plain language, were developed and are regularly updated. NRC successfully applied these and other institutional changes as it completed final regulations for Yucca Mountain, when introducing a draft license review plan for public comment, and when responding to public requests for information on NRC's licensing and hearing process.

Stakeholders can and do participate in NRC's licensing process. The Atomic Energy Act of 1954, as amended, and NRC regulations contain provisions for public hearings and other means, such as petitions and rulemaking requests for the public to challenge NRC decisions and licensing actions.

EPA, in implementing its responsibilities regarding WIPP, committed to conducting an open public process including interaction with all interested parties. A successful communications and consultation program facilitates the regulatory oversight process and promotes sound public policy decisions. EPA conducted a public consultation and communication "needs assessment" as a first step in meeting its commitment to an open public process. This assessment was designed to obtain input from citizen and environmental groups and the public on their key concerns about EPA's role and responsibilities at the WIPP, and the best methods for communicating with them. EPA provided opportunities throughout the WIPP certification process, for public involvement beyond those required in typical U.S. regulatory programs. This increased the public's understanding of EPA's role and responsibilities for the WIPP project, enabled the public to make informed decisions about the project by increasing their knowledge about radiation and it's risks, and enhanced the overall decision-making process. The final step in the public consultation and communications process was to evaluate the effectiveness of the WIPP public outreach program.

Hearing Procedures. In January 2004, NRC amended its regulations concerning the rules of practice to fashion hearing procedures that are tailored to the various types of regulatory activities that NRC conducts. These revisions will make NRC's hearing process more effective and efficient and will better focus the limited resources of involved parties.

Radioactive waste management in Finland

J.Reig

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1. Introduction. General overview

1.1. Nuclear energy programme

In Finland, two NPPs, with a total capacity of 2 656 MWe(net), are currently in operation. The Loviisa plant includes two 488 MWe PWR units, operated by Fortum Power and Heat Oy (FPH) and the Olkiluoto plant two 840 MWe BWR units, operated by Teollisuuden Voima Oy (TVO). The NPP units were connected to the electrical network as follows: Loviisa 1 in 1977, Loviisa 2 in 1980, Olkiluoto 1 in 1978 and Olkiluoto 2 in 1980.

A Decision-in-principle to construct a new NPP unit was made by the Council of State and confirmed by the Parliament in 2002. Teollisuuden Voima Oy has filed an application for a Construction License at the beginning of 2004 to construct a Pressurized Water Reactor (PWR) unit of nominal reactor thermal power 4300 MW at the Olkiluoto site (Olkiluoto 3). The construction licence for a new PWR unit, Olkiluoto 3 of 1600 MWe was granted by the Government in February 2005. The unit is planned to be operational in 2010.

All spent fuel generated at the Olkiluoto plant is stored on-site. Previously the spent fuel of the Loviisa plant was transported to the Mayak facilities in the Russian Federation, after interim storage of a few years. An amendment to the Nuclear Energy Act was passed in 1994 stating that spent fuel generated in Finland has to be treated, stored and disposed of in Finland. Spent fuel shipments to the Russia were terminated at the end of 1996, and since then the spent fuel generated at the Loviisa plant has been stored at the plant.

There are intermediate spent fuel storage facilities and final disposal facilities for low and medium level radioactive waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and at Loviisa in 1998. For taking care of the spent fuel final disposal, a joint company Posiva Oy has been established by Fortum and Teollisuuden Voima Oy. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in early 2020. The repository will be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility was commenced in mid-2004. Finnish Parliament has endorsed a Decision-in-principle made by the Government for the implementation of Finnish Disposal Facility to the Olkiluoto site.

The Finnish fuel cycle policy is based on the once-through option. In 1999 Posiva proposed, in a Decision-in-Principle application, to site a disposal facility for spent nuclear fuel at Olkiluoto in Eurajoki, a couple of kilometres from the NPP. This application was approved by the municipality of Eurajoki in January 2000, the Finnish Government made the Decision-in-Principle in December 2000 and the Parliament endorsed it in May 2001. The application for the construction licence is scheduled to be submitted by the end of 2012 and the operating licence application around the year 2020.

In the context of endorsement of the Decision-in-Principle concerning the fifth reactor in Finland in May 2002 the Finnish Parliament also endorsed a separate Decision-in Principle on the extension of the Olkiluoto disposal facility to cover the spent fuel from the new unit.

A research reactor FiR 1 (TRIGA Mark II, 250 kW) is situated in Espoo and operated by the VTT, Technical Research Centre of Finland. It was taken into operation in 1962. VTT has also radiochemical laboratories and a hot-cell for testing radioactive materials. Radiochemical and particle accelerator laboratories are also located at the universities of Helsinki, Turku and Jyväskylä.

Two pilot-scale uranium mining and milling facilities were operational in late 1950's – early 1960's. Small amounts of radioactive wastes arise from a number of facilities using radioactive sources in medical, research and industrial applications.

1.2. Waste categorization

Nuclear waste is defined in Section 3 of the Nuclear Energy Act as radioactive waste in form of spent fuel or in some other form, generated in connection with or as a result of the use of nuclear energy, and materials, objects and structures which, having become radioactive in connection with or as a result of the use of nuclear energy and having been removed from use, requires special measures because of the danger arising from their radioactivity.

Other radioactive waste than nuclear waste is regulated in the framework of Radiation Act and Decree. According to the Radiation Act, radioactive waste is radioactive materials which have no use and have to be rendered harmless owing to their radioactivity. The definition includes also equipment, goods and materials that are contaminated by radioactive materials. Radioactive materials and radiation appliances containing radioactive material whose owner cannot be found shall also be regarded as radioactive waste.

The main sources of radioactive waste are nuclear wastes generated from the operation of the four power reactors and the research reactor. Other radioactive waste arises from a number of facilities using radioisotopes in medical, research and industrial applications. Respectively, the Finnish waste classification system includes two main categories: nuclear waste and radioactive waste not originating from the nuclear fuel cycle.

Low and intermediate level waste from nuclear facilities (LILW)

The classification system for the purpose of predisposal management of LILW from NPPs is based on activity concentrations, given in Finnish Safety Guide YVL 8.3 as follows:

Solid and liquid waste arising from the controlled area of a NPP and that contain almost exclusively short-lived beta and gamma emitters, are grouped into the following activity categories:

- **Low level waste** contains so little radioactivity that it can be treated at the NPP without any special radiation protection arrangements. The activity concentration in waste is then not more than 1 MBq/kg, as a rule.

- **Intermediate level waste** contains radioactivity to the extent that effective radiation protection arrangements are needed when they are treated. The activity concentration in the waste is then from 1 MBq/kg to 10 GBq/kg, as a rule.

For conditional and unconditional removal from control, both options are founded upon the criteria of triviality of dose, as follows:

Radiation exposure to the public or the workers at the waste treatment facility caused by wastes from the use of a NPP or a nuclear facility of other kind shall not exceed

- an effective dose of 10 microSv/year for the most exposed individuals (members of the critical group), and

- a collective dose commitment of 1 manSv from one year of performance of the practice, except when the assessment according to Section 2 of the Radiation Act (optimization) shows that removal from control is the best option.

Mass and surface concentration based activity limits for unconditional removal from control are given in YVL 8.2. The limits can be applied for limited waste quantities not exceeding 100 tonnes/year for one NPP or other nuclear installation. In conditional removal from control the activity concentrations are determined on case-by-case basis but care has to be taken that they do not exceed the exemption limits given e.g. in the Euratom Council Directive 96/92.

Guide YVL 8.2 is currently being updated to cover also removal of control from large amount of material resulting from decommissioning and release of regulated sites.

Radioactive waste from medical use, research and industry

For small user waste, constraints for disposal in landfill or sewage system are provided in Guide ST 6.2. The criteria are based on the triviality of the dose.

According to Guide ST 6.2, liquid waste can be disposed of into a sewage system and solid waste can be delivered to a landfill site or an incineration plant, if the activities are below the nuclide specific limits based on the Annual Limit on Intake values. The upper level of radioactivity for a sealed source eligible to be as solid waste and within these activity limits is 100 kBq. Sealed sources with higher radionuclide content and other radioactive waste not eligible for disposal to landfill have to be delivered to a site approved by STUK for storage and disposal

1.3. Waste production: Current status and forecast

The major generators of radioactive waste in Finland are the two nuclear power plants, the Loviisa and Olkiluoto plants.

Both operating nuclear power plants have interim storages for spent fuel as well as facilities for the management of low and intermediate level waste. The facility for final disposal of low and intermediate level radioactive wastes was taken into operation at Olkiluoto in 1992 and the facility for disposal of low level waste at Loviisa in 1998. Disposal of spent nuclear fuel is under preparation and has passed the first authorization step, so called Government's Decision-in-Principle, which was endorsed by the Parliament in 2001. The construction of an underground rock characterisation facility started in 2004. No decommissioning projects of nuclear facilities are underway.

Other generators of radioactive waste are the research reactor FiR 1 and various small users of radioactive substances, such as hospitals, universities, research institutes and industry. Finland has only insignificant amounts of radioactive waste generated from past practices requiring further management measures.

Spent fuel and radioactive waste management facilities

The ownership, characteristics and inventories of spent fuel and radioactive waste management facilities in Finland are given in table 6.1: spent fuel storage; table 6.2: predisposal waste; and table 6.3: waste disposal facilities.

Loviisa nuclear power plant	
Owner	Private utility
Location	Southern Finland (NPP site)
Purpose	Interim storage of spent fuel
Capacity	520 TU
Inventory	351 TU (2947 assemblies)
Features	Pool storage inside reactor building and in auxiliary building
Olkiluoto nuclear power plant	
Owner	Private utility
Location	South-Western Finland (NPP site)
Purpose	Interim storage of spent fuel
Capacity	1570 TU
Inventory	1025 TU (6050 assemblies)
Features	Pool storage inside reactor building and in separate facility

Table 6.1. Spent Fuel Storage.

FIR 1 research reactor	
Owner	Public centre
Location	Southern Finland (Research site)
Purpose	Interim storage of spent fuel
Inventory	2,4 Kg U (13 elements)
Features	Racks at the walls of reactor pool

Table 6.1. Spent Fuel Storage. (continuation).

Loviisa nuclear power plant	
Owner	Private utility
Location	Southern Finland (NPP site)
Purpose	Treatment, conditioning and interim storage of LILW
Inventory	1478 m^3
Features	Treatment of solid and liquid waste
	Liquid tanks and storage rooms
Olkiluoto nuclear power plant	
Owner	Private utility
Location	South-Western Finland (NPP site)
Purpose	Treatment, conditioning and interim storage of LILW
Inventory	506 m^3
Features	Treatment of solid and liquid waste
	Liquid tanks and storage rooms
FIR 1 research reactor	
Owner	Public centre
Location	Southern Finland (Research site)
Purpose	Interim storage of LILW
Inventory	6 m^3
Features	Storage room
STUK waste storage	
Owner	Regulator
Location	Southern Finland (Research site)
Purpose	Interim storage of LILW from small user
Inventory	0.5 m^3
Features	Storage room
State-owned waste storage	
Owner	Ministry of Social Affairs and Health
Location	South-Western Finland (Olkiluoto)
Purpose	Long term interim storage of sealed sources and waste from small users
Inventory	47.7 m^3
Features	Rock cavern at the Olkiluoto disposal facility

Table 6.2. Predisposal of radioactive waste.

Loviisa disposal facility	
Owner	Private utility
Location	Southern Finland (island)
Purpose	Disposal of LILW
Inventory	1234 m^3
Features	Rock tunnels
Olkiluoto disposal facility	
Owner	Private utility
Location	South-Western Finland (island)
Purpose	Disposal of LILW
Inventory	4140 m^3
Features	Rock silos

Table 6.3. Disposal of radioactive waste.

1.4. Decommissioning

Section 19 of the Nuclear Energy Act states that sufficient and appropriate methods for arranging the decommissioning of a nuclear facility have to be identified before the construction licence is granted. Provisions for decommissioning of the NPPs shall be made already during the design phase. Limitation of radioactive waste generation and of the radiation exposure of workers and the environment arising from decommissioning shall be considered.

The decommissioning has been taken into account in the design of the new NPP unit Olkiluoto 3. For example, the layout of the plant has been designed to have an easy access for repair and maintenance. In addition, the buildings and rooms of different radiation levels have been separated to facilitate the control of contamination and radiation levels and to keep the dose rates low during operation and maintenance. The aim of the design has also been to minimize the amount of radioactive waste, to ease dismantling and removal of components and structural materials, and to reduce decommissioning costs.

The general provisions for licensing and the waste management obligation included in the current nuclear energy legislation are adequate for regulating a decommissioning project. The Government Decisions related to nuclear and waste management safety are at the present under revision and the provisions for decommissioning are planned to be included in the update. The update of the guide on clearance will cover the removal of control of materials arising from decommissioning of nuclear facilities and of previously licensed sites.

Decommissioning plans

The four currently existing Finnish nuclear power units have been in operation for 25 to 28 years and are planned to be operated at least for two more decades. No nuclear power plants are being decommissioned and such decommissioning projects are neither foreseen in the near future. The current licence of FiR 1 research reactor is valid until 2011. Nevertheless, the operator of FiR1, VTT Technical Research Centre of Finland has started a more detailed planning of the shutdown and decommissioning of the research reactor as a preparatory action to the possible decision of the closure of the facility. The decision to implement the plan is dependent on the outcome of efforts to arrange alternative, sustainable funding for continued operation of the research reactor.

According to the governmental policy decision of 1983 and later decisions by the Ministry of Trade and Industry, the licensees are obliged to prepare decommissioning plans for regulatory review and to update them every five years. These plans aim at ensuring that decommissioning can be appropriately performed when needed and that the estimates for decommissioning costs are realistic. The latest updates of the NPP decommissioning plans were published at the end of 2003. The next plan for the Olkiluoto NPP to be prepared by the end of 2008 will also include the decommissioning plan for Olkiluoto 3.

The decommissioning plans include assessments of occupational and off-site safety of the operations. They include rather detailed descriptions of the required dismantling and waste management operations and estimates of workforce and other resources needed. The plans are based on the actual designs of the nuclear facilities and they take into account the activity inventories in the facilities. The contamination levels in the facilities are followed by means of specific monitoring and recording programmes.

The cost estimates of decommissioning are depending on the amount of waste to be disposed as radioactive and thus the limits to be applied for removal of material from control (clearance limits).

The decommissioning plan for the NPP units Loviisa 1 and 2 is based on 50 years operation and inmediate dismantling. Large and heavy reactor components, e.g. reactor pressure vessels and steam generators, will be removed intact without cutting them in pieces. The advantages of the method are saving of time and occupational radiation doses. Activated components accumulated during the operation will be packed into the reactor vessels which will serve as additional barriers. The waste will be disposed to Loviisa site by extending the current LILW repository. The next decommission plan for Olkiluoto 1 and 2 units will be based on 60 years of operation and 30 years of safe enclosure. For Olkiluoto 3, immediate dismantling is considered as an option as well. As in the case of Loviisa, the reactor pressure vessels of Olkiluoto 1 & 2 are planned to be removed and disposed as such, in one piece at Olkiluoto site.

The decommissioning plan of the research reactor FiR 1 is also updated every five year, the latest update being carried out in the year 2000. A more detailed plan will be prepared in 2005. Studies are under way on the technical feasibility of disposing of the decommissioning wastes in one of the disposal facilities at the NPP sites.

2. Institutional framework

In Finland, the legislation for the use of nuclear energy and for radiation protection was established in 1957. Since then, several amendments and new regulations have been issued.

In 1987, a completely revised Nuclear Energy Act came into force and a supporting Nuclear Energy Decree in 1988. The scope of this legislation covers e.g.

- the construction and operation of nuclear facilities; nuclear facilities refer to facilities for producing nuclear energy, including research reactors, facilities performing extensive disposal of nuclear waste, and facilities used for extensive manufacture, production, use, handling or storage of nuclear materials or nuclear wastes
- mining and enrichment operations aimed at producing uranium or thorium
- the possession, manufacture, production, transfer, handling, use, storage, transport, export and import of nuclear material and nuclear waste as well as the export and import of ores and ore concentrates containing uranium or thorium.

A significant amendment to the Nuclear Energy Act was passed in 1994, to reflect a new policy that emphasises the national responsibility to manage nuclear waste generated in Finland. In general, the export and import of nuclear waste, including spent fuel, is prohibited in the revised Act.

Based on the Nuclear Energy Act, the Government has issued the following decisions:

- Decision of the Government on the General Regulations for the Safety of Nuclear Power Plants (395/1991)
- Decision of the Government on the General Regulations for Physical Protection of Nuclear Power Plants (396/1991)
- Decision of the Government on the General Regulations for Emergency Response Arrangements at Nuclear Power Plants (397/1991)
- Decision of the Government on the General Regulations for the Safety of a Disposal Facility for Reactor Waste (398/1991)
- Decision of the Government on the Safety of Disposal of Spent Nuclear Fuel (478/1999).

The general regulations 395/1991, 396/1991 and 397/1991 are applied to a NPP which is defined to be a nuclear facility equipped with a nuclear reactor and intended for electricity generation, or if such or other nuclear facilities have been placed on the same site, the entirety of facilities formed by them. Thus, spent fuel and radioactive waste management at the NPP sites are covered with these regulations. The general regulations are also applied to other nuclear facilities to the extent applicable.

Detailed safety requirements on the management of spent nuclear fuel and radioactive waste resulting from the production of nuclear energy are provided in YVL Guides. YVL Guides also provide administrative procedures for the regulation. YVL Guides are issued by STUK, as stipulated in the Nuclear Energy Act. YVL Guides are rules an individual licensee or any other organisations concerned shall comply with, unless some other acceptable procedure or solution has been presented to STUK by which the safety level laid down in an YVL Guide is achieved.

Legislation and regulations for the use of radiation sources

The Radiation Act and Decree were revised in 1991, taking into account the ICRP Publication 60 (1990 Recommendations of the International Commission on Radiological Protection). The Radiation Act and Decree were further amended in 1998 to be in conformance with the European Community Radiation Protection Legislation including the Council Directive 96/29/EURATOM of 13 May 1996, on the Protection of the Health of Workers and General Public Against the Dangers Arising from Ionizing Radiation. The Council Directive 2003/1227 Euratom of 22 December 2003 on the Control of High-Activity Sealed Radiation Sources and Orphan Sources will be implemented by revising the Radiation Act and Decree accordingly.

Detailed safety requirements on the management of radioactive waste, subject to the Radiation Act, are provided in STUK's ST Guides. The responsible party running a radiation practice is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

The regulatory responsibilities in the area of nuclear waste management are set forth in the Nuclear Energy Act. The overall authority in the field of nuclear energy is the Ministry of Trade and Industry which has the responsibility of formulation of the national energy policy. The Ministry shall decide, having consulted, when necessary, the Ministry of the Environment in the matter, the principles on the basis of which the waste management obligation is to be implemented. The Ministry prepares matters concerning nuclear energy, including the nuclear waste management, to the Government for decision-making and grants certain import and export licences for nuclear equipment and materials.

In the area of radioactive, non-nuclear waste management the Ministry of Social Affairs and Health is the supreme authority on the supervision of practices involving exposure to radiation.

Regulatory authority for radiation and nuclear safety

STUK is an independent governmental organisation for the regulatory control of radiation and nuclear safety. No ministry can take for its decision a matter that has been defined by law to STUK. The current Act on STUK was given in 1983 and the Decree in 1997. According to the Decree, STUK has the following duties:

- regulatory control of safety of the use of nuclear energy, emergency preparedness, physical protection and nuclear materials safeguards
- regulatory control of the use of radiation and other radiation practices
- monitoring the radiation situation in Finland, and maintaining preparedness for abnormal radiation situations
- maintaining national metrological standards for radiological measurements

- research and development work for enhancing radiation and nuclear safety
- providing information and publishing reports on radiation and nuclear safety issues, and participating in training activities in the field
- producing expert services in the field
- making proposals for developing the legislation and preparing the decisions of the Government in the radiation and nuclear safety fields, and issuing general guides in these fields
- participating in international co-operation, and taking care of international control, contact or reporting activities as enacted or defined.

STUK is administratively under the Ministry of Social Affairs and Health. It is emphasised that the regulatory control of the safe use of nuclear energy and radiation is independently carried out by STUK, and it has no responsibilities or duties which would be in conflict with regulatory control.

STUK does not grant construction or operating licences for nuclear facilities. However, in practice no such licence would be issued without STUK's statement where the fulfilment of the safety regulations is confirmed.

STUK is participating actively in European and international co-operation in the field of nuclear, waste and radiation safety. STUK's experts have participation, memberships and chairmanships in the OECD/NEA, IAEA, IRPA and ICRP. STUK is also involved in the work of European Commission through Atomic Questions Group, NRWG, CONCERT and RAMG-related PHARE- and TACIS- programmes, EBRD as well as through European regulators' association WENRA. In addition, there are regulatory co-operation through Nordic co-operation programmes. STUK also co-operates actively with the Russian regulator Rostechnadzor, and the multinational group CEG concerning the safety of waste management close to the Finnish borders. Finnish government finances this co-operation.

STUK receives part of its financial resources through the Government budget. In the area of regulatory control, the licence holders pay the regulatory control fees directly to STUK. The amounts charged are under the control of the Ministry of Social Affairs and Health.

Regulatory support organisations

An Advisory Committee on Nuclear Safety has been established by a separate decree. It has a special section for nuclear waste management issues. The Committee gives advice to STUK on important safety issues and regulations. In addition, an Advisory Board for Radiation Safety has been established for advising the Ministry for Health and Social Affairs. The members of both Committees are nominated by the Government.

The main technical support organisations of STUK in the field of nuclear waste management are the VTT Technical Research Centre of Finland and Geological Survey of Finland (GTK). In VTT, GTK and other Governmental institutes, about 30 experts are working in the area of spent nuclear fuel and radioactive waste management.

A support group of international experts has been established by STUK for the ONKALO project. This group consists of experts in geology, rock engineering, geohydrology, geochemistry and seismology. The members of the group assist STUK in the review of the ONKALO plans, reports and investigation material.

Independent expertise in the nuclear waste management field is fostered by a separate national research programme KYT. It focuses on generic studies on nuclear waste management and on such studies on the safety of spent nuclear fuel disposal which are not directly related to Posiva's disposal project.

Reports on the regulatory control of nuclear and radiation safety, including radioactive waste management, are published annually.

3. Management of low and intermediate level waste

LILW from nuclear facilities

According to the national policy, low and intermediate level wastes from reactor operations are disposed of in the bedrock at the power plant sites. The construction of the repository at the Olkiluoto site began in 1988 and the operation in 1992. The construction of the repository at the Loviisa site was started in 1993 and the part for the LLW disposal was taken into operation in 1998.

The Loviisa repository is located at the depth of approximately 110 m in granite bedrock. The repository consists of two tunnels for solid LLW and a cavern for immobilised ILW. The cavern for ILW has been excavated and the construction and installation works will be completed by the end of year 2006. After the regulatory review that cavern can be taken into operation as well.

The Olkiluoto repository consists of two silos at the depth of 60 to 95 m in tonalite bedrock, one for solid LLW and the other for bituminized ILW. The silo for solid LLW is a shotcreted rock silo, while the silo for bituminized waste consists of a thick-walled concrete silo inside the rock silo. All wastes will be emplaced in concrete boxes that take 16 waste drums. The LILW from Olkiluoto 3 will be disposed of to the same repository. The repository will be extended in the future, to be able to receive all the waste from Olkiluoto 1, 2 and 3 units during the planned 60 years of operation of the units.

Predisposal management of LILW takes place at the NPPs under their Operation Licences and other provisions. The wastes are segregated, treated, conditioned, packaged, monitored and stored, as appropriate, before they are transferred to the disposal facilities.

At Loviisa, wet LILW (radioactive concentrates, such as spent ion exchange resins, evaporator bottoms, corrosion sludge, absorbent carbon sludge and decontamination slurries) are for the time being stored in tanks at the NPP. A cementation facility is under construction and planned to be operational in 2006 after a pertinent regulatory review.

At Olkiluoto, wet LILW is immobilized in bitumen before transfer to the disposal facility. At the both NPPs, solid LLW is after conditioning transferred to the disposal facilities. Sludge, radioactive concentrates and spent ion exchange resins from liquid waste treatment in Olkiluoto 3 are planned to be dried in drums. For disposal the drums are envisaged to be emplaced in concrete boxes, where space between drums is filled with cement.

Options for very low level waste management are either unconditional or conditional removal from control. Such waste can be reused, recycled or disposed at landfills. At Olkiluoto the NPP has its own landfill while the Loviisa NPP has shipped cleared waste to municipal landfills.

Activated metal waste consists of irradiated components and devices that have been removed from inside the reactor vessel. So far this kind of highly activated waste has not been conditioned but is stored at the NPPs and is expected to be conditioned and disposed of together with decommissioning waste of similar type.

LILW generated from the operation of the research reactor FiR 1 is stored at the reactor facility until decommissioning. Disposal of the operational and decommissioning waste from FiR 1 to the disposal facility at Loviisa site is under discussion and further studies were performed in 2004 concerning the feasibility of such disposal. However, no formal agreement or decision has yet been made between VTT and the utility.

Past practices

In 1958–1961, a company established by the Finnish industry carried out uranium mining and enrichment activities in a pilot scale in the municipality of Eno in the Eastern part of Finland. About 31 000 tonnes of uranium ore were excavated from small open mines and an underground mine. After the termination of the activities the mines were left open and the mine and mill tailings were left at the site.

The restoration of the site was carried out in 1992–1994 by the current owner of the area. The mine and mill tailings were covered with layers of clay and gravel and a soil layer on the top. Finally, trees were planted on top of the disposal site. Furthermore, the bottom sediment of a nearby lake was covered by a layer of soil and other material. However, restrictions for utilization of the site were imposed: any permanent occupancy, construction work or earthmoving is not allowed in the area.

Radioactive waste arising from small use of radioactive sources

An applicant for a licence for the use of unsealed sources is required to submit for STUK's approval a waste management plan describing the intended releases of radioactive substances into sewer system or atmosphere and deliveries of solid radioactive waste to a landfill site or to interim storage. The conditions for such disposal of radioactive waste are then specified in the license, as necessary. The conditions may include site specific limits on discharges, requirements on discharge and environmental monitoring or other control measurements necessary e.g. for estimating doses to the population.

The two options for the management of disused sealed sources are either return to the supplier/manufacturer of the source or delivery to STUK against a waste management fee. STUK takes care of the conditioning and packaging of the sources and they are stored under the administrative control of STUK in a separate cave in the LILW repository at Olkiluoto.

A licensee can be exempted from preparing a waste management plan if the operations are arranged such that the activity limits regarding gaseous or liquid discharges or solid-waste disposal established in the Guide ST 6.2 are not exceeded. However, even in this case STUK may order monitoring of discharges and reporting thereof, if this is considered necessary due to environmental considerations, nature of the work and the nature and amount of radioactive substances in use. In addition, although being below the limits all discharges to the environment shall be as low as reasonably achievable.

In practice, most of waste from the use of unsealed sources in Finland arise in such low activity concentrations or amounts that it is not necessary to arrange the final disposal of generated waste in the same way as e.g. for the sealed sources. A common practice is that radionuclide laboratories store their short lived radioactive wastes at their premises until they have decayed below the limits set for discharges in the Guide ST 6.2. However, some waste resulting from radiochemical research at the VTT are submitted to STUK for storage with the state own waste in Olkiluoto. In addition, the wastes resulting from studies conducted by VTT for FPH are returned back to FPH for disposal in Loviisa LILW repository.

All radionuclide laboratories – thus also the storages and other activities related to waste management – are inspected by STUK regularly, every 1–5 years, depending on the type and size of the practice.

4. Management of high level waste and spent fuel

4.1. Strategies, objectives and main milestones of management programme

Spent fuel and radioactive waste management policy

According to the Nuclear Energy Act nuclear waste generated in Finland shall be handled, stored and permanently disposed of in Finland. Respectively, nuclear waste generated elsewhere than in Finland, shall not be handled, stored or permanently disposed of in Finland. There are only minor exemptions to these principles, notably the spent nuclear fuel arising from the research reactor. That fuel can be handled, stored and disposed of outside Finland, if justified on grounds of safety or due to a significant economic or other weighty reason.

According to the Nuclear Energy Act, generators of nuclear waste are responsible for all nuclear waste management measures and their appropriate preparation, and are also responsible for the expenses arisen. The state has the secondary responsibility in case that any producer of nuclear waste is incapable of fulfilling its management obligation.

The principles of the nuclear waste management policy were originally set in the Finnish Government's policy decision of 1983 and later in the decisions by the Ministry of Trade and Industry (MTI). These decisions set also a long-term schedule for the implementation of nuclear waste management including the site selection and start of the operation of the spent fuel disposal facility.

Other radioactive waste

Other radioactive waste than nuclear waste is regulated in the framework of Radiation Act and Decree. The organization engaged in radiation practice is required to take any measures to render harmless radioactive wastes arising from its operation. Rendering radioactive waste harmless means any measure needed to treat, isolate or dispose of the waste, or to restrict its use so that it does not endanger human health or the environment. The state has the secondary responsibility in case that a producer of radioactive waste is incapable of fulfilling its management obligation.

4.2. Facilities (in operation and planned)

Spent fuel management

Spent nuclear fuel from NPPs is stored at the power plant sites until it will be disposed of. Initially, the fuel is cooled for a few years at reactor pools. In addition to the pools in the reactor buildings, the Loviisa NPP has basket type and rack type pool storages attached to the reactor building. The effective storage capacity (excluding reserves for repair work) is about 520 tU. The most recent enlargement of the pool facility was commissioned in 2001. The current capacity is adequate until about 2010. The needed additional capacity is planned to be achieved by providing pools with dense racks.

At the Olkiluoto plant, the effective capacity (excluding reserves for repair work) of the pools at the reactor buildings is about 370 tU. Subsequently, the spent fuel is transferred to an on-site facility with three storage pools, the capacity of each being about 400 tU, with high-capacity fuel racks. The spent fuel storage facility was commissioned in 1987. The current capacity is adequate until early 2010's. The planning for extension of the storage has been started. The construction of Olkiluoto 3 unit will be taken into account in the design of the extension of the storage.

The nuclear legislation provides for disposal of nuclear waste into the Finnish bedrock. Posiva is implementing the spent fuel disposal programme with the following main targets, which are in line with the Government Policy Decision of 1983:

- Disposal site selection in 2000 (The Olkiluoto site was proposed by Posiva in the Decision-in-Principle application of 1999; this application was approved by the host municipality in January 2000, the Decision was made by the Government in December 2000 and it was ratified by the Parliament in May 2001.);
- Start of construction of an underground rock characterisation facility in Olkiluoto in 2004 (The construction started in July 2004.);
- Preparedness for the application of the Construction Licence in 2012;
- Disposal facility should be ready for operation around in 2020.

The current estimate for the amount of spent fuel to be disposed of in Olkiluoto is 5640 tonnes: 1020 from Loviisa 1 and 2, 2620 tonnes from Olkiluoto 1 and 2, and 2000 tonnes from Olkiluoto 3. The estimates are based on the expectation that the units Loviisa 1 and 2 are operational until 2030, Olkiluoto 1 and 2 until 2040 and Olkiluoto 3 until 2070. However, the operation licences of the NPPs are granted only for 10 to 20 years at a time.

Spent fuel will be stored in water pools for some decades and thereafter transferred to the encapsulation and disposal facilities which will be located at Olkiluoto. Spent fuel would be encapsulated in copper-iron canisters each containing 12 BWR or PWR (Loviisa 1 & 2) fuel assemblies. The canisters for Olkiluoto 3 reactor (EPR) fuel are planned to contain 4 PWR fuel assemblies. The canister design consists of a cast iron insert as a load-bearing element and an outer container of oxygen-free copper to provide a shield against corrosion. The canisters will be emplaced in a network of tunnels, which will be constructed at a depth of about 400 to 500 m in crystalline bedrock. The annulus between the canister and the rock wall will be filled with compacted bentonite. The canisters can be positioned either vertically or horizontally. Both options are under investigation.

The pre-designs of the encapsulation and disposal facilities, operational and post-closure safety assessments and summaries of site characterisation were included in Posiva's Decision-in-Principle application and in the supporting documents. STUK's preliminary safety appraisal of the Decision-in-Principle application was published in January 2000. The design of facilities and the site baseline description have been updated in 2003–2005.

The spent fuel generated at Olkiluoto 3 will be first transferred to an at-reactor pool storage and after some years to a separate on-site pool storage. Extension of the separate pool storage by early 2010's is under consideration to cover the required storage capacity for the Olkiluoto1, 2 and 3 spent fuel until the final disposal facility is available.

Spent fuel of the research reactor FiR1 is stored at the facility. The decision on the further use of FiR 1 is dependent on the outcome of the efforts to find an alternative, sustainable source of funding of its operation and maintenance. The first option for the management of spent fuel is interim storage at the facility and later on, disposal into the spent fuel repository at Olkiluoto. The second option would be to return the fuel to the United States. Recently the USDoE has made a decision to extend by additional ten years the time schedule for accepting spent fuel from foreign research reactors. Thus, the operation of FiR1 could be continued until 2016 without losing the opportunity to return the spent fuel to the supplier.

4.3. R&D needs. Knowledge and technology development

The Nuclear Energy Act was amended in late 2003 to ensure stable funding for a long term nuclear safety and nuclear waste management research in Finland. The objective of the funds is to guarantee the high level of national safety research and to maintain the national competence in the long run. For the waste research, the annual payments are proportional to the assessed liabilities in the Nuclear Waste Management Fund at the end of previous year. The total annual volume of funds for KYT programme for nuclear waste management is about 1 M€. The research projects are selected so that they support and develop the competences in spent nuclear fuel and nuclear waste management. In addition, STUK finances research assignments supporting more directly regulatory control activities, notably safety reviews of the final disposal of spent fuel.

Posiva Oy, Teollisuuden Voima Oy and Fortum Power and Heat Oy published in late 2003 a report called "Nuclear waste management of the Olkiluoto and Loviisa power plants. Programme for research, development and technical design for 2004–2006". It is an overview of the R&D and technical design in the field of nuclear waste management by Posiva and its owners in the recent years and also a plan for future activities. It is focused on the years 2004–2006.

In the safe management of spent fuel and radioactive waste, international co-operation is of high importance, and the Finnish regulatory authorities, nuclear power and waste management companies and research institutes have actively looked for co-operation with foreign organisations. In this respect, especially the activities of the IAEA and OECD/NEA and the R&D framework programmes of the European Union are essential.

4.4. Safety and licensing

The authorization processes are defined in the legislation. For a NPP, spent fuel storage, nuclear waste disposal facility or other significant nuclear facility the process consists of three steps:

- Decision-in Principle – granted by the Government and confirmed by the Parliament
- Construction Licence – granted by the Government
- Operating Licence – granted by the Government.

The conditions for granting a licence are prescribed in the Nuclear Energy Act. The operating licences of a nuclear facility are granted for a limited period of time, generally for 10–20 years. In case the operating licence is granted for longer periods than 10 years, a periodic safety review is anyway required to be presented to STUK. The periodic re-licensing or review have allowed good opportunities for a comprehensive safety review.

Before a construction licence for a NPP, spent fuel storage, nuclear waste disposal facility or other significant nuclear facility can be applied, a Decision-in-Principle (DiP) by the Government is needed. An Environmental Impact Assessment (EIA) procedure has to be conducted prior to the application of the DiP and the EIA report annexed to the DiP application. A condition for granting the Decision-in-Principle is that the construction of the facility in question is in line with the overall good for the society. Further conditions are as follows:

- the municipality of the intended site of the nuclear facility is in favour of constructing the facility
- no factors indicate a lack of sufficient prerequisites for constructing the facility so that the use of nuclear energy is safe; it shall not cause injury to people, or damage to the environment or property.

The entry into force of the Decision-in-Principle further requires a confirmation by a majority of the Parliament. The Parliament can not make any changes to the Decision; it can only approve or reject it as such. In the DiP stage the full process is required, for the construction and operation licences the acceptance of the Parliament and the host municipality are not any more needed.

If the licensee intends to make such modifications in the systems, structures, components or operational procedures of a nuclear facility which could affect the safety, the approval of STUK for the modifications is required beforehand.

On the basis of the Nuclear Energy Act, minor licences for spent fuel and nuclear waste management activities (export, import, transfer and transport licence and licences for operations) are granted by either Ministry of Trade and Industry or STUK; the licensing authority in each case is specified in the Nuclear Energy Decree.

The licensing system for practises under the Radiation Act is described in the Act. The use of radiation requires a safety licence, which can be granted by STUK upon application. A safety licence can be subject to extra conditions needed to ensure safety. In addition, the cases where a licence is not needed are identified, e.g. when the use of radiation or a devise is exempted.

According to the Nuclear Energy Act, a licensee, whose operation generate or have generated nuclear waste, shall be responsible for all nuclear waste management measures and their appropriate preparation, and is responsible for the arising expenses. In case of the research reactor, the operator is also fully responsible for spent nuclear fuel and waste management. The State has deposited the necessary funds to the State Nuclear Waste Management Fund on behalf of the operator of the research reactor.

The NPP utilities FPH and TVO themselves take care of interim storage of spent fuel, of management of LILW including disposal, and of planning for the decommissioning of the NPPs. Their jointly owned company, Posiva, is taking care of the preparations for and later implementation of spent fuel encapsulation and disposal.

For management of radioactive waste from non-nuclear applications, the responsible party (i.e. the licensee or any company or organization which uses radiation sources in its practices) is required to take all measures needed to render radioactive waste arising from its operation harmless. In case where the practice produce or may produce radioactive waste that can not be rendered harmless without considerable expenses, a financial security shall be furnished to ensure that these costs and those arising in performing any necessary environmental decontamination measures are met.

The state has the secondary responsibility in case that a producer of nuclear waste or other radioactive waste is incapable of fulfilling its management obligation. STUK operates an interim storage of radioactive waste, where limited amounts of spent sealed sources and other radioactive waste are received upon compensation covering their further management costs.

General safety requirements

The predisposal management facilities for low and intermediate level radioactive waste in Loviisa and Olkiluoto NPPs and the FiR 1 research reactor are covered by the respective Operation Licences of the reactors. The safety reviews carried out in the context of renewal of the Operation Licences are described in Chapter G.5.1 and the conclusions drawn are valid for LILW management as well. At the Loviisa NPP, a waste solidification facility based on cementation is currently under construction. The appropriate amendment of the FSAR has to be approved by STUK before the start of the operation of the facility.

The LILW disposal facilities have separate licences. According to the Government Decision 398/91 thorough assessments of the safety of the facilities were carried out by the licensees and reviewed by STUK in connection with the construction and operation licence applications. The safety reassessment review of the LILW disposal facilities will be made at 15 years interval. The Olkiluoto LILW disposal facility was taken into operation in 1992 and consequently its safety review is to be made in 2007. In the same context the suitability of the waste packages from the new Olkiluoto 3 NPP unit for disposal in the facility will be evaluated. The first stage of the Loviisa LILW disposal facility (LLW disposal tunnel) was taken in operation in 1998. The second stage of the facility (ILW disposal tunnel) is currently under construction and the FSAR of the facility will be accordingly updated and reviewed by STUK in 2006.

Criticality and removal of residual heat

On spent fuel encapsulation and disposal it is required that the formation of such spent fuel configurations that would cause an uncontrolled chain reaction of fission shall be prevented by means of structural design of systems and components. The transport casks, storage rooms and handling equipment as well as the waste canisters shall be designed so that no critical fuel concentrations may be formed in any operational situations, including anticipated operational transients and postulated accidents. The canisters emplaced in the geological repository shall retain their subcriticality in the long-term, when the internal structures of the canisters may have corroded and the canisters partly filled with groundwater.

A spent fuel disposal canister must meet the normal criticality safety criteria. The effective multiplication factor must be less than 0.95 also when the canister is in the most reactive credible configuration (optimum moderation and close reflection). Uncertainties in the calculation methods may necessitate the use of an even lower reactivity limit.

Furhermore, a canister used for final disposal of nuclear fuel must be sub-critical also under very unfavourable conditions, i.e. for instance, when:

- the fuel in the canister is in the most reactive credible configuration
- the moderation by water is at its optimum
- the neutron reflection on all sides is as effective as credibly possible.

All the three types of spent fuel disposal canisters planned to be used for final disposal in Finland have been analysed. It has been proved in an earlier study by Posiva (1995), that a version of the VVER canister loaded with twelve similar fresh VVER 440 assemblies with the initial enrichment of 4.2% fulfils the criticality safety criteria. Also an earlier design of the BWR canister loaded with twelve fresh BWR assemblies of so-called ATRIUM 10x10-9Q type with the initial enrichment of 3.8% and without burnable absorbers has been proved to meet the safety criteria.

In the recent study in 2005 the main emphasis has been on the EPR canister. This new canister type fulfils the criticality safety criteria only if the so called burnup credit principle is applied in calculations. The fuel bundles to be loaded in an EPR canister should have been irradiated at least to a burnup of 20 MWd/kgU. In the year 2005 study only a few calculations have been carried out for the present versions of VVER and BWR canisters and the results are in good agreement with the previous ones.

Residual heat generation of spent fuel will be taken into account in the design of the encapsulation facility and the disposal concept. Spent fuel disposal shall be implemented with due regard to long-term safety, and in doing so, one aspect to be considered is the reduction of the activity and heat generation prior to disposal. The safety systems in the encapsulation facility, intended for the prevention of overheating of spent fuel assemblies, must be designed with regard to the single failure criterion. Posiva's spent fuel disposal canister and its loading has been designed so that the multiplication factor (kc) remains below 0.95 and the outer temperature below 100ºC.

The maximum specified canister surface temperature is 100ºC and a margin of 10ºC is used in the dimensioning calculations. The maximum temperature of disposal canister surface is reached within 10 to 15 years after the disposal.

Thermal dimensioning including the detailed heat transfer phenomena in the near field and optimisation of the repository has been studied. The canisters are planned to be emplaced in disposal holes in tunnels with a span of 8.6 m for VVER 440 canister, 11 m for BWR canister and 10.6 m for EPR canister. The distance between parallel disposal tunnels is 25 m in the planned reference case.

Waste minimization

Guide YVL 8.3 underlines that generation of waste shall be limited i.a. by proper planning of repair and maintenance wastes and by means of decontamination, clearance and volume reduction practices. The Guide also refers to sound working methods for waste minimization, e.g. by volume reduction of waste, by avoiding transfer of unnecessary objects and materials in the controlled areas and by adoption of working processes that create little or easily manageable wastes.

Removal of very low level waste from control (clearance) is regulated by virtue of Guide YVL 8.2. Both conditional and unconditional removal from control is effectively used for waste minimization by the NPPs.

The average annual accumulation of LILW to be disposed of has been fairly low: about 80 m3 per reactor. The accumulation of waste has in some years even turned to decline by effective waste minimization measures, such as radiochemical treatment of liquid waste and campaigns for removal of very low level waste from control and compaction of maintenance waste.

FPH developed in 1990's together with University of Helsinki (Laboratory of Radiochemistry) sophisticated selective ion exchange methods for purification of liquid waste (especially the removal of Cs, Sr and Co). The benefits of the system can be seen in the decrease of the doses to the critical group.

TVO has made a construction change in both plants in the condensate polishing system to decrease the temperature and thus increasing the lifetime of precoat resins. The amount of spent resins has decreased considerably. Low and intermediate level waste subject to long-term storage at the Olki-luoto plant mostly includes components removed from inside the reactor pressure vessels, which are stored in the fuel pools. The cutting up and final disposal of steam separators started in 2004. The same year, TVO begun to use a crusher to cut pipes and other metal components in small pieces for minimizing the waste volume.

At the new Olkiluoto 3 NPP unit an in-drum drying facility will be used for conditioning of liquid wastes, which provides very effective volume reduction.

Basic radiation protection requirements

Basic requirements for the safe use of nuclear energy are given in the Nuclear Energy Act. The principles of justification, optimisation and dose limitation are included in the Radiation Act, in particular occupational dose limits and dose limits for the general public. These limits are in conformity with the ICRP 60 Recommendation (1990) and the Council Directive 96/29 EURATOM.

The effective dose caused by radiation work to a worker shall not exceed 20 mSv per year as an average over five years or 50 mSv in any single year.

The detailed instructions on the application of the maximum values laid down for radiation exposure and on the calculation of radiation doses shall be issued by STUK. STUK may, in individual cases, set constraints lower than the maximum values, if such constraints are needed to take account of radiation exposure originating in different sources and to keep the exposure as low as reasonably achievable.

The constraint for the dose commitment of the individual among the population, arising in one year from the normal operation and anticipated operational transients of a NPP, is 0.1 mSv. The individual dose constraint for postulated accidents is 5 mSv in a year. The dose constraints are defined for the entire NPP, including all units. Thus the future operation of Olkiluoto 3 will not increase the applied dose constraints at the site.

Government Decision 398/1991, dealing with the safety of LILW disposal, provides that the constraint for the expectation value of the annual effective dose to any member of the public is 0.1 mSv. The constraint for the annual dose to any member of the public, arising from accident conditions which are caused by natural events or human actions and which are considered to be plausible, is 5 mSv.

According to Government Decision 478/1999, a spent fuel disposal facility and its operation shall be designed so that as a consequence of undisturbed operation of the facility, discharges of radioactive substances to the environment remain insignificantly low. In Guide YVL 8.5 on the operational safety of spent fuel disposal this requirement is interpreted as a constraint of 0.01 mSv annual effective dose to the most exposed members of the public. The radiological consequence of anticipated operational transients as annual effective dose to the most exposed members of the public shall remain below 0.1 mSv. The annual effective dose caused by postulated accidents shall remain below 1 mSv.

Regarding the long term radiation protection requirements for LILW disposal, Government Decision 398/1991 requires that the radiation exposure arising from the disposed waste shall be kept as low as reasonably achievable. The constraint for the expectation value of the annual dose to any member of the public is 0.1 mSv. The constraint for the annual dose to any member of the public, arising from accident conditions which are caused by natural events or human actions and which are considered possible, is 5 mSv. The increase in the total activity concentration of radioactive substances in the biosphere, arising from the disposed waste, shall remain insignificant in any part of the biosphere.

According to the Decision, disposal of LILW shall be based on multiple natural and engineered barriers. Engineered barriers shall effectively limit the migration of radioactive substances from the waste emplacement rooms for at least 500 years. Thereafter, natural barriers in the first place shall be able to limit the migration of radioactive substances to the biosphere at a level that is in compliance with the requirements for radiation protection.

The Government Decision 478/1999 requires that the operation of a spent fuel encapsulation and disposal facility shall not cause radiation exposure that could endanger occupational or public safety or could otherwise harm the environment or property. They shall be designed so that as a consequence of undisturbed operation of the facility, discharges of radioactive substances to the environment would remain insignificantly low, that the annual effective dose to the most exposed members of the public as a consequence of anticipated operational transients remains below 0.1 mSv and as a consequence of postulated accidents below 1 mSv. In Guide YVL 8.5 the requirement of insignificantly low exposure posed by the normal operation has been interpreted to mean 0.01 mSv/a.

Regarding the long term radiation protection requirements for spent fuel disposal, Government Decision 478/1999 requires that in the period of first several thousands of years the annual effective dose to the most exposed members of the public shall remain below 0.1 mSv and the average annual effective doses to other members of the public shall remain insignificantly low. Beyond that period the average quantities of radioactive substances over long time periods, releasing from the disposed waste and migrating further to the environment, shall remain below the nuclide specific constraints defined by STUK. These constraints are given in the Guide YVL 8.4 as limits for annual activity releases to the environment. They are defined so that, at their maximum, the radiation impacts arising from disposal are comparable to those arising from natural radioactive substances and, on a large scale, the radiation impacts remain insignificantly low.

In addition, the Guide YVL 8.4 gives due regard to the protection of the living nature requiring that disposal of spent fuel shall not affect detrimentally to species of fauna and flora. This shall be demonstrated in the safety assessment by assessing the typical radiation exposures of terrestrial and aquatic populations in the disposal site environment, assuming the present kind of living populations. These exposures shall remain clearly below the levels which, on the basis of the best available scientific knowledge, would cause decline in biodiversity or other significant detriment to any living population. Moreover, rare animals and plants as well as domestic animals shall not be exposed detrimentally as individuals.

Other hazards than those posed by radiation (biological, chemical, etc) are considered in the EIA reports in the same way as in the connection with other industrial activities but are not especially dealt with in the safety analysis of LILW repositories.

5. Financial provisions

Waste management costs, including those arising from decommissioning of the NPPs, are included in the price of nuclear electricity. Initially, the nuclear power companies had internal funds for that purpose, but by virtue of entry into force of the Nuclear Energy Act, the State Nuclear Waste Management Fund was established under the Ministry of Trade and Industry (MTI) in 1988. To ensure that the financial liability is covered, the nuclear power companies and the operator of the research reactor are each year obliged to present cost estimates for the future management of nuclear wastes and take care that the required amount of money is set aside to the State Nuclear Waste Management Fund. In order to provide for the insolvency of the nuclear utilities, they shall provide securities to MTI for the part of financial liability which is not covered by the Fund. In case of the research reactor, the operator is also fully responsible for spent nuclear fuel and waste management. In that case the state has deposited the necessary funds to the State Nuclear Waste management Fund on behalf of the operator of the research reactor (VTT).

The Radiation Act provides for furnishing the financial security of radioactive waste management for non-nuclear practices as follows: to ensure that the licensee meets the costs incurred in rendering radioactive waste harmless and in carrying out any decontamination measures that may be needed in the environment, it shall furnish security if the operations produce or are liable to produce radioactive waste that cannot be rendered harmless without substantial cost. The Radiation Decree, Section 15, defines more precisely cases where financial security shall be furnished.

The Nuclear Energy Act provide detailed regulations for the financial arrangements for nuclear waste management and the Decree on the State Nuclear Waste Management Fund further specifies the financing system. Generators of nuclear waste are responsible for estimating annually future cost of managing the existing waste, including spent fuel disposal and decommissioning of NPPs. The Ministry of Trade and Industry (MTI) confirms the assessed liability and the proportion of liability to be paid into the Nuclear Waste Management Fund (fund target). The waste generators pay annually the difference of fund target and the amount already existing in the Fund, but can also be reimbursed if the Fund exceeds the liabilities. The waste generators shall provide securities to MTI for the portion of financial liability that is not yet covered by the Fund.

For the FiR1 research reactor somewhat modified practices are followed. The state has initially provided the funds on behalf of the operator (VTT). In the future the State will take care of the payments to cover the difference between the Fund target and the amount already existing in the Fund. The possible interest reimbursements are returned to the State.

The current estimates, including costs from management of existing waste quantities and from decommissioning of current NPPs and the research reactor, arise to about 1400 million Euros with no discounting. At the end of the year 2004, the funded money covered the whole liability corresponding to the current waste amounts.

According to the Nuclear Energy Act, a Construction Licence for a nuclear facility can be granted only if the applicant has sufficient financial resources. This condition shall be complied with throughout the operation of the facility. For example, the licensee shall have adequate financial resources to enhance the safety of the facility based on operating experience and the results of safety research as well as on the advancement of science and technology. In particular the operation of the nuclear facility shall not be started until the Ministry of Trade and Industry has ascertained that the provision for the cost of waste management has been arranged. Furthermore, the application for the construction and operating licence of a nuclear facility shall include information on the financial resources of the applicant, cost estimates and financial plan for the nuclear facility programme, as well as a description of the timetable of nuclear waste management and its estimated costs.

According to the Radiation Act, the licensee shall furnish security to ensure that it will meet the costs of waste management or any decontamination measures, if the operations are liable to produce radioactive waste that cannot be rendered harmless without substantial cost. The need to furnish security and the amount of it shall be decided by STUK when the safety licence is granted.

The licensees are responsible for the implementation of decommissioning. In the event that the licensee is incapable of doing so, the state has the secondary responsibility. In this case, the costs are covered by assets collected in the Nuclear Waste Management Fund and by securities provided by the licensees. The financing of decommissioning of the research reactor FiR 1 and the management of resulting waste is also covered by assets in the Nuclear Waste Management Fund. The decommissioning of facilities subject to the Radiation Act is covered by the security referred to in Section 19 of the Act.

According to the Nuclear Energy Act, a condition for the expiry of waste management obligation of a nuclear waste generator is that the waste has been permanently disposed of in an approved manner and a lump sum to the State for the further control of the waste has been paid. Thereafter, the State is responsible for the necessary waste management measures and incurred costs.

The responsible party and others who have taken part in producing or handling the radioactive materials or waste shall compensate the State for the costs incurred by the measures taken to render the waste harmless and to decontaminate the environment.

6. Social, public opinion and communication aspects

STUK's public communication aims at being proactive, open, timely and understandable. Communication is always based on best available information. STUK's web page is an important tool in communication. In recent years STUK has published a series of books on radiation and nuclear safety. The books are intended to be used as handbooks for those who work in the field and for students. Five parts have been issued covering the following fields: radiation and measuring, radiation in the environment, use of radiation, health effects of radiation, and nuclear safety, including waste management. Two more parts regarding non-ionizing radiation (electromagnetic fields and ultraviolet and laser radiation) are scheduled to be published in 2005–2006.

The availability of information in case of the siting process for a major nuclear facility is based on the Finnish legislation on the openness of information, notably on the Act on the Openness of Government Activities (1999). Further requirements are based on the Act and Decree on the Environmental Impact Assessment Procedure and the Nuclear Energy Act. The first step of consultation with the general public is the Environmental Impact Assessment (EIA) process. Public hearings are arranged both in the preparation stage of the EIA programme and during the actual assessment. The responsible contact authority for that process is the Ministry of Trade and Industry. The EIA report must be attached to the application for the Decision-in-Principle.

The Nuclear Energy Act states that, before the Decision-in-Principle is made, the applicant shall make available to the public an overall description of the facility, of the environmental effects it is expected to have and of its safety. The Ministry of Trade and Industry shall provide residents and municipalities in the immediate vicinity of the nuclear facility as well as local authorities chance to present their opinions in writing before the Decision-in-Principle is made. Furthermore, the Ministry shall arrange a public hearing in the municipality where the planned site of the facility is located and during this hearing the public shall have the opportunity to give their opinions either orally or in writing. The presented opinions have to be made known to the Government. The Act provides further that a necessary prerequisite for the Decision-in-Principle is that the planned host municipality for the nuclear facility is in favour of siting the facility in that municipality.

Institutional control

Two types of institutional control may be implemented: restrictions in land use (passive control) and technical post-closure surveillance (active control).

According to the Nuclear Energy Act, STUK's supervisory rights include issuing land use restrictions after the closure of the disposal facility when deemed necessary. An adequate protection zone shall be reserved around the disposal facility. According to Guide YVL 8.1 it can be assumed that human activities, affecting the repository or the nearby host rock, are precluded for 200 years at the most by means of land use restrictions and other passive controls. This assumption is relevant for the choice of scenarios in the safety assessment.

Provisions shall be made for such reliable technical post-closure surveillance measures that will not have an adverse impact on the safety of disposal. The closure plan shall include inter alia a plan for post-closure surveillance. However, technical post-closure surveillance shall not be taken into account as a safety supporting factor in the safety analyses.

Radioactive waste management in Japan

J.Reig

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1. Introduction. General overview

1.1. Nuclear energy programme

Operation of the first commercial nuclear power reactor in Japan started in 1966. Following the 1973 oil crisis, there was active support to build nuclear power plants, and now a total of 55 commercial nuclear power reactors exist in Japan. One reactor is at the decommissioning stage. Nuclear fuel cycle facilities related to commercial power generation, including 2 enrichment facilities, 4 fuel manufacturing facilities, 2 reprocessing facilities, 2 disposal facilities are in operation or under construction. In addition, sixteen research reactors are in operation at national and private institutes and universities.

Various forms of utilization of radiation are also widely applied in research applications, in medical diagnosis and treatment and in commercial activities. There are more than 5000 national or private facilities using various types of radiation.

The last Energy Master Plan was decided by the Cabinet of Ministers and reported to the Diet in October 2003 in accordance with the Basic Law on Energy Policy. The plan states that nuclear power generation should be promoted as a basic power supply recognizing the excellent characteristics of nuclear power generation in terms of stable supply of electricity and a measure against global warming, and that necessary investment should be encouraged under the framework of electricity market liberalization.

The 55 nuclear installations in Japan are shown in table 7.1. 53 units are in operation, 1 unit is under construction and one unit ceased operation in March 2003 for the preparation of decommissioning. Electricity generated from nuclear power in 2005 was 294.9 billion kWh, that is 31.2 percent of 944.7 billion kWh electricity generated in Japan.

Type	Status		Number of Units
Commercial power reactor	Boiling water reactor (BWR)	in operation	30
	Pressurized water reactor (PWR)	in operation	23
Power reactor in research and development stage		under construction	1
		in preparation for decommissioning	1

Table 7.1. Commercial Nuclear Power Plants.

1.2. Waste categorization

Radioactive waste is classified in Japan into two categories. One is high-level waste (HLW) generated from spent fuel reprocessing, and the rest is low-level waste (LLW). The LLW is sub-classified according to origin (radionuclide composition) and level of radioactivity. The Atomic Energy Commission (AEC) decides on the basic policy for disposal of radioactive waste. Based on the classification, the Nuclear Safety Commission (NSC) decides fundamental concept for safety regulations on radioactive waste disposal, upper bound of radioactivity concentration in disposal and the guidance on safety assessment of radioactive waste disposal facilities. The Ministry of Energy, Transport and Industry (METI) and the Ministry of Education, Science and Technology (MEXT) establish relevant regulations.

The Table 2 shows the two categories of radioactive waste, namely HLW and LLW. Depending on its origin, the LLW is sub-classified into waste from power reactors, radioactive waste containing transuranic nuclides (reprocessing facility, MOX fuel manufacturing facility), uranium waste (uranium fuel manufacturing facility, uranium enrichment facility) and radioactive waste from medical, industrial and research facilities.

For the three subcategories of wastes from power reactors as shown in the table 7.2, the NSC has calculated the concentrations of the radionuclides that correspond to the reference dose values, using safety assessment concept, models and parameters which are consistent to the international standards.

The NSC then, in consideration of the concentration distribution of the radioactive waste, has established the upper bound of the concentrations of radionuclides for radioactive waste to be disposed of. Based on this value, the upper bound of radionuclides concentrations for license application of waste repository has been provided in the Reactor Regulation Law. In addition, a clearance system has also been established. The AEC issued the report "Policy on Processing and Disposal of Radioactive Wastes" in August 1984 about the concept of the clearance level that divides wastes into the radioactive waste and the "materials not requiring treatment as radioactive wastes". In response to the above policy, the NSC presented a basic concept of "materials not requiring consideration of particularities as radioactive wastes" in 1985, consistent with IAEA-TECDOC-855, and referring to the dose values due to cleared materials shown in the recommendation by the International Commission on Radiological Protection (ICRP- Pub. 46).

Classification			Example	Origin of Waste
High-Level Radioactive Waste			Canister High-Level Liquid Waste	– Reprocessing facilities
Low-Level Radioactive Waste	Waste from Power Reactors	Relatively Higher Radioactive Waste	Control Rods Core Internals Spent Ion Exchange Resin	Power Reactors
		Relatively Lower Radioactive Waste	Liquid Waste Filters Used Equipment Expendables	
		Very Low-Level Radioactive Waste	Concrete Metals	
	Waste Containing Transuranic Nuclides		Parts of Fuel Rod Liquid waste Filters	– Reprocessing Facilities – MOX Fuel Manufacturing Facilities
	Uranium Waste		Expendables Sludge Used Equipment	– Enrichment and Fuel Manufacturing Facilities
	Radioisotope and Waste from Research Facilities and other		Liquid waste Metals Concrete Plastics Filters Disposable Syringe	– Fuel Material Use Facilities – Radioisotope Use Facilities – Research Reactor Facilities – Reactors at the Research and Development Stage – Medical Institutions – Research Organizations – Medicine Manufacturers
Material that need not be treated as radioactive waste (Waste below the Clearance Level)			A Part of Waste from Decommissioning	Sources as shown above

Table 7.2. Classification of Radioactive Wastes.

1.3. Waste production: Current status and forecast

Spent fuel from power reactor facilities is being held in storage at spent fuel management facilities within power reactor facilities or at the spent fuel management facilities within the Tokai Reprocessing Facility of JNC and Rokkasho Reprocessing Plant of JNFL. Spent fuel from research reactor facilities is being held in storage at spent fuel management facilities of the research reactor facilities. There are in all 27 facilities to store spent fuel wastes, most of them (23) use a wet storage system, 2 use a dry storage system and the other two use both dry and wet storage system. The facilities are distributed in 15 Prefectures, being those of Fukui and Ibaraki the prefectures hosting more storage facilities.

The inventory of spent fuel stored in the spent fuel management facilities totals approximately 13000 tons as of the end of March, 2005.

The radioactive waste management facilities in **power reactors** include: waste processing facilities where waste generated at the reactor facility is processed; solid waste storage facilities where drums (homogeneous solidification, fill-up solidification, miscellaneous solid and others), filled with processed waste are stored; storage facilities where the replaced steam generators and other large solid wastes are stored; spent fuel pools where the disused control rods, the disused channel boxes, are stored; and tanks where the spent ion exchange resin is being stored.

The radioactive waste management facilities in **enrichment and fuel manufacturing** plants include: waste processing equipments that processes waste generated at the plants; and solid waste storage facilities where drums filled with processed waste are stored.

The radioactive waste management facilities in spent fuel **reprocessing plants** include: waste processing equipments that processes waste generated at the plant; waste storage facilities where vitrified waste and high level liquid waste are stored; and waste storage facilities where low level liquid waste and low level solid waste are stored.

The radioactive waste management facilities in **research reactors** and major fuel material facilities include: waste processing equipments that processes low level radioactive waste generated at those facilities; and solid waste storage facilities where drums filled with processed waste are stored.

There are 20 waste storage facilities at reactor sites. The inventory of radioactive wastes stored in the radioactive waste management facilities of nuclear power reactor include, as of March 2005, approximately 560000 drums (200 litters) in solid waste storage facilities, 29 steam generators in steam generator storage facilities, used control rods, disused channel boxes and spent resin in spent fuel pools.

There are 34 waste storage facilities other than nuclear power reactor facilities, mostly dedicated to fuel fabrication, enrichment, reprocessing, fuel material use and research. As of March 2005, an inventory of HLW of approximately 1100 vitrified packages and approximately 400m^3 high level liquid waste are stored in fuel reprocessing facilities, and LLW of approximately 440000 drums (200 litters) and approximately 4000m^3 low level liquid waste are stored in fuel reprocessing facilities, fuel fabrication facilities, laboratories, research reactor facilities of universities, and storage facilities of Japan Radioisotopes Association.

A portion of LLW stored at radioactive waste management facilities of commercial power reactor facilities, which has comparatively low concentration of radionuclides, has been transported to a radioactive waste disposal facility of JNFL and disposed of at near surface disposal facility since 1992.

Presently, the disposal facility of JNFL is in operation and has disposed of about 170000 drums (200 litters) of waste, as of the end of March 2005. At the disposal facility of Tokai Research Establishment of JAERI, about 1670 tons of very low level waste resulting from dismantling of JPDR were disposed of. The facility has started operation in 1995, and has been at the preservation stage since October 1997.

1.4. Decommissioning

The AEC Long Term Program states that nuclear facilities licensed on the basis of the Reactor Regulation Law should be decommissioned safely at the responsibility of their operators, with the understanding and support of the local community, and that the land, after decommissioning of commercial power reactors, is expected to serve as sites for new nuclear power plants, again with the support of local communities.

The regulatory policy for decommissioning of reactor facilities in Japan has been thoroughly discussed and documented in the following reports:

(1) "Basic Philosophy to Assure Safety for the Dismantling Nuclear Reactor Facilities" (December 1985, Decision by the NSC, later revised in 2001),

(2) "Aiming at Decommissioning of Commercial Nuclear Power Facilities" (January 1997, Nuclear Energy Subcommittee, Advisory Committee for Natural Resources and Energy),

(3) "Philosophy for Safety Assurance and Safety Regulation on the Decommissioning of Commercial Power Reactor Facilities" (August 2001, Decommissioning Safety Subcommittee, Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy).

Based on these reports, and in order to ensure the safety during the decommissioning of commercial nuclear power reactors, regulation was implemented by applying existing provisions in the Reactor Regulation Law.

Concerning decommissioning activity in Japan, dismantling of the Japan Power Demonstration Reactor (JPDR) was completed in May 1996. The very low-level concrete waste generated by dismantling was disposed of at a disposal facility, which was closed in 1997. A reactor at the Tokai Power Station of the Japan Atomic Power Co. ceased operation in 1998 and has been in decommissioning stage since December 2001. The advanced thermal reactor "Fugen" of JNC ceased operation in March 2003. Spent fuel is being transferred to Tokai Facility of JNC, and decommissioning is being planned. The development and application of dismantling technologies have progressed, and the know-how for decommissioning has been accumulated through these processes.

The Decommissioning Safety Subcommittee, reporting to METI, has reviewed the appropriate regulatory system of decommissioning, based on the regulatory experiences on decommissioning of reactor facilities under the current system, aiming for amendment of legislations, with the main goal of ensuring safety.

The review was conducted from view points of ensuring transparency of regulations, and graded regulatory approach for the evolution of the decommissioning process, the diversity of each facility, reflecting the experiences of decommissioning, and development of technology in the near future. The results were reported in "The Way of the Decommissioning Regulation of the Nuclear Facilities" (December 9, 2004)). In this investigation, the Subcommittee recognized that the decommissioning of nuclear reactors is becoming systematic, and the amendment of legislation must promote a graded approach by regulatory body and clarification of the responsibilities of operators with the principle of ensuring safety. The main goal for this review were (i) to clarify the requirement in decommissioning regulations, (ii) to keep the transparency on procedures for the operators, and (iii) to obtain the understanding and confidence of local residents.

In the proposal, the following process is considered:

(1) The operator submits the decommissioning plan including process of decommissioning, methods of dismantling, method of managing the radioactive waste generated during the dismantling, the safety analysis and the financial plan.

(2) The regulatory body reviews the plan on the conformity with technical criteria and approve it.

(3) The operator conducts the decommissioning in accordance with the decommissioning plan. Since normally the decommissioning takes a long time and consists of several steps, it is allowed to modify the program at the beginning of each step with the prospect that the completion of decommissioning is ensured. These modifications are subject to the approval of the regulator for the revised decommissioning plan.

The amendment of the Reactor Regulation Law was approved in May 2005, according to the main results from the above proposal, and the associated detailed provisions are under preparation. The regulations on radiation protection applied to nuclear facilities in operation are also applicable to nuclear facilities in the process of being decommissioned.

Electric utilities have deposited funds for decommissioning of commercial power reactor facilities using the Dismantling Reserve Funds.

In addition, the Reactor Regulation Law requests to keep important records such as inspection records, radiation control records, even at decommissioning stage. And other records specific to decommissioning such as each equipment or system being dismantled, schedule and method for dismantling it, are required to be recorded and kept at the end of each dismantling process. Thus the regulatory body can confirm that the decommissioning has been appropriately completed ensuring safety and in compliance with the Decommissioning Plan.

2. Institutional framework

The Minister of METI serves as the competent minister for safety regulation on activities concerning utilization of nuclear energy, and NISA administers the regulatory activities as a special organization for METI. The Minister of MEXT serves as the competent minister for the safety regulation over the nuclear utilization associated with science and technology and the utilization of radioisotopes (except medicines, etc.), and the Science and Technology Policy Bureau (STPB) administers the regulatory activities.

These regulatory bodies have clearly defined duties on safety regulation, and their independence is ensured both in legislation and in substance.

Nuclear and industrial safety agency (NISA)

The Minister of METI, as the competent minister stipulated in the Reactor Regulation Law and the Electric Utilities Industry Law, enforce the safety regulation over all activities on the utilization of nuclear energy, including nuclear power generation, and NISA was established as a special organization of METI to administer the safety regulation, independently from the Agency of Natural Resources and Energy that promotes nuclear energy utilization.

The Minister of METI, as the competent minister, provided by the Reactor Regulation Law and the Electric Utilities Industry Law has the authority to examine the nuclear facilities whether its siting, structure and equipment are conform for the requirement of prevention of radiation hazards, and if in the case of the licensee violate the laws, the minister has the authority to revoke the license.

On the basis of METI Establishment Law, the Advisory Committee for Natural Resources and Energy is established, a subcommittee of which is the Nuclear and Industrial Safety Subcommittee that develops policies on nuclear safety and safety of electric power. The experts in the Subcommittee are assigned based on their knowledge and experience in specialized fields including nuclear and thermal-hydraulic design, system design, seismic design, radiation control, and radioactive waste disposal.

In October 2003, the Japanese Nuclear Energy Safety organisation (JNES) was established as a supporting organization for NISA in ensuring safety in utilization of nuclear energy. JNES implements the following activities to accomplish its mission:

- Inspection of nuclear and reactor facilities;
- Safety analysis and evaluation of designs of nuclear and reactor facilities;
- Investigation, testing, research, and training concerning ensuring safety in utilization of nuclear power as energy.; and
- Collection, analysis and transmission of information relating to ensure nuclear safety.

NISA develops a plan on each activity based on the regulatory needs, and defines the medium-term objective in accordance with the Law. JNES then prepares a medium-term program to accomplish the objective, subject to the approval of METI. The budget for JNES consists of government budget and income from inspection fees.

Science and Technology Policy Bureau (STPB), ministry of education, culture, sports, science and technology (MEXT)

The safety regulation concerning the activities around the nuclear utilization from a scientific and technological aspect and the utilization of radioisotopes (excluding medicines) is regulated by the Minister of MEXT as the competent minister, and is administered by the Science and Technology Policy Bureau (STPB).

With regard to the licensing of research reactor facilities and use of nuclear fuel materials under the Reactor Regulation Law, and the radioisotope waste management under the Radiation Hazards Prevention Law, the Minister of MEXT has the authority to issue the respective licenses, after conducting an examination of the site, structure and equipment from the standpoint of nuclear safety. The Minister also has the authority to revoke the licenses under certain circumstances, such as the violation of applicable laws and regulations by the license holder.

The STPB includes the Nuclear Safety Division, which has the responsibility for regulation of research reactors, waste and fuel facilities, regulations for radioisotopes and environmental radiation measures. An inspector for the safety management of nuclear facility is assigned as resident to each research reactor facilities and major fuel material use facilities, to conduct examinations and inspections stipulated in the Reactor Regulation Law four times a year, to confirm compliance with the Operational safety program and surveillance of reactor operation management, and to respond to an emergency situation.

The STPB holds advisory committee on nuclear safety regulation, with an objective to contribute to the transparent and efficient administration of nuclear safety by MEXT. Under this committee, sub-committees are held, in order to consider the safety regulations for research reactor and for radiation protection.

Nuclear Safety Commission (NSC)

The NSC, which was established within the Cabinet Office under the Atomic Energy Basic Law, consists of five members who are appointed by the Prime Minister with the consent of the Diet. The chairperson is elected by mutual voting.

The NSC has the duties of planning, deliberation and decisions on matters that are related to ensuring the safety of nuclear energy uses, and establishes guidelines to be used for the safety examination. If the NSC deems it necessary as part of its assigned duties, the NSC can advise and require reporting from relevant administrative organization by way of the Prime Minister.

The NSC can request submission of reports, statement of views and explanation from relevant administrative organization if it is necessary. When the regulatory body issues a license for a nuclear facility (excluding nuclear fuel material use facility and facility handling RI) based on the Reactor Regulation Law, the NSC may independently re-examine and review the applicants' technical ability, the adequacy of location of nuclear facilities, and the measures for preventing failures of safety structures and equipments.

Even in construction and operational stage of the nuclear facility following their license, the NSC receives quarterly reports from the regulatory body on the approval and changes of the Operational Safety Program, the compliance with the Operational Safety Program by the operator, results of the Periodical Inspection of Facility, etc. And the NSC independently monitors and reviews the adequacy of the regulatory activities, if needed.

The NSC has a technical secretariat in the Cabinet Office. The Secretariat of the NSC is composed of the Secretary-General, the General Affairs Division, the Regulatory Guides and Review Division, the Radiation Protection and Accident Management Division, and the Subsequent Regulation Review Division, and has about 100 staffs. In the NSC, two Committees for Examination, eight Special Committees, and two Technical Advisory Bodies and others are organized, and discussing the relevant issues. The NSC opens to the public and permits the hearing of all deliberations of the special committees and subcommittees, and the contents are publicly available through the web-site and the Nuclear Energy Library.

The Atomic Energy Commission (AEC)

The AEC consists of the chairman and four other members appointed by the Prime Minister with the consent of the Diet. The AEC has duties of planning, deliberation and decisions concerning the research, development and utilization of nuclear energy (excluding safety regulations). The AEC issues "the Long-Term Plan for Research, Development and Utilization of Nuclear Energy", which describes the fundamental framework of nuclear policies in Japan every five years.

When the AEC deems it necessary as part of its assigned mandate, it has the authority to recommend and demand reports to relevant administrative organizations through Prime Minister, and the AEC also has the authority to request the submission of materials and assessments from relevant administrative organizations. Furthermore, before the regulatory body issues a license for a nuclear facility (excluding fuel material use facility), the competent minister inquiries about the opinions of the AEC on whether the nuclear facility will be used for peaceful purposes, whether the plan of the applicant conform to the planned development or utilization of nuclear energy, and whether the applicant has an adequate financial resources to construct and maintain the nuclear facility.

The Radiation Review Council (RRC)

The Radiation Review Council is established within MEXT under "the Law for Technical Standards of Radiation Hazards Prevention". The mandate of the Radiation Review Council is to establish basic policies on technical standards for prevention of radiation hazards and to maintain consistency among related technical standards. The basic policy is that the radiation doses of occupational personnel and the general public be less than the dose that may cause radiation hazards. The Council receives reports from the administrative organizations concerned with technical standards for prevention of radiation hazards, and state its opinion to the organizations to keep consistency among technical standards.

The Radiation Review Council consists of a maximum of 20 members, and the Basic Committee composed of experts from different fields is established under the council.

The Nuclear Waste Management Organization (NUMO) of Japan

The Specified Radioactive Waste Final Disposal Act, approved in the year 2000, provides for an implementing organization for disposal of the HLW generated from spent fuel reprocessing, financial resource reserved for the disposal and the procedure for selecting disposal sites. In the year 2000, based on the law, Nuclear Waste Management Organization (NUMO) of Japan was established. In 2002, the organization started open solicitation for candidate site as Preliminary Investigation Areas, which is the first step to select geological disposal site.

3. Management of low and intermediate level waste

The basic policy on the radioactive waste management is that the current generations, who receive the benefit of nuclear energy, should bear the responsibility to manage the resulting waste generated in the research, development and utilization of nuclear energy, and should make continued efforts at promoting adequate radioactive waste disposal. The operator of the facility that produces waste has the primary responsibility for safe processing and disposal of the waste, and based on the principle, they prepare and implement their plans with consultation of other relevant organizations. Meanwhile, the government regulates, and issues guidance to, the producers, ensuring that waste processing and disposal are carried out appropriately and safely. The Reactor Regulation Law was amended in May 2005 to provide for clearance, and relevant regulations are being established based on IAEA safety standard.

LLW generated in reactors and reprocessing facilities is processed and temporarily stored in storage facility in these facilities and then sent to disposal facility. LLWs below the upper bound level from power reactors are being transferred to the waste disposal facility of Japan Nuclear Fuel Ltd. for disposal. Concerning other LLW from power reactors which are in storage, relevant safety criteria on disposal are being prepared. Disposal of very low-level concrete waste from dismantling of the Japan Power Demonstration Reactor (JPDR) was completed and the disposal facility was closed in 1997.

Liquid waste concentrate from NPP operation is solidified with cement in drums after evaporation. Paper, clothing and other combustibles are placed in drums after incineration. Plastics, metals and other non-combustibles are placed in drums after compaction. Replaced steam generators and other large-volume solid wastes are placed in storage facilities. Replaced control rods and channel boxes, etc. are stored in spent fuel pools and spent ion exchange resins are stored in tanks.

For non-radioactive waste generated in non-nuclear facilities, the waste generators are requested to minimize the generation, to reuse, to reprocess and to dispose appropriately of waste.

Liquid transuranic waste generated at the Tokai Reprocessing Plant of JNC is stored in tanks and concentrated by evaporation, and a portion of it is solidified in drums. Segmented fuel cladding, used filters and sampling bottles are put in containers and other solid waste is put in drums. These drums and the containers are being held in storage at on-site storage facilities.

Transuranic waste generated at spent fuel reprocessing plant in France and UK will be returned to Japan after 2013. Utilities are planning to construct a storage facility for it. Research and development programs on transuranic waste disposal have been promoted by JNC and utilities. They published a report in June 2005 titled "Technological Report on TRU Waste Disposal, 2nd report".

Liquid waste, containing uranium, generated from enrichment and/or fuel manufacturing facilities of JNC and/or other private facilities are stored in tanks. Solid uranium waste and ash resulting from incineration are put in drums. They are held in storage at on-site storage facilities.

Radioactive waste generated from medical, industrial and research facilities are collected by the license holders of radioactive waste management facility, who store it at their own storage facilities after compaction or incineration. Radioactive waste generated in facilities of research reactor and fuel material use of the Japan Atomic Energy Agency (JAEA), the JNC and universities are stored in drums at their own storage facilities after compaction or incineration.

Near-surface disposal of solidified liquid waste and compacted and solidified non-combustible wastes started in 1992 at the disposal facility of JNFL at Rokkasho in Aomori Prefecture.

4. Management of high level waste and spent fuel

4.1. Strategies, objectives and main milestones of management programme

The most recent AEC Long Term Program states that nuclear power generation should contribute to energy supply system in Japan as an economical, stable and environmentally acceptable source of energy, and that nuclear fuel cycle technologies have the potential to further improve these aspects, having possibilities for people to enjoy the benefits of nuclear power generation over a long period of time. Recognizing these features, and the geographical conditions and energy resources of the country, and considering the economical conditions, Japan has made it a basic policy to reprocess spent fuel and to make effective use of the recovered uranium, plutonium and other usable elements, while ensuring safety and nuclear non-proliferation. Also, Japan intends to reprocess all spent fuel within the country as a national policy, ensuring self-sustainable nuclear fuel cycle. The Program also states that interim storage of spent fuel ensures flexibility in the nuclear fuel cycle, allowing sufficient time before reprocessing.

There are public concerns in Japan about safety and nuclear proliferation related to the use of plutonium recovered from reprocessing of spent fuel. To address these concerns, Japanese Government is making significant efforts to ensure safety and nuclear non-proliferation, and to make the waste management policy of Japan understood in the international community.

The Specified Radioactive Waste Final Disposal Act, approved in 2000, provides for an implementing organization for disposal of the HLW generated from spent fuel reprocessing, financial resource reserved for the disposal and the procedure for selecting disposal sites. In the year 2000, based on the law, NUMO was established. In 2002, the organization started open solicitation for candidate site as Preliminary Investigation Areas, which is the first step to select geological disposal site.

Spent fuel generated in power reactors are sent to reprocessing facilities after a period of on-site cooling and storage. The spent fuel has been reprocessed overseas in accordance with contracts with British and French companies, with the exception of a portion reprocessed by the Tokai Reprocessing Plant of the JNC. In the meantime, considering national demand for reprocessing, JNFL began constructing the Spent Fuel Reprocessing Plant in Rokkasho-mura, based on operational experience accumulated at the Tokai Reprocessing Plant and on technologies and experience from other countries. The plant was in the situation of test operation using uranium in March 2005, and will start operation from 2007. Storage of spent fuel at storage facility in the plant started since 1999, and export of spent fuel to foreign reprocessing plants ended in July 2001.

The Reactor Regulation Law was amended in 1999 to incorporate provisions on interim spent fuel storage, and a company is currently preparing for commercial operation of interim fuel storage facilities in 2010. The spent fuel from research reactor facilities has been exported to the USA, or is to be reprocessed in Japan.

Further, the AEC states that the government should play an appropriate role in implementing the disposal program for radioactive waste, with a view to ensuring long-term safety, in addition to its activities related to promotion of research and development activities and safety regulation.

METI and MEXT have established and continued to improve the legal framework consisting of the Reactor Regulation Law and the Radiation Hazards Prevention Law, for safe and proper processing, storage and disposal of radioactive waste, on the bases of studies and decisions made by the AEC and the NSC.

The Reactor Regulation Law was amended in May 2005 to provide for clearance level and the procedure for its monitoring for compliance, while the relevant regulations are going to be established in future. The AEC makes decision on the basic policy for radioactive waste disposal. Based on the policy, the NSC decides on the basic concept for the safety regulations for land disposal, upper bounds of radioactivity concentration for disposal of radioactive materials and methods for safety assessment of disposal facilities. METI and MEXT establish relevant regulations.

There are two basic concepts for land disposal, "geological disposal" and "near surface and intermediate depth disposal with institutional control". The near surface and intermediate depth disposal consists of near surface disposal with artificial barrier (concrete vault), near surface disposal without artificial barrier (trench) and intermediate depth disposal (disposal at a depth sufficient to safety margin for conventional underground building). HLW is disposed of solely by geological disposal, and LLW can be disposed of either by geological disposal or near surface and intermediate depth disposal with institutional control, depending on the property of the waste. Vitrified HLW is emplaced in a stable geological formation at a depth of more than 300 meters, following 30 to 50 years of interim storage to allow cooling. Among LLW from power reactors, relatively higher radioactive wastes are disposed of in intermediate depth disposal facilities, relatively lower radioactive waste are disposed of in near surface disposal facilities with artificial barriers, and very low level waste are disposed of in near surface disposal facilities without artificial barriers. Radioactive wastes containing transuranic nuclides from reprocessing process, uranium waste from enrichment and/or fuel manufacturing, and radioactive waste from medical, industrial and research facilities are disposed of either by geological disposal or near surface and intermediate depth disposal with institutional control, depending on types of radionuclides and levels of radioactivity. In the future, discussions will continue on measures that can be taken to provide different disposal methods in a single disposal facility, or to dispose of wastes of different origin in a single disposal facility.

In compliance with the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972) and its amendment to Annex I in 1993, the AEC decided on November 2, 1993 to eliminate the option of sea dumping of radioactive waste. Based on this decision the Reactor Regulation Law was amended in May, 2005.

The regulatory body establishes regulations on HLW disposal, while NUMO is responsible for implementing HLW disposal economically and efficiently. Japan Nuclear Cycle Development Institute and other national institutes conduct various programs to develop safety assessment methodology, to promote fundamental research on deep geological formation, etc. and to enhance reliability of geological disposal technology.

Regarding site selection, the Nuclear Safety Committee issued a report "Environmental Requirements to be Considered at the Selection of the Preliminary Investigation Areas for High-Level Radioactive Wastes Disposal" in September 2002. The environmental requirements shown in the report are reflected in the report of NUMO "Considerations for Selection of the Preliminary Investigation Areas".

Partitioning and transmutation is a technology to separate radioactive materials with long half-lives in HLW from the rest of the waste and convert them into short half-lives or stable materials. This technology, even though it is still in early stage of development, should be further pursued because it may contribute to reduction of waste processing and disposal cost and to effective use of available resources.

4.2. Facilities (in operation and planned)

In Japan, spent fuel has been reprocessed by the Tokai Reprocessing Plant of the JNC and by reprocessing plants in France and the United Kingdom. JNFL is constructing a vitrification facility of HLW, attached to its reprocessing plant, at Rokkasho-mura in Aomori prefecture. This facility is to be completed by 2007. High-level liquid waste generated at the Tokai Reprocessing Plant of the JNC is stored in storage tanks within the facility. The vitrification facility started operation in January 1995. As of March 2005, about 400 cubic meters of liquid waste and 169 vitrified waste canisters are in storage. Utilities in Japan have concluded reprocessing contracts with British and French companies for a total of 5,600 t U of spent fuel from light water reactors and 1,500 t U of spent fuel from a gas cooled reactor. In accordance with these contracts, vitrified waste canisters are returned to the utilities and are stored by JNFL. By March 2005, 892 vitrified canisters had been returned, and a total of 2,200 canisters will be returned, with remaining packages in the next ten years.

Vitrified HLW will be disposed of by geological disposal. Based on the Specified Radioactive Waste Final Disposal Act, NUMO the responsible implementing organization, will start disposal in late 2030s after three steps procedure of site selection, that is, selection of the preliminary investigation areas, detailed investigation areas and final disposal facility. NUMO, in 2002, started the first step by open solicitation of candidate of sites for the preliminary investigation areas, and published the "application format", "outline of the disposal facility", "investigation items" and "coexistence of disposal facility and local community". In case of receiving proposal of candidate areas, NUMO will assess validity of the candidates by conducting survey of the site with existing literature on volcanic activities, active faults and other geological conditions, and will decide the preliminary investigation areas by 2010.

4.3. R&D needs. Knowledge and technology development

The NSC issued a report "Nuclear Research Programs Important to Safety" in July 2004, which shows the requirements at the selection for the detailed investigation areas, and the research tasks needed for safety examination. The program also describes research tasks for development of the safety evaluation concerning processing and disposal of low-level wastes of comparatively high radioactivity, TRU wastes and uranium wastes in addition to the decommissioning technology.

Since 1976, the NSC has been promoting research on the safety of nuclear facilities, environmental radioactivity and radioactive waste. To respond to the possible expansion and diversification of nuclear power development and utilization, the NSC has utilized the results of the safety research in the establishment of safety policy, basic principles, and various standards and guidelines.

Since 2001, the relevant organizations have been conducting research related to the areas of near surface disposal, geological disposal, and clearance level, contributing to the establishment of standards for the disposal of radioactive waste. Subjects of research include, in the area of near surface disposal, research on the migration of radio-nuclides and the safety assessment for disposal of radioactive wastes from Radioisotopes use facilities and research facilities, and, in the area of geological disposal, research on the long-term stability of the geological environment and on the long-term behaviour of the engineered barriers and surrounding bedrock, and, in the area of clearance level, research on verification methods of clearance level of the wastes generated from decommissioning of nuclear facilities.

In addition to the above described research, intensive research and development on geological disposal of HLW have been conducted by the government and related organizations as described in the Long-Term Program for Research, Development and Utilization of Nuclear Energy (2000). The research and development consist of research needed for safety regulations of final disposal of HLW and safety assessment, basic research such as the geo-scientific study on the geological environment of deep underground and research and developments for technological improvement of reliability of geological disposal technologies. Especially, two underground research facilities programs being conducted by Japan Nuclear Cycle Development Institute, one is with granite and the other with young argillaceous sediments, are expected to be the programs not only for the above mentioned objectives but also for promotion of better understanding of general public in Japan about geological disposal of HLW.

4.4. Safety and licensing

Fundamental laws to ensure safety in the utilization of nuclear energy and radiation are the Law for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Reactor Regulation Law) and the Law Concerning Prevention from Radiation Hazards due to Radioisotopes (the Radiation Hazards Prevention Law), both of which are based on the Atomic Energy Law. These laws and their related regulations have been amended, as appropriate, as the utilization of nuclear energy and radiation expands and diversifies. The laws are consistent among them in terms of the basics and details of radiation protection. The NSC, established on the basis of the Atomic Energy Basic Law, plans, deliberates and makes decisions on policies aimed at ensuring the safe utilization of nuclear energy. As the regulatory bodies responsible for ensuring safety within their particular area of competence, NISA of METI and the STPB of MEXT regulate and issue guidance on relevant activities. Operators of nuclear facilities conduct their activities under the policies and the regulations mentioned above.

Based on the Reactor Regulation Law and/or Electricity Utilities Industry Law, NISA of METI regulates and issues guidance on facility and activities ensuring the safety of radioactive waste management in repositories, power reactors, uranium enrichment facilities, fuel manufacturing facilities and reprocessing facilities. In each nuclear facility and activity, according to the grade of importance of safety, criteria and guidance are established for each facility to regulate each stage of licensing design, construction, operation and decommissioning, including emergency preparedness.

Based on the Reactor Regulation Law, the STPB of MEXT regulates and issues guidance on activities to ensure the safety of radioactive waste management in research reactors and fuel material use for research and development purposes, and establishes regulations according to the characteristics and scale of each facility. The STPB, on the basis of the Radiation Hazards Prevention Law, regulates, and issues guidance on activities of radioactive waste management to ensure the safety of facilities using radioisotopes.

In accordance with the objectives of "the Atomic Energy Basic Law", the Reactor Regulation Law, to ensure that the uses of nuclear source material, nuclear fuel material, and reactors are limited to peaceful purposes, and carried out in a planned manner, and to ensure public safety by preventing hazards and providing physical protection of nuclear fuel material. The Reactor Regulation Law provides on the safety requirement for the following facilities and activities:

- Nuclear fuel fabrication
- Establishment and operation of reactor facilities
- Spent fuel storage
- Spent fuel reprocessing
- Radioactive waste disposal
- Use of nuclear fuel material, and
- Radioactive waste management outside of the licensed site.

The safety of spent fuel generated in a reactor facility and stored on site, spent fuel stored off site or spent fuel brought into and stored in a reprocessing facility, is regulated by the provisions on the establishment and operation of reactor facilities, by the provisions on the spent fuel storage or by the provisions on the spent fuel reprocessing, respectively.

At the stage of issuing the License for a nuclear facility, the regulatory body conducts an examination to determine adequacy of the site and adequacy of the basic design of structure and equipment from the point of prevention of radiological hazards. In addition, the regulatory body confirms that the nuclear facility will not be used for non-peaceful purposes, the license accommodates to planned development and utilization of atomic energy, and the applicant planning to establish the nuclear facility has sufficient technical capability to ensure safety and sufficient financial resources to execute the plan. In the radioactive waste disposal, the regulatory body confirms whether the radioactive waste disposal facility, the waste packages and the safety measures are in accordance with the technical standards.

Concerning the clearance system, clearance level is defined as "radioactivity concentration level of the materials, on which no measures are required to prevent hazard due to the radiation". The operator carries out measurement and estimate radiation concentration level by the method approved by NISA. Detailed regulations both on decommissioning and clearance level will be established in future.

"The Specified Radioactive Waste Final Disposal Act", established in May, 2000 provided the framework for the planned and steady final disposal of "Specified Radioactive Waste" which is high level radioactive waste (HLW) resulted from reprocessing of spent nuclear fuel. The major points of the law are, (1) the government establishes basic policy and plan on final disposal of specific wastes (Final Disposal Plan), (2) establishment of an implementing organization, (3) measures to secure financial resources for disposal, and (4) site selection procedure.

The Minister of METI establishes basic policy and based on this, provides Final Disposal Plan. Nuclear Waste Management Organization of Japan (NUMO), which was established as an implementing organization based on the Final Disposal Plan, carries out the activities of final disposal. Utilities shall contribute financial resources to the fund reserved for disposal, which is managed by an organization designated by the Minister of METI. NUMO promotes site selection by a three step procedure, that is, selection of the preliminary investigation area, detailed investigation area and site for disposal facility, and obtain approval of the Minister of METI at each step of procedure.

The three step procedure for site selection is as follows, and items for investigation and evaluation are clearly defined.

- Preliminary investigation area
  Definition: The area to investigate by boring whether the geological formation concerned is stable for long term.
  Requirements for selection: There shall be no record of remarkable variation of the geological formations by natural phenomena, such as earthquakes.

- Detailed investigation area
  Definition: The area to investigate, by constructing underground facility with testing and measuring equipment, whether the property of the geological formation concerned is suitable for construction of disposal facility.
  Requirements for selection: Remarkable variation of the geological formations by natural phenomena, such as earthquakes, has not occurred for long term.

- Selection of Final disposal facility construction site
  Definition: The site where the final disposal facility is to be built.
  Requirements for selection: It is expected that underground facility to be built within the geological formation will not be attacked by an extraordinary pressure, and that physical property of the geological formation is suitable for the final disposal facility.

When a site is selected as the final disposal facility, The Minister of METI have to consult with governors and local governments, and revise and finalize the Final Disposal Plan as appropriate considering the opinions.

The safety management of spent fuel on a reactor facility site or a reprocessing plant site is regulated by the provisions of the Reactor Regulation Law concerning the establishment and operation of nuclear reactors or reprocessing facilities. More specifically, spent fuel management facilities are regulated as associated facilities operated in the respective reactors or facilities. On the other hand, the safety management of spent fuel stored outside a reactor or a reprocessing plant site is regulated in accordance with the provisions for storage in the Reactor Regulation Law, and is regulated as specialized facilities concerning licensing, permission, approval and inspections. At present, there is no storage facility which is in operation, under construction or for which an application for licensing of construction has been filed.

Present regulations have been established assuming storage of spent fuels in water pools or metal dry casks at the sites of nuclear reactor facilities, in water pools at the sites of reprocessing facilities, and in metal, or concrete, dry casks at the specialized storage facilities.

The regulatory process concerning spent fuel storage facilities includes different steps. The process begins with an application for a license. The regulatory body grants an operator of a license for storage facility after the Safety Examination. Prior to construction of the installation, the regulatory body examines design and construction plan and approves them if they are acceptable. When construction of the facility requires prescribed welding process, the regulatory body confirms it through the Welding Inspections or the Welding Safety Management Inspections. In addition, the regulatory body conducts the Pre-Service Inspections to make sure that the construction works are being carried out in accordance with the approved design and construction plan. The regulatory body requires the operator to establish the Operational Safety Program and approves it. The operator starts operation of the facility (excluding reactor facilities), after notifying the regulatory body of it.

After the facility started operation, the regulatory body conducts the Periodical Inspection of Facility to confirm the integrity of the facility, and the Nuclear Safety Inspection to confirm the operator's compliance with the Operational Safety Program.

The operator starts decommissioning after preparing a decommissioning plan describing the decommissioning processes, the financial plan, and obtaining approval by the regulatory body. Decommissioning procedure finishes when the regulatory body confirms completion of the dismantling.

The Reactor Regulation Law has provisions in corresponding chapter for the waste management facilities and activities which are divided to two categories. One is a waste disposal in near surface and intermediate depth repository and the other is a treatment and storage of radioactive wastes. The Radiation Hazards Prevention Law has provisions for the waste management services, which deal with repackaging, storage and near surface disposal of wastes.

The Reactor Regulation Law also provides that the radioactive wastes generated from a nuclear facility should be treated and stored inside the facility. High-level radioactive wastes(HLW) generated by contracting overseas reprocessing of Japanese spent fuel are returned to Japan and stored at the radioactive waste management facility of the Japan Nuclear Fuel Ltd. LLW generated by the reprocessing at overseas are also to be returned to Japan in the future.

In regard to the geological disposal of HLW safety regulations are under development, and the open solicitation of candidate site for safe disposal of HLW for survey that is the first stage of selection process of the potential site is carrying out by NUMO, in accordance with the procedure subscribed in the "Specific Radioactive Waste Final Disposal Act"(2000).

The procedure of regulation on the near surface disposal of LLW generated from operation of nuclear reactor facilities deals with both cases of wastes disposal, one with waste disposal of relatively lower radioactivity level and solidified in drum and disposed in a repository with engineered barriers such as concrete pits and the other with very low level radioactivity not solidified in drum and disposed in a repository without engineered barriers.

The regulatory procedure starts with an application of a license by a waste disposal facility operator. The regulatory body carries out necessary examination and issue the license when the application is conformed with the regulation. The regulatory body confirms that the waste disposal facility and the safety operation measures to be taken are in compliance with the technical standards provided in the Reactor Regulation Law. After the confirmation by the regulatory body, the operator submits a notice of the start of operation and then starts operation.

After the start of operation, the regulatory body conducts the nuclear safety inspection four times a year. Other than this inspection, it conducts the confirmation prior to the disposal of waste packages that the waste packages are in compliance with technical criteria provided in the Reactor Regulation Law (Safety Verification of Radioactive Waste Packages).

After completion of transportation of waste packages to the repository, the open space between and surrounding the packages is filled with mortar to avoid voids. The repository is then covered its surface with soil. The regulatory body confirms that the cover with soil is in compliance with technical standards for waste disposal facilities etc. (Safety Verification of Disposal Facility).

The guides of the NSC "Fundamental Guidelines for Licensing Review of Land Disposal Facility of Low-Level Radioactive Waste" (issued in 2001) describes that stepwise management is applied to the waste disposal site until the radioactivity level become lower than the established level, due to decay of radio-nuclides. The details of the management of the repositories with and without engineered barriers differ each other. The institutional control after closure of the repository can be terminated within a reasonable time period, provided that expected public exposure is such a low level that does not need any management for radiation control. At the end of the institutional control, the operator shall submit the notice of the termination of the license.

Concerning the regulations for disposal of LLW from power reactors, the upper bounds of radioactivity concentration, to be applied for license for radioactive waste disposal, have already been established on the basis of the Reactor Regulation Law. The radioactive waste returned from overseas reprocessing is to be disposed of together with waste from domestic reprocessing.

The NSC issued the "Basic Concept of Regulation on HLW disposal" in November 2000, and indicated a schedule to establish basic guidelines for safety examination before the selection of the site, and other guidelines for safety examination before the start of the safety examination of the disposal facility.

5. Financial provisions

The Law for Deposit and Management of the Fund Reserved for Spent Fuel Reprocessing in the Nuclear Power Generation, established in May 2005, provides the framework for deposit and management of the fund reserved for spent fuel reprocessing. The fund is managed by an organization designated by the Minister of METI (Fund Management Organization). The Minister of METI, every fiscal year, notifies utilities of the amount of deposit based on the amount of electricity generated by nuclear energy, and utilities deposit the amount in the Fund Management Organization. Related regulations are being prepared.

In accordance with the Specified Radioactive Waste Final Disposal Act enacted in May 2000, operators of power reactor facilities deposit funds for disposal of high level radioactive waste to the Nuclear Waste Management Organization of Japan, the implementing body for disposal, who entrusts management of the fund to the Radioactive Waste Management Funding and Research Center. The amount of deposit per vitrified package was 33,964,000 yen in the year of 2004. The amount of money for construction of repository in mid-2030s and disposal of about 40,000 vitrified packages of high level waste is estimated about 3 trillion yen.

When issuing a licence for a nuclear facility, except for nuclear fuel material use facility, the regulatory body, in accordance with the Reactor Regulation Law, confirms that the applicant for the license possesses necessary financial basis, then consults with the AEC. The Reactor Regulation Law stipulates that applicant should submit financial documents attached to the application format. An applicant for waste repository should attach such documents as the "Scheduled Date of the Commencement of Operation of Facility and Activities", the "Annual Plan for Acceptance and Disposal of Radioactive Wastes", the "Financial Plan and Estimated Annual Financial Balance" and the "Other Financial Matters" to the application format.

Electric utilities have deposited two internal reserves for reprocessing of spent fuel and for decommissioning, on the basis of the Ministerial Order established under the Electricity Utilities Industry Law.

The reserve of spent fuel reprocessing will pay for reprocessing expense subtracting the value of recovered uranium and plutonium. The amount of reserve by the end of March 2005 is about 3,100 billion yen by 10 electric utilities. As the Law on the Management of the Fund Reserved for Spent Fuel Reprocessing was enacted in May 2005, the internal reserve of electric utilities is to be transferred to an organization designated by the Minister of METI.

The reserves for decommissioning of nuclear power generation facilities will pay for the expense of dismantling and removal of commercial power reactor facilities, and the processing and disposal of the waste. The amount of reserve by the end of March 2005 is about 1,100 billion yen by 10 electric utilities.

6. Social, public opinion and communication aspects

The Public Information Law, approved in April 2001, provides for disclosure of regulatory information on request, promoting transparency of activities on safety regulation. NISA, at the website, discloses information on licensing of nuclear facilities, accidents and failures, radiation control and activities of nuclear energy related councils. In April 2004, NISA established the Nuclear Safety Public Relations and Training Division, and stationed the Regional Public Relations Officers for Nuclear Safety in the areas where major nuclear facilities are located, to further strengthen its public relation activities including holding public meetings in local communities, distributing periodicals on activities of NISA.

The Japanese policy regarding waste management is that the current generation, who receive the benefits of nuclear energy, should bear the responsibility of safe disposal of waste generated by the research, development and utilization of nuclear energy.

For approval of a waste disposal facility, the licensing review has been conducted in accordance with the Fundamental Guidelines of Licensing Review of Land Disposal Facility of Radioactive Waste. These guidelines describe the long-term safety assurance of waste repository facility to avoid imposing excessive impact on future generations, and indicate the involvement of local authorities and residents in the licensing process.

Japanese Government policies attach great importance to the support of local communities, consequently, the scientific and engineering aspects of waste management safety are no longer of exclusive importance. Technical competence is necessary but not sufficient: although safety concerns maintain highest priority, it is clear that stakeholder confidence and trust in institutions are seen as key conditions for a successful societal decision-making process for radioactive waste management.

Japanese policy for waste repository implementation includes:

- A clear strategy for the long-term management solution and support by the government and local authorities, based on the recognition of responsibilities and needs .
- A gradual decision-making process, which allows the accommodation of public and stakeholder needs
- The commitment of all involved parties, including affected municipalities and the appropriate regulatory authorities.
- A well-structured process of dialogue/interaction between implementer, regulators, political decision-makers and the general public.

Since the responsibility of regulators is to protect the public health and safety, regulators have a mission in service to the public. It is important that regulators, representing the interests of the public safety, be involved early in the siting process and collaborate with the local communities to the extent that this is compatible with the regulatory framework.

Japanese policy is that the process of rule making and its application to facility site selection and licensing should be transparent and comprehensible. This implies an open process in which the public and other stakeholders can comment on the approaches used by the regulators.

Since local authorities are key decision-makers in the overall repository siting process they are natural contacts for dialogue with the technical regulatory authorities for waste disposal. In the first instance, the technical regulators' role should be one of collaboration, acting proactively on the side of municipalities. The objective is to build up the regulator's credibility and gain public confidence as well as to provide national and local decision-makers with the necessary information on safety matters. In this sense, communication with the public and the news media is a matter of particular importance.

Japanese policy states that the independence and public accountability of the regulatory authorities are crucial to public confidence in the national radioactive waste management program, especially in the HLW programme.

Index

Executive summary

Chapter 1
Radioactive waste management in Germany

Chapter 2
Radwaste management in France situation and perspectives

Chapter 3
Study of future energy issues: UK situation

Chapter 5
Radioactive waste management in USA

Chapter 6
Radioactive waste management in Finland

Chapter 7
Radioactive waste management in Japan

Radioactive Waste Management: Situation, Analysis and Perspectives

An overview of the situation in the main OECD countries

Volume 2

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