The management of radioactive waste
A description of ten countries

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Building confidence in the long-term safety of deep geological disposal is a key issue for the nuclear waste management community. It involves nurturing confidence in long-term safety measures on the part not only of technical specialists and the scientific community, but also of political decision-makers and the general public. Typically, repository development proceeds in stages, and flexibility must be built into the development process at each stage so as to allow for both new and better understanding and the demands of society at large in terms of reviewing the process. Confidence in long-term safety thus requires communication with a wide audience on a variety of issues involved in the stepwise implementation process.

For several years now, international organisations such as the NEA (the Nuclear Energy Agency of the OECD), the IAEA (International Atomic Energy Agency) and Euratom have been responsible for managing international problems relating to radioactive waste management.

EDRAM, the International Association for Environmentally Safe Disposal of Radioactive Materials, was created a few years ago with a view to promoting national programmes and co-ordinating the knowledge and experience gained from them. The twelve member organisations from eleven countries are ONDRAF/NIRAS (Belgium), Ontario Power Generation (Canada), POSIVA OY (Finland), ANDRA (France), BfS and DBE (Germany), NUMO (Japan), ENRESA (Spain), SKB (Sweden), NAGRA (Switzerland), Nirex (United Kingdom) and DOE-OCRWM (United States of America).

Professor Rolf Lidskog and BA Ann-Catrin Andersson at Örebro University in Sweden have prepared this report at the request of an EDRAM Work Group. The report provides a description of how the responsible authorities/ companies in ten EDRAM countries handle the management of radioactive waste, including technical, economic and socio-political aspects (NUMO was not a member of EDRAM when work on the report first started, and Japan is therefore not represented in the report). The report also examines the flexible stepwise approach and the issue of public involvement in decision-making.

The report describes the development and situation in each country up to the end of 2001, or later if noted as such in the country report.

It should be emphasised that the evaluations, viewpoints and conclusions presented in this report are those of the authors and that they do not necessarily coincide with those of the EDRAM member organisations.

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1 Introduction

1.1 Radwaste – a national problem with international dimensions

Although most countries with nuclear power now seem to have opted for geological disposal as the ultimate solution to the problem of processed or non-processed spent nuclear fuel, no state has yet made a definitive decision concerning siting. Although different policies for radwaste management have developed in different countries, the basic problem is the same everywhere: to find a location and a method for isolating radwaste from the biosphere.[1]

Many nations with nuclear power have by now advanced beyond the pure research level and are facing a complex implementation phase. The management of nuclear waste involves technical, socio-political and economic aspects, such as:

- Choice of system (technical and geological issues).
- Choice of place (criteria for site selection).
- Choice of decision-making process (closed or open, fixed or flexible, exclusive or inclusive).
- Choice of financial system.
- Gaining public trust and political acceptance.

In short, the challenge is to create a radwaste management system that is scientifically, politically and publicly acceptable. The scientific aspects of radwaste management have undergone extensive development in a variety of countries. Research, development and demonstration projects have been conducted with the aim of finding suitable natural and technical barriers that will ensure the safe disposal of radwaste. In an attempt to find adequate methods for the handling and disposal of radioactive waste, various types of formal and informal networks have been established within as well as between countries. Today, organisations such as the Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and Euratom focus on international nuclear surveillance and research, both with regard to nuclear power use and nuclear waste problems.

In recent decades, however, there has been a growing awareness that socio-political aspects need to be considered when discussing the implementation of disposal systems for radwaste. In a democratic society, a disposal strategy, however scientifically sound it may be, is entirely without value if it is rejected by both politicians and large segments of the

[1] Berkhout, F. (1991) *Radioactive Waste. Politics and Technology.* Routledge, p. 4.

public. Experience gained from other relevant areas – not least the siting of facilities for hazardous waste management – show that conflicts often occur when general policy takes the form of site-specific proposals, and that local opposition is one of the biggest single obstacles to implementing a siting plan.[2]

In many countries, the responsible authorities and companies are now facing the task of implementing a ready-formulated radwaste policy. However, experience in a number of countries shows that the transportation of radwaste and the siting of facilities for radwaste storage is often a highly controversial issue, involving conflicts between players at different levels. Some researchers see the issue of radwaste as the "Achilles' heel" of nuclear power.[3] At the same time, it should be pointed out that there have been a number of successful implementations, such as the solutions for final storage of low- and intermediate-level radwaste implemented in Finland and Sweden without any major political or public opposition. The very different results of the implementation process in different countries – the successful process of locating intermediate storage facilities for spent nuclear fuel in Sweden (CLAB at Oskarshamn) compared with the public and political opposition which stopped, or at least delayed, the implementations in the UK and Switzerland – demonstrate that political acceptance and public confidence are crucial when progressing to the implementation phase of the radwaste management policy.

Within the technical community, as well as within most waste management companies and authorities, there is a growing awareness of the fact that public and political acceptance is crucial to successful implementation. This implies that radwaste management needs to be viewed in a wider social context, where issues such as ecological sustainability, equitable risk distribution and economic realities are likely to gain increasing prominence.[4]

1.2 A flexible stepwise approach to radwaste management

EDRAM – International Association for Environmentally Safe Disposal of Radioactive Materials – was created with the aim of sharing research results with a view to broadening the field of research on nuclear waste. EDRAM is composed of the organisations (companies or governmental agencies) responsible for radioactive waste management in eleven countries: Belgium (ONDRAF/NIRAS), Canada (Ontario Power Generation), Finland (POSIVA OY), France (ANDRA), Germany (BfS, DBE), Japan (NUMO), Spain (ENRESA), Sweden (SKB), Switzerland (NAGRA), the United Kingdom (Nirex), and the United States (OCRWM).

One issue on the EDRAM agenda is the flexible, stepwise approach to radwaste management. EDRAM itself has not specified an explicit definition of this approach, although the radioactive waste management committee (RWMC) at NEA has defined the stepwise

[2] Lake R, Disch L, 1992. "Structural constraints and pluralist contradictions in hazardous waste regulation", *Environment and Planning A* 24: 663–681.

[3] Blowers A, Lowry D, Solomon B D, 1991. *The International politics of nuclear waste.* London: Croom Helm; Kemp, R., O'Riordan, T. & Purdue, M. (1986) "Environmental politics in the 1980s: The public examination of radioactive waste disposal", *Policy and Politics* 14(1); Openshaw, S, Carver, S. & Fernie, J, (1989) *Britain's nuclear waste. Safety and siting.* London: Belhaven Press.

[4] NEA, 1999. *Geological disposal of radioactive waste: Review of the development in the last decade.* Paris: OECD publication No. 51101, p. 10.

approach to implementation as a process involving discrete and easily overviewed steps that facilitates the traceability of decisions, allows feedback from the public and/or representatives, and promotes the strengthening of public and political confidence in the safety of a facility, along with trust in the competence of the regulators and implementers of disposal projects.[5] Within the EDRAM context, a Flexible Stepwise Approach has been discussed with regard to three areas: technology, the economic arena and the socio-political arena. This echoes the post-Rio agenda, where the core concept – sustainable development – comprises economic, social and ecological dimensions. All three dimensions are relevant when discussing a stepwise approach.

1.2.1 The study: purpose, method and material

The aim of this report is to provide a description of how the responsible authorities/ companies in ten EDRAM countries deal with the management of radioactive waste. The focus is on how the responsible organisation currently handles this issue, including technical, economic and socio-political aspects. The material used was primarily produced by the companies/authorities themselves. The report describes the development and situation in each country up to the end of 2001, or later if noted as such in the country report.

The scope of this report does not permit an evaluation of how successful and effective the companies and authorities have been in implementing their plans and ambitions. The report does not therefore include the views of other national stakeholders concerning radwaste management, or their opinions of the way that the authorities/companies handle the issue of radwaste.

The description is based on a series of questions that were drawn up and discussed at the initial stage of the EDRAM co-operation. Obviously, it is not possible to provide comprehensive answers to these multi-faceted questions, but they have been useful in helping with the systematic description of radwaste management in the different countries.

Technological aspects

1. What technology is used? How is research and development promoted and executed?
2. Where is the waste to be put? What criteria does each country search for?
3. How is security to be maintained? Who can obtain a license for handling nuclear waste?

Economic aspects

1. In what way do the countries in question discuss the time aspects as regards delays and similar?
2. How are the economic and financial aspects of the process dealt with? Where does the money come from?

[5] NEA (1999), *Ibid,* p.11.

Socio-political aspects

4. What role do politicians play and to what extent is social acceptance a part of the process? What part does public opinion play?
5. How flexible is the decision-making process and can decisions be revised?
6. Does the public have confidence in the industry and the decision-makers?
7. What kind of institutional problems arise?

With regard to **public involvement** in decision-making, there are several aspects that need to be taken into account.

1. Is there public participation at every level?
2. Might there be stages in the process where public involvement has a negative or positive impact on the final result?
3. How do the communication and information processes work? Can they be improved or changed?

Data was collected by inviting representatives from the ten countries to submit relevant material. It was also collected by the authors themselves, primarily through online searches. A draft report was delivered to the representatives, and a revision was made on the basis of their comments and the submission of further material. Furthermore, a short questionnaire was sent to all the representatives, requesting topics relevant to the flexible stepwise approach. A preliminary version of the final report was presented to the representatives before the final completion of the report. These contacts with the EDRAM representatives have primarily been used to obtain factual knowledge about the ongoing work within their countries. However, it should be noted that the evaluations, viewpoints and conclusions presented in this report are those of the authors and do not necessarily coincide with those of the national organisations that are part of EDRAM.

Any national radwaste policy is governed by a number of factors, such as political culture, national history and geographical factors. It has not been possible in this report to investigate factors that have shaped – and continue to shape – radwaste policy. This means that the description focuses only to a limited extent on the contextual factors that are important when trying to understand the different processes in each country. The aim, however, is not to explain the different national situations that have emerged, but to describe the ongoing work and plans relating to the implementation of radwaste management in the ten EDRAM countries. This description is intended as a basis for discussion and further initiatives within the context of the flexible stepwise approach to the implementation of radwaste management.

1.3 Concluding remarks

One general conclusion to be drawn from the material submitted is that there seems to be a growing awareness that the implementation of radwaste management programmes has to be viewed in a wider social context and focus on social acceptance and public confidence. All of the countries seem to have experienced local resistance to transportation of waste or to the siting of facilities, and there seems to be a general opinion that there is a need for increased public confidence in the radwaste management system selected, as well as in the ambitions and efforts of the institutions responsible.

1.3.1 Democratic decision-making

All the political systems of the EDRAM countries are representative democracies. The national level is obviously the key level since this is a national issue. However, when discussing the actual outcome of this national policy – interim storage, final disposal of low- and intermediate-level radwaste, transport of radwaste by sea and over land and final disposal of high-level waste – it is of course necessary to focus on sub-national levels.

The EDRAM countries have different national practices and customs (legal and political) when it comes to the role of the sub-national level in the decision-making process for radwaste management. In Switzerland, a canton may hold a referendum that will stop a siting, and in Canada no region can be forced to accept a repository, whereas it is at least possible in legal terms in Sweden for the Cabinet to overrule the veto of a municipal board. In the USA, the investigation of Yucca Mountain continues despite strong opposition from the state of Nevada. The role of sub-national political levels in the decision-making process seems to be crucial when considering the social acceptability of radwaste management.

There are also differences in the extent to which people other than elected representatives and political institutions can be included in the decision-making process. The question that many countries now face is the extent to which formal political institutions need to be complemented with other forms of decision-making forums, such as local referendums or different kinds of partnerships. Thus, even if radwaste management is an issue for national policy-making, sub-national levels seem to have attracted growing interest in all EDRAM countries.

1.3.2 Public participation

In many countries, public involvement seems to be a key issue for the successful implementation of radwaste management.[6] It is believed that more public involvement and improved communication will lead to greater social acceptance. In the material analysed, public participation is mentioned as an important part of the implementation of any radwaste policy. Most of the countries emphasise the importance of communicating with stakeholders and the possibility of creating a forum where stakeholders, experts, local action groups and laymen can meet. In Canada, a number of studies of public participation will be conducted, while in Finland, the explicit goal is to involve citizens of the municipalities that are being studied. In France, specific councils will be created, while the United Kingdom is making efforts to launch a constructive dialogue with stakeholders and Belgium has created local partnerships.

1.3.3 Public confidence and social acceptability

The paths selected in the transition towards implementation are not only determined by technical issues, but also, and to a greater extent, by issues of public confidence and social acceptance.[7] Many of the delays in national radwaste management programmes

[6] cf. NEA (1999) *ibid,* p. 30.

[7] NEA 1999, *ibid.*

have been caused by various socio-political aspects. The result of the public inquiry in the United Kingdom and the result of the public referendum in Switzerland are examples that illustrate how the lack of public confidence may have a considerable impact on the implementation timetable and even on the formulated policy itself.

Most of the EDRAM countries share an emphasis on the need for public acceptance of the radwaste management system, and different methods are suggested for creating public confidence:

- good relations with the public,
- creation of local partnership with different stakeholders at local level,
- transparency in the decision-making process,
- public review of documents and plans,
- distribution of materials to all parties and the creation of information strategies,
- local information offices at feasibility study sites and site tours,
- changes in internal organisation to make openness the key concept for all employees,
- feedback mechanisms for every phase of the process,
- issue-specific voting and the creation of ad-hoc groups for discussion,
- stepwise and flexible approach involving discrete and explicit implementation steps,
- progressivity and reversibility of the implementation process,
- retrievability of the waste,
- postponed final decisions, which means that there is ample opportunity for knowledge dissemination, discussion and reflection.

These methods have started to be implemented to varying extents. The task is to develop, implement and evaluate these forms of public participation.

1.3.4 Conclusion

The stepwise approach could be a way to solve the problems involved in the implementation of radwaste management. It consists of a process where discrete and explicit steps are taken in repository planning and where the possibility of public input to the process is clearly stated. By increasing the transparency of the decision-making process, any counter-productive effects of public participation programmes may be avoided.

There seems to be a widespread awareness among EDRAM members that greater public confidence is needed for the successful implementation of radwaste management. The stepwise approach has been adopted to varying degrees, and there is a growing awareness that it will facilitate the work involved in gaining public confidence.

2 Nuclear waste management in Belgium – Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS)

2.1 Introduction

In Belgium, radioactive waste management is handled by ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials. ONDRAF/NIRAS is a public (federal) institution and has been responsible since 1980 for the safe management of all radioactive waste produced in Belgium, including the management of excess enriched fissile materials and the decommissioning of nuclear facilities that have been closed down, as well all nuclear power plants.

The industrial production of electricity from nuclear origin in Belgium began in 1974 with the installation by the electricity production company ELECTRABEL of the first nuclear power units on the Doel site (near the city of Antwerpen) and the Tihange site (near the city of Namur). The seven reactors currently in operation on these two sites delivered 55% of Belgium's national electricity production in 1999, with a nominal power of 5.7 GWe.

About 80% of routine radioactive waste comes from the electronuclear sector, and primarily from nuclear power plant operation. Four other areas of the nuclear sector also produce waste: fuel fabrication, spent fuel reprocessing operated by COGEMA[1], nuclear research (SCK•CEN[2] and IRMM[3]) and the production of radioisotopes (IRE[4]). Finally, the non-nuclear sector (agriculture, industry, scientific research and the medical sector) also produces radioactive waste. At the end of June 1999, Belgium's stock of conditioned waste was as follows:

- 10,845 m^3 of A waste (low-level and short-lived),
- 3,786 m^3 of B waste (intermediate-level or long-lived low-level),
- 215 m^3 of C waste (high-level and long-lived).

[1] The French company COGEMA used to reprocess Belgian spent fuel for the company SYNATOM, which is responsible for the entire domestic nuclear fuel cycle management.

[2] Belgian Nuclear Research Centre, based in the municipality of Mol.

[3] EU's Institute for Reference Materials and Measurements, based in the municipality of Geel.

[4] Radio-Elements Institute, based in the municipalities of Fleurus and Farciennes.

This waste is in safe interim storage at BELGOPROCESS[5]. The total volume of A waste that will be produced from now until 2070, i.e. the year in which the dismantling activities are due to end, is estimated to be 60,000 m^3. The total volume of dismantling waste is estimated at 39,000 m^3. Even if Belgium were to decide today to close down its nuclear power plants immediately, 2/3 of the total volume of category A waste already exists.

2.2 Technical aspects

2.2.1 Present management methods

Processing and conditioning of waste

Low-level and short-lived waste (A waste)
Certain types of waste (resins and filters) are directly processed and conditioned at the nuclear plants. Other types of waste that fall below specific activity limits are processed by BELGOPROCESS, embedded in cement in standardised 400 litre galvanised steel drums.

Intermediate-level and long-lived low-level waste (B waste)
Most of the waste in this category comes from SCK•CEN, IRE and the international reprocessing pilot plant EUROCHEMIC in Dessel, which was closed at the end of the seventies. This waste is cast in cement or bitumen and conditioned in 400 litre drums.

High-level and long-lived waste (C waste)
The spent fuel used at the nuclear plants of Doel and Tihange is removed from the reactors and stored in on-site pools for several years. It is then sent to the reprocessing plant COGEMA (La Hague, France) which extracts reusable plutonium and uranium and processes the fission products and transuranic elements into a borosolicate glass matrix that is returned to Belgium in 150 litre stainless steel canisters.

Several years ago, the federal government declared a moratorium on the reprocessing of Belgian spent fuel. As a result of this decision, reprocessing could in the long run be completely abandoned. This would mean direct conditioning of spent fuel elements in containers adapted for deep disposal after the required decay period.

Interim storage of conditioned waste

Low-level and short-lived waste (A waste)
All conditioned waste produced in Belgium is temporarily stored in facilities on the site of BELGOPROCESS. The storage capacity is currently around 14,000 m^3, which makes it possible to accept produced waste until 2010. If no solution for surface or deep disposal has been found by this time, new storage facilities will have to be built.

Intermediate-level and long-lived low-level waste (B waste)
At the end of 1999, the stock of B waste comprised 17,021 metal drums of 200 and 400 litre containing waste from different origins, embedded in cement or bitumen and stored in specific buildings on the BELGOPROCESS site.

[5] ONDRAF/NIRAS' industrial subsidiary, located in the municipality of Dessel.

High-level and long-lived waste (C waste)
A storage facility for HLW has been built on the BELGOPROCESS site. This facility, in which canisters will be stored for several decades prior to their deep disposal, is equipped with a forced convection ventilation system for the removal of heat produced by the waste. The first transport of 28 vitrified waste canisters from France to Belgium occurred in spring 2000. In the future, these transports will follow each other at a rate of two or three per year.

Final waste disposal projects

Low-level and short-lived waste (A waste)
The Belgian government decided in 1998 in favour of a final solution, or a solution of a definitive nature, for the long-term management of this waste category. Surface or deep disposal was found to be preferable to long-term storage in constantly accessible buildings. The government has, however, not yet chosen between surface and deep disposal. As a result, ONDRAF/NIRAS has developed concepts for both types of disposal option.

Surface disposal

The project for final surface disposal provides for the immobilisation of the waste drums in groups of four by using mortar in concrete cubic monoliths which are then stacked up in 27 m long, 25 m wide and 10 m high reinforced concrete rectangular modules.

Two rows of ten of these modules are placed side by side and are then covered by an additional barrier consisting of a succession of clay layers, drainage gravel, geosynthetic membranes and arable ground. Inspection galleries are planned to be built under the rows of modules in order to control infiltration of rainwater. It will take 300 years before the activity of the waste is negligibly low. It will be possible to reverse the process or to retrieve the waste at any time during the different phases.

Deep disposal

For deep disposal, the Boom Clay[6] formation has so far been studied as the host formation. The disposal facility project comprises vertical shafts and horizontal galleries. The two shafts, with a diameter of about 6 m, are about 170 m apart. One serves as an access shaft and the other as a ventilation and personnel transfer shaft. These two shafts are connected to a main gallery of the same diameter dug at a depth of about 220 m in the clay and lined by reinforced concrete segments. This main gallery leads to a series of six 1,600 m long disposal galleries with a diameter of 5 m. These galleries, which are also lined with reinforced concrete segments, are 20 m apart.

Intermediate-level and long-lived low-level waste (B waste) and high-level and long-lived waste (C waste)
For these two categories of waste, Belgium has, since 1975, undertaken an R&D programme focusing on final disposal in the Boom Clay formation. It has built a methodological underground laboratory in this formation at a depth of 220 m under

6 Oligocene (Rupelian) clay formation located at a depth of about 200 m under the Mol-Dessel Nuclear site with a thickness of about 90 m.

the site of SCK•CEN. The option currently being developed involves the separate final disposal of B and C waste in a facility similar to the one described for A waste (vertical shafts, main gallery and disposal galleries), but adapted to the thermal and radiological characteristics of B and C waste. The possibility of retrieving the waste after disposal presents a difficult technical problem that has not yet been studied, but which could result in important modifications of the disposal concepts.

Deep disposal of B waste

The disposal of B waste, for which no specific concept has so far been developed, must take into account the variety of forms, volumes, dimensions and weights, as well as specific activity and heat production levels of the waste containers used for this category in the handling, packaging and backfilling operations.

Deep disposal of C waste

The disposal of C waste is the object of a reference concept that has been developed over the last few years and tested on a full-scale surface model. This concept will be tested in real conditions within a few years in the underground laboratory (PRACLAY/EURIDICE Project). Taking into account the very high activity level of the waste packages, all of the handling operations from the surface to the disposal galleries will be performed by remotely controlled transfer equipment. The succession of phases following the placing of the waste, i.e. the control, the backfill of the main galleries and of the access shafts and the closing of the site, has not yet been determined, since the facility is still awaiting decisions that are due to be made by the safety authorities concerning the possibility of retrieving the waste.

2.2.2 Research and development for disposal projects

Low-level and short-lived waste (A waste)

The R&D programme aims to present a project for final surface disposal in one of the four existing nuclear zones, or deep final disposal in the Boom Clay formation. ONDRAF/NIRAS will be calling upon various scientific institutions (study centres and universities) and private sector consultants for the implementation of this programme, which focuses on three main axes: earth sciences, concepts and safety.

Earth Sciences

This axis constitutes the basis of the entire R&D programme, since it provides the geological, geotechnical and hydrogeological parameters of the zones under consideration. In a first phase, thorough bibliographic studies of the zone are used to identify fields in which further study is required, as well as the methods to use in the field. In a second phase, field reconnaissance campaigns are carried out (boreholes, geophysical measurements, piezometric network, hydraulic balance of the basin, geochemical measurements, etc.), as well as hydrogeologic modelling on the basis of the data gathered.

Concepts

Based on the geotechnical and hydrogeological data, the quantity of waste and the safety and control constraints, a generic concept adapted to the zone concerned is developed. The different phases of construction, exploitation and control are analysed from a technical and economic point of view, as well as in terms of their impact on the environment.

Safety

This axis of the R&D programme aims to evaluate the overall safety of the disposal concept and its impact on man and the environment. Models for the analysis of the processes developed by SCK•CEN are used. These models take account of the composition of the waste, the characteristics of the disposal concept (longevity of the technical barriers), the geological and hydrogeological characteristics of the surrounding geosphere (retention/dilution capacity, rate of drainage), as well as the possible climatic changes that might modify the present hydraulic or hydrogeological conditions.

Intermediate-level and long-lived low-level waste (B waste) and high-level and long-lived waste (C waste)
The R&D programme concerning these waste categories aims to present a final deep disposal project in a clay formation within a period of about 15 years. At present, the Boom Clay layer constitutes the reference formation and is the object of an intensive R&D programme set up by SCK•CEN with the help of the European Union in 1975.

ONDRAF/NIRAS reports regularly to the government on the results of the R&D programme with a view to helping the federal authorities evaluate the research in progress and recommend its continuation or the launching of new research. These reports take the form of *Safety and Feasibility Interim Reports* (SAFIR), the first of which was submitted to the government in 1989.

An international assessment committee set up by the minister in charge of Energy concluded in its final report that the choice of the Boom Clay layer under the nuclear site of Mol-Dessel was justified for the study of the disposal of high-level and long-lived waste.

Ten years after the publication of the first SAFIR, a new report (SAFIR 2) is now in preparation. The first objective of SAFIR 2 is to present all relevant technical information relating to deep disposal of B and C waste in a deep clay layer. This will give the authorities full knowledge of the facts and allow them to evaluate the technical feasibility of such a project in the future. The second objective is to intensify interaction and co-ordination with the safety authorities. This interaction must lead to a better definition of the research efforts that still have to be made to ensure both a safe solution and its acceptance.

Before being edited, SAFIR 2 was submitted to an internal scientific committee for evaluation. The minister involved has also expressed his intention to submit it at a later stage to an international peer review organised by the NEA. Current R&D programmes (1998–2003) will then be reviewed and, if necessary, re-oriented on the basis of the Peer Review and the Belgian government's conclusions and recommendations.

The next important step in this stepwise approach is the selection of a site for which a "*Preliminary Safety Assessment Report*" (PSAR) will be drawn up. The intention is to submit this report to the competent authorities by 2013.

2.2.3 Siting process

Low-level and short-lived waste (A waste)
Over the last few years, ONDRAF/NIRAS has looked systematically for favourable sites for final surface disposal. About 90 sites with adequate characteristics have been short-listed for later studies. In view of the unanimous and vehement reactions of the public to this preselection process, the federal government entrusted ONDRAF/NIRAS in 1998 with the task of searching for final surface disposal locations exclusively on the four sites officially defined as nuclear zones. These are the zones of Mol-Dessel, Fleurus-Farciennes, Doel and Tihange.

ONDRAF/NIRAS was also entrusted with the task of setting up partnership structures for these nuclear zones with the local authorities and populations with a view to involving them in the search for a solution.

Intermediate-level and long-lived low-level waste (B waste) and high-level and long-lived waste (C waste)
The reference host formation for the final deep disposal of these categories of waste has always been the Boom Clay formation present in the underground of the nuclear zone of Mol-Dessel. A methodological laboratory was dug in this formation and is presently being extended. The government has also asked ONDRAF/NIRAS to study the characteristics of another clay formation located under the nuclear zone of Doel (Ypresian Clays).

2.2.4 Safety evaluations, safety demonstration and licensing

For both surface and deep repositories, four factors contributing to safety or confidence in the safety of a final disposal facility are considered:

- The first factor covers the so-called "*safety functions*" of the final disposal system, guaranteed by the various natural and artificial barriers of the facilities.

The robustness of a disposal facility (i.e. its capacity to offer adequate protection despite all the uncertainties that inevitably remain) is the result of four essential combined safety functions.

Physical confinement

The first safety function aims to isolate the waste as much as possible from water by using a multibarrier system. In a surface disposal facility, the waste is adequately isolated by watertight covering layers, concrete modules and concrete monoliths. In the case of deep disposal of medium- or high-level waste in the Boom Clay formation, this function is performed by the stainless steel overpack of the conditioned waste form and the engineered barriers.

Retardation and spreading of the release

The second safety function aims to prevent, or at least slow down, the migration of radioactive elements into the biosphere. In a surface disposal facility, the conditioned waste, the concrete walls of the monoliths and the disposal modules form the main barriers to the release of radioactive elements.

For deep disposal in the Boom Clay formation, the barrier that contributes most to this safety function is the host rock itself.

Dispersion and dilution

The third safety function ensures that the radioactive elements that might cross the artificial barriers are gradually dispersed and diluted when they migrate towards or into the biosphere.

For shallow-land or deep disposal, the dispersion and dilution safety function is, however, considered less important than the first two functions.

Limitation of accessibility

The fourth safety function aims to exclude human intrusions, or at least to render them very unlikely and to limit their consequences.

Different safety indicators are used to evaluate these four safety functions, as well as the overall performance of the disposal system. The robustness of each of these safety indicators can be analysed, quantified, compared and optimised.

- The second factor covers the *safety demonstration*, which has to prove that all the safety functions effectively ensure the required safety level.

In its R&D programme, ONDRAF/NIRAS co-operates closely with the federal safety authorities in order to guarantee compatibility with the safety requirements of the developed solutions.

To be convincing, the safety demonstration must involve a system of barriers and safety functions that are as simple and free of unknown variables as possible and that strengthen its robustness while simplifying the comprehension of the system itself. The projected disposal systems are also submitted to a whole series of tests based on mathematical models and calculation codes. A great number of potential situations that might influence safety are both envisaged and tested. These include several evolution scenarios, various mechanisms for the degradation of the barriers and different values for the parameters.

- The third factor covers the *progressive and flexible nature* of the implementation of waste disposal and the possibility of retrieving it.

Confidence in the level of safety of the disposal facilities is directly dependent on the system's robustness. But it is also dependent on the possibility of intervening during the implementation itself and on the possibility of retrieving the waste if this should prove necessary.

Progressiveness

Given the fact that the development and construction of a disposal facility is a progressive process that will take several decades, it will be possible to benefit from the evolution of scientific and technical knowledge. It will also be possible to take account of the results of the safety evaluations that are due to be performed throughout the R&D, construction and operation processes.

Flexibility

The progressive decision-making process will make it possible to return to and review previous decisions whenever necessary. For deep disposal, this will be the case for several decades, while for surface disposal, it will be the case for several centuries.

Retrievability

The disposal plans will be implemented in such a way that the retrieval of waste remains possible for a long period of time and will be both easy and safe. Retrievability requirements are a direct result of applying the precaution principle.

- The fourth factor covers the *legal norms and procedures*, as well as the evaluations, assessments and independent controls of safety that are performed throughout the development and construction of the disposal facilities.

In addition, the safety authorities will be providing an important guarantee during the decision-making process concerning the fact that all safety aspects of the final disposal solution will be submitted to a thorough, critical and independent examination. They must be unanimously convinced that a high level of safety can be guaranteed before giving the green light to start the next phase of the realisation of the disposal plants.

ONDRAF/NIRAS maintains regular and close contact with the federal safety authorities with a view to working out a common strategy concerning the safety aspects of the long-term management of various categories of waste. Nevertheless, taking into account the current status of the siting process, the question of licensing has not yet been discussed.

2.3 Economic aspects

2.3.1 Financial issues

The Royal decrees of 30 March 1981 and 16 October 1991 define the financing principles of ONDRAF/NIRAS.

- All costs are charged to those who benefit from waste management activities (Polluter Pays Principle). These charges are assessed at cost price.

- Long-term expenses relating to waste disposal operations (including interim storage) are borne by a special fund known as the long-term fund (LTF), which is financed by contributions from waste owners, i.e. private producers and the Belgian State. The fund is subjected to regular audits by a specific committee. R&D expenses incurred prior to the industrial project are borne by separate multi-annual agreements defining the necessary research budgets and distributing them among the waste producers and the Belgian State in accordance with objective criteria.

- A special fund has been set up to ensure payment even in cases where producers become insolvent. The fund is financed by a permanent contribution representing an additional 5% on the annual charges of all waste owners.
- Financial modalities have to be defined in a bilateral agreement with the main waste producers for their current waste and with the Belgian State regarding the management and decommissioning of historical waste sites.

To respect these principles, in particular the cost price requirement, ONDRAF/NIRAS has established a financing system based on the immediate payment of a unit charge, or *tariff*, on each volume unit taken over from waste producers or from the Belgian State. From 1996 onwards, an additional financial mechanism has been added which is known as *reservation of capacity*[7]. The fixed costs of installations and services are distributed according to objective criteria as stipulated by the Royal Decree. As part of this approach to the long-term costs of disposal covered by the LTF, a contractual guarantee has been established for the main waste owners. The tariffs applicable to interim storage and disposal operations for all waste categories are calculated by using the committed waste programmes and cautious estimates of the future costs of the disposal projects. Contingency margins are added to reflect the maturity status of the projects and their associated technologies in accordance with the methodology adopted by ONDRAF/NIRAS and originally developed by the Electric Power Research Institute[8]. Total contingency margins may exceed 100% for deep disposal in clay. The proceeds are paid into the long-term fund (LTF). Their fixed part reduces the initial producers' contractual guarantees on the fixed costs. Should a producer deliver more waste than originally planned, the total contractual guarantee is correspondingly increased.

Tariffs and guarantees have a 10-year validity for interim storage and disposal, currently starting in 1996 and running until 2005. They are escalated each year to safeguard against inflation, using the risk-free interest rate of 2%, which represents the cost of the capital in the LTF. Until termination of the contractual relationship with ONDRAF/NIRAS, a waste producer pays the outstanding part of his contractual guarantee.

2.3.2 Time aspects for delays or unexpected events

The terms of the bilateral agreements between ONDRAF/NIRAS and the waste owners for storage and disposal are renewed every ten years to take account of all experience gained and all information accumulated on waste production programmes, project costs and available assets in the LTF.

Drifts in cost assessments resulting from delays, unexpected events or changes in the rules applicable to radioactive waste management are in theory only addressed by

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7 Kunsch, P.L., and Emmery, D. 1996 A New technique for Covering the Financial Risk of a Waste Management Programme – *Waste Management Conference Proceedings,* Tucson, February 1996.

8 ONDRAF report 97-04 *Comparaison des diverses options pour la gestion à long terme des déchets radioactifs de faible activité et de courte durée de vie.*

ONDRAF/NIRAS after the termination of each 10-year term. Provisions are nevertheless made in the 10-year agreements for immediate action in case of emergency situations that directly jeopardise the financial balance of the LTF.

The financial approach introduced by ONDRAF/NIRAS is considered to be robust, even under liberalised market conditions[9]. The joint mechanisms of revisable tariffs and prudent margins, contractual guarantees of still outstanding payments and excess returns generated by appropriate fund asset management are designed to dampen the effects of most unexpected contingencies.

2.4 Socio-political aspects

Low-level and short-lived waste (A waste)
ONDRAF/NIRAS uses a flexible stepwise approach in the framework of partnerships with local authorities and populations. Partnerships between municipalities and ONDRAF/NIRAS are entitled to make all decisions concerning the technical, socio-economic, political and communication aspects of disposal projects. All these aspects have to be assessed and presented to the federal authorities, which then have to make a choice among the projects presented by the different partnerships. Each project in each municipality is reversible in the sense that each municipality can unilaterally withdraw from the project at any time if it so wishes.[10]

So far, two partnerships have been established with the municipalities of Dessel and Mol. These are non-profit associations and they are entirely financed by ONDRAF/NIRAS within certain budgetary limits. They have the same four structural levels: a *general assembly*, which gathers all partners and which represents and legitimises the partnership; a *board of management*, which gathers representatives of the various partners; a *project co-ordination group* appointed by the board of management, which manages the partnership's activities on a day-to-day basis; and, finally, the *working groups*, which develop the project in concrete terms, propose and discuss possible options, weigh up the pros and cons, and obtain expert opinions. This is the level at which non-partners are able to contribute if they want to.

Different working groups have been set up to work with the important aspect of involving the local population (frequent evening meetings attended by numerous citizens). The local partnerships regularly report to and inform the local population via folders or specific web sites on the results achieved so far and on activities in the pipeline. By the year 2003, the two local partnerships are expected to present an integrated disposal project to the federal authorities, along with appropriate compensation proposals.

There are currently four working groups in each partnership:

- *location and design*, which looks at the various possibilities of a disposal concept and its location in a local environment (for instance regarding infrastructure),

[9] Kunsch P L, 1999. Radioactive Waste Management in an Open Market Economy: risks and opportunities, TOPSEAL '99, *ENS Conference proceedings*, Antwerp, October 1999.

[10] Answer questionnaire, ONDRAF/NIRAS 2001.

- *local development*, which examines the possible surplus value of the disposal site at the socio-economic level, taking account of such diverse aspects as local economy, tourism, nature, culture, recreation, mobility, welfare, etc.,
- *environment and health*, which studies the possible consequences (radiological and others) for the environment and public health,
- *safety*, which examines all aspects of safety, emergency planning and so on.

As far as the IRE nuclear zone of Fleurus-Farciennes is concerned, an information committee has been set up with the two municipalities involved. This committee aims to exchange information between ONDRAF/NIRAS and the municipalities' stakeholders. Thorough geological, geotechnical and hydrogeological field reconnaissance campaigns have been carried out on the IRE site and in its vicinity and are currently being analysed. The municipalities' authorities are waiting for the results of this analysis to decide whether or not a partnership will be established in the future.

The two other nuclear zones of Doel and Tihange have so far rejected the principle of a partnership with ONDRAF/NIRAS.

Intermediate-level and long-lived low-level waste (B waste) and high-level and long-lived waste (C waste)
All R&D activities relating to the disposal of these two waste categories have concentrated on the Mol-Dessel-Geel nuclear zone. The Boom Clay formation present in the subsurface of this zone is being investigated by ONDRAF/NIRAS as a potential site. However no decision has yet been taken as far as the selection of the final host rock and disposal site are concerned.

The final decision to confirm this zone as a repository site rests with the federal government on the basis of the SAFIR and PSAR processes (see § 2.1).

The repository does not have to be built for at least two or three decades. However, if the Mol-Dessel-Geel zone is finally chosen by the federal government, a very important effort will have to be launched in terms of communication, dialogue and consultation with a view to setting up a broader partnership with the local communities.

3 Nuclear waste management in Canada – Ontario Power Generation

3.1 Introduction

In 1946, recognizing the need for an effective regulatory framework to govern the peaceful development, application and use of nuclear energy, the Government of Canada passed the Atomic Energy Control Act, creating the Atomic Energy Control Board as Canada's national nuclear regulator. The Nuclear Safety and Control Act (NSCA) was passed by Parliament in 1997 to better reflect the current regulatory mandate and priorities. It came into force in May 2000. The NSCA replaced the outdated Atomic Energy Control Act and paved the way for the creation of the Canadian Nuclear Safety Commission (CNSC), which replaced the Atomic Energy Control Board. The Commission consists of seven members, with a staff of about 400 employees.

The CNSC's mandate is to regulate the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada's international commitments on the peaceful use of nuclear energy.

In 1996 the Policy Framework for Radioactive Waste outlined principles for financial and institutional management, by the waste producers and owners, concerning radioactive waste.

The Canadian Nuclear Fuel Waste Management program was initiated in 1978 and Atomic Energy of Canada Limited (AECL) was given the lead role to develop the concept of deep geologic disposal. An Environmental Assessment Panel was established in 1989 to review the disposal concept and issued its report in 1998.

Canada has today 22 reactors at 6 power plants. 20 of these reactors are located in Ontario and were owned by Ontario Hydro until 1999 and by Ontario Power Generation today. Hydro Québec and New Brunswick Power are operating one plant each. In May 2001, Ontario Power Generation concluded an agreement with Bruce Power to lease its eight reactors at the Bruce Power Development site. The aim is to support the efforts of making the electric power industry more competitive.[1] 87% of the total amount of nuclear waste derives from the Ontario area and nuclear power energy constitutes 16% of the total electricity production in Canada. Some of the reactors have had some problems during the last years and Ontario Hydro decided in 1997 to temporarily close down seven reactors. Activities to restart four of these reactors (Pickering 1-4) are underway and Bruce Power has announced plans to restart Bruce units 3 and 4. In April 1999 the operation of Ontario Hydro's generating assets, thus the nuclear reactors, was taken over by Ontario Power Generation (OPG), one of the autonomous companies succeeding Ontario Hydro.[2]

1 Information provided by Mr. Frank King, Ontario Power Generation. *Nuclear Waste Management in Canada. Ontario Power Generation.* August 16 2000. p. 1.

2 http://ourworld.compuserve.com/homepages/geodev/can.htm 20002009

The federal government through the ministry of Natural Resources Canada establishes nuclear waste policy in Canada. The 1996 policy on nuclear waste states that:

- The federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally sound, comprehensive, cost-effective, and integrated manner.
- The federal government has the responsibility to develop policy, to regulate, and to oversee producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans.
- The waste producers are responsible for funding, organizing, managing and operating disposal facilities and other facilities required for their wastes, according to the Polluter Pays Principle.[3]

In April 2001 the federal government introduced a Nuclear Fuel Waste Act into Parliament. This Act requires:

- Fuel waste owners to establish a separate waste management organization (WMO).
- Fuel waste owners to set up a segregated fund to pay for long-term fuel waste management.
- The WMO to establish a broad-based Advisory Council.
- The WMO to conduct a study of possible approaches to the long-term management of fuel waste including, deep geologic disposal extended on-site storage and centralized storage. This study is to be submitted to the government within 3 years of the Act coming into force.
- The federal government to select the approach it prefers and the WMO to implement that approach.

Canada has signed a number of international agreements such as the Non-Proliferation of Nuclear Weapons (NPT) and is therefore under the international supervision of the IAEA concerning safeguarding of certain nuclear waste management activities.[4]

3.2 Technical aspects

3.2.1 Present management methods

Used fuel management

At present every reactor site has temporary storage of used nuclear fuel in water-filled basins. There are also dry storage facilities in operation at Ontario Power Generation's Pickering Nuclear Generation station and construction of a new dry storage facility is underway at the Bruce site. An environmental assessment for a dry storage facility at the

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[3] Information provided by Mr. Frank King, Ontario Power Generation. *Nuclear Waste Management in Canada. Ontario Power Generation.* August 16 2000. p. 1.

[4] *Regulating nuclear fuel waste*. Atomic Energy Control Board. p. 3.

Darlington Nuclear Generating Station has been started. There are also dry storage facilities in operation at Hydro Québec's site in Gentilly and at the New Brunswick Power's site at Pt. Lepreau.[5]

As mentioned in the introduction, the Nuclear Fuel Waste Management Program was set up in 1978 to develop a safe means for the disposal of used nuclear fuel. Among the research activities was the construction of an underground research laboratory near Whiteshell Laboratories in Manitoba. In 1994 AECL submitted an environment impact statement report based on the concept of placing the waste in containers at the depth of 500–1,000 meters in granitic rock of the Canadian Shield.[6]

The Canadian-developed geologic disposal method is based on a multi-barrier system, where the first barrier is the actual fuel, which is not easily soluble in water. The second barrier is the metal container. The container is surrounded by bentonite clay – the third barrier. The primary rock is the final barrier and this method is similar to those in Sweden, Finland and Switzerland.[7]

Reprocessing is not considered in Canada because it is not economically justifiable.

Centralized storage and extended on-site storage of used fuel will be furthered studied in response to the recently-introduced Nuclear Fuel Waste Act.

Should the federal government decide to select the geologic disposal approach for Canada, the earliest assumed date for in-service is 2035.

Low- and intermediate level waste management

There is currently a storage facility at the Bruce Nuclear Power Development site for all Ontario Power Generation's low- and intermediate level waste. Some of the incoming waste is incinerated or compacted in order to reduce storage volume. The waste is stored both above ground and below surface in structures depending on the specific character of the waste. Hydro Québec and New Brunswick Power are storing their waste in above ground facilities at their reactor sites. AECL has applied to the CNSC for the construction of a disposal facility in Chalk River (IRUS: Intrusion Resistant Underground structure). The application is still under consideration.

3.2.2 Research and development

Research and development on geologic disposal of used fuel is primarily funded and directed by Ontario Power Generation. The primary location for research is AECL's underground research laboratory at Whiteshell, Manitoba. Research and development is also being conducted by consulting companies and in universities.

[5] Information provided by Mr. Frank King, Ontario Power Generation. *Nuclear Waste Management in Canada. Ontario Power Generation.* August 16 2000. p. 2.

[6] Information provided by Mr. Frank King, Ontario Power Generation. *Nuclear Waste Management in Canada. Ontario Power Generation.* August 16 2000. p. 2.

[7] http://www.skb.se/omskb/lander7kanada.htm 20000209

3.2.3 The siting process for radioactive waste facilities

No siting activities have occurred related to used fuel disposal facilities in Canada. An application is being examined concerning disposing of some forms of low- waste in Chalk River. The waste is to be put in steel cylinders. The cylinders are put in concrete containers and covered by concrete. The method is called IRUS – Intrusion Resistant Underground Structure. However, there are no plans to implement the IRUS concept at this time. In June 2001 it was announced that a local disposal facility for historic contaminated soil waste from the uranium refining industry would be developed near Port Hope, Ontario. The Low-level Radioactive Waste Management Office in AECL, reporting to Natural Resources Canada, is responsible for developing a safe disposal method for this waste.[8]

As with the Port Hope solution, it is expected that any other future siting efforts will require the acceptance of the hosting community.

3.2.4 Safety and licensing

The Canadian Nuclear Safety Commission is responsible for ensuring and reviewing the long-term safety of nuclear waste management. Their main task is to ensure that the method of deposition protects human health, minimizes the risk for future generations, and is environmentally safe. They have issued a regulatory policy document which among other things states:

- The repository must be safe for future generations.
- The method has to be based on the multi-barrier system.
- All the different phases in the process must be supervised and evaluated.
- The repository must be able to handle any natural disturbances, such as landslides and earthquakes.
- The repository must be constructed in such a way that a future intrusion, possibly by accident, or retrieval does not endanger future generations or compromise the efficiency of the deposition.
- The repository must be constructed in a technically suitable way.
- The process should take socio-economical implications into consideration.
- Finally the repository in question should naturally meet all the requirements concerning human health and safety, especially regarding radiation.[9]

Concerning the actual location, the CNSC finds that it is not necessary to search for the perfect place, but to find a location where the conditions are suitable. It has to be able to ensure a safe deposition and a possibility of restoring the location after closure, so that it could be used for other purposes. When a company wants to establish a waste repository it has to file an application to the CNSC and it has to contain a site description and a

8 http://www.skb.se/omskb/lander/kanada.htm 20000209

9 *Regulating nuclear fuel waste*. Atomic Energy Control Board. pp. 13–14.

long-term safety plan. CNSC has to approve of the repository before it can be operational and it might ask for additional information on technological aspects, the design of the repository, safety issues, and on the operational procedures. The CNSC also monitors the progress concerning safety and is using internationally accepted methods.[10]

The CNSC handles licences for nuclear waste management and is responsible before the Canadian parliament. The CNSC has constructed a multi-licence process where the licensees must account for all stages in the process. It is the task of the CNSC to regulate all nuclear activities and issue licences when a company can meet the requirements. The organization can also revoke licences if the regulations are not followed and file for prosecution of those responsible for the violation. The overall safety in nuclear processes is the key issue for the CNSC.[11]

An application to construct a waste management facility must be based on an environmental assessment approval, in accordance with the Canadian Environmental Assessment Act, before the application is sent to the CNSC.[12]

3.3 Economical aspects

Financial issues

Owners of nuclear power plants are responsible for the financial issues concerning waste management. Ontario Hydro and its successors have been and are collecting funds from the users of nuclear power through fees. The funds are calculated to cover the nuclear waste program and are regularly supervised concerning the financial status.[13]

The funds are still supervised internally by the nuclear plant owners, however, under the proposed Nuclear Fuel Waste Act, funds for the long-term management of nuclear fuel waste will need to be held by a third party. According to the Canadian Nuclear Safety and Control Act, the nuclear plant owners have to provide certain financial guarantees for the operation of nuclear facilities. These financial guarantees can be provided in various forms.

[10] Ibid., pp. 14–17.

[11] *Regulating nuclear fuel waste*. Atomic Energy Control Board, pp. 2.

[12] Information provided by Mr. Frank King, Ontario Power Generation. *Nuclear Waste Management in Canada. Ontario Power Generation.* August 16 2000. p. 2.

[13] *Submission to the Federal Panel Reviewing the Nuclear Fuel Waste Management and Disposal Concept*. Ontario Hydro. February 28, 1996. pp. 4–5.

3.4 Socio-political aspects

3.4.1 The role of politicians and public opinion

As mentioned, the federal government of Canada has the final word concerning the waste management method. Politicians therefore play an important part of the process.

Public opinion has proven to be quite important. Repository plans can be stopped due to local resistance, which means that the parties involved should be sensitive to public opinion in the matter. The responsible authorities in Canada have, for example, been sensitive towards the opinion of the aboriginal population.

3.4.2 Decision-making process

It is important that the citizens involved take part of the process and study the information at hand. It is especially important to involve the aboriginal people in the decision-making process. If an intrusion is going to be made in their "territory" it will be of an enormous importance to include them in the process.[14]

The nuclear power plant owners such as the Ontario Power Generation, recognizes the necessity of an open process where citizens can be a part of the decision-making process. Social and economical aspects of a particular region need to be taken into consideration as well as technological.

3.4.3 Public confidence

Canada seems to be in a situation of developing a public confidence for nuclear issues in general. Citizens have obviously been very concerned and worried about where the nuclear waste is to be put. There are a number of studies and investigations concerning public participation on different levels, and involving the public in the process seems to be the crucial point of current nuclear waste management. This could be considered as an institutional problem, where the democratic process has not yet been fully developed.

The government, the supervising organizations, and the nuclear power plant owners seem to be very interested in making the public more involved in the waste management process. The citizens can affect the national politics through elections but many decisions are made between the election periods.

The local opinion has been important for the decisions taken, but there is no obvious public confidence in the authorities. As we have mentioned in earlier chapters public participation can be negative if there is only one option of location and where the public opinion does not accept the depository. What will happen then? On the other hand, this is an important issue for all citizens and public participation should be a positive thing. This legitimizes the nuclear waste management process.

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[14] *Federal Environmental Assessment and Review Process. Nuclear Fuel Waste Management and Disposal Concept. Report of the Nuclear Fuel Waste Management and Disposal Concept.* Environmental Assess ment Panel. February 1998. p. 20.is estimated to come to 26,000 m3. Even if Belgium were to decide today to close down its nuclear power plants immediately, 2/3 of the total volume of category A waste already exists.

As mentioned in the introduction the waste management organization has to report to the government on certain issues and among those were public participation, Aboriginal participation and an ethical and social assessment framework. These investigations by the nuclear waste management organization can create public confidence and that their point of view is reported to the government.

3.4.4 Information and communication

Information about the nuclear waste management licensing can be obtained through the CNSC. Almost all information is free and only a small portion is protected due to security reasons. The Board distributes information concerning licensing, the activities at the nuclear power plants, and potential hazards. In 1981 the AECB initiated the Consultative Document System, which means that the public can get access to documents, on for example safety matters, before they are issued as requirements.

Information on waste management programs can be obtained through the nuclear utilities and AECL.

4 Nuclear waste management in Finland – Posiva Oy

4.1 Introduction[1]

In Finland there are two nuclear plants, with two reactors each, located in the southern part of the country. The owners, Teollisuuden Voima Oy and Fortum Power and Heat Oy, are responsible for the nuclear waste management. The reactors were built in the 1970s' and at the same time the planning into nuclear waste management was initiated. A long-term plan regarding research and development was decided on in 1983 and in 1988 a new nuclear energy law was proclaimed. It gives clear directions on the nuclear waste management in Finland and it was revised in 1994 when it was decided that the waste was going to be taken care of in Finland. Before that, export of the spent fuel to the Soviet Union was taking place from the Loviisa reactors. Posiva Oy was founded in 1995 by the owner companies and is responsible for the development and for the implementation of disposal of spent fuel in Finland.

There are a number of official authorities with specific duties and responsibilities. The Ministry of Trade and Industry is highest supervising authority and prepares licensing for Government for decision making. The Government grants licenses, decision in principle, construction license and operation license. The Parliament has to ratify the Government's decision in principle. The local authority, that is the municipal council has a right for veto in the siting of the facility. The Finnish Authority for Radiation and Nuclear Safety (STUK) supervises the nuclear activities and develops regulations.

4.2 Technical aspects

4.2.1 Present management methods

The two nuclear plants in Loviisa and Olkiluoto represent about 25% of the total electricity production in Finland. The nuclear waste produced is either directly disposed of in the repository for low and medium level waste or is put, in the case of spent fuel, in water-filled basins in the reactor building for a couple of years. It is thereafter transferred to an storage with similar basins. The spent fuel is expected to be stored in these basins for several decades. This is an intermediate storage and the final goal is to dispose of the spent fuel in the deep repository excavated in the bedrock of Olkiluoto.

Finland has selected the KBS-3 type concept for the disposal of spent fuel. It means that the spent fuel is put in watertight canisters that are deposited 400–700 meters below ground level. The basis for the deposition is the multi-barrier system, where the waste is

[1] This description is based on Posiva Oy (1999) *The final disposal facility for spent nuclear fuel. Environmental impact report.* Helsinki: Posiva.

protected by the canisters, the bentonite clay and the primary rock. There are different types of solutions concerning the actual design of the underground facility. The entrance to the repository could be a spiral ramp or a vertical shaft and the deposition tunnels should be from 100 to 300 meters long, 25 meters apart. The facility will be constructed according to the structure of the bedrock of Olkiluoto which is the selected site for disposal. The repository should be constructed though in such a way that the waste can be retrieved by future generations if development of technology makes it a preferred option.

In Finland there will be 2,600 tons of spent fuel by 2020 and if the reactors are run for 60 years there will be an amount of 4,000 tons by 2040. The construction of the repository at Olkiluoto has been planned to start after the year 2010 and become operational by 2020. The transports from Loviisa to Olkiluoto can be executed by road, by rail or by sea.

4.2.2 Research and development

Research into the Finnish bedrock began in the 1970s'. The goal of the first phase of research was to develop an underground repository for low and medium active waste. These repositories were built in Loviisa and at Olkiluoto. The disposal of waste started at Olkiluoto in 1992 and in Loviisa 1997.

The research for the deep repository needed for disposal of spent fuel was initiated in early 1980s. Investigations at different locations were carried out to find out the suitable site. This process culminated finally in 1999 selection of Olkiluoto site and this site was proposed in Posiva's application for Government's decision in principle. Government made a positive decision in December 2000 and the decision was later ratified by Parliament in May, 2001.

4.2.3 The siting process for deep repository

In 1987 five locations were chosen for preliminary site characterisation and these were Hyrynsalmi, Äänekoski, Kuhmo, Sievi, and Eurajoki. The selection of these sites was based on the thorough study of the bedrock of the whole country. These sites represent all the different types of rock in Finland. In 1992 the report was released concerning the locating process and the research was continued on all different locations except Sievi and Hyrynsalmi. After the export of spent fuel was prohibited by law the Hästholmen island in Loviisa was added in site characterisation programme 1997.

Environmental impact assessment was carried out in 1997–1999 and given to the authorities in 1999 as an appendix to application for Government´s decision. It gives a picture not only on the concrete environmental aspects such as the effects on the wildlife but also how the disposal facility will affect the citizens. A majority of the citizens in Loviisa and Olkiluoto in Eurajoki are positive towards a deep repository whilst the citizens in Kuhmo and Äänekoski were negative towards deep disposal. There are many reasons to the opinion of the local population. It has to do with the knowledge about nuclear power, unemployment, the development of the region, and the general culture of the region. In Loviisa and Euråminne nuclear power is already accepted and a final deposition does not seem to worry the population. In Äänekoski and Kuhmo the nuclear power is not as accepted and in Kuhmo a similar opinion as in northern Sweden has arisen concerning the tourism, that might be endangered because of the deposition. According to Posiva Oy, the repository seems to have positive effects though on the unemployment in Kuhmo. A decision on the final deposition was made in 2001 and the siting location for nuclear waste will be Olkiluoto in Eurajoki.

4.2.4 Safety and licensing

In order to construct a disposal facility in Finland the Finnish government needs to approve of the application of the Posiva Oy. The management of the spent fuel has to follow the laws set up and the safety instructions from the authorities. The decision-making process is regulated in the Nuclear Energy Act of 1987. The first step on the way to a final repository is a decision in principle, which is a policy decision and related to the siting process. The nuclear energy act though requires that an Environmental Impact Assessment has to be carried out in accordance with the regulation on these assessments, before any application for decision in principle is submitted. An application for a decision in principle is submitted by the responsible organization and before a decision, the government consults the STUK and the municipality for their comments. These comments must be positive towards the applicant before the government can make a favorable decision. If the decision is a positive the Parliament has to ratify it. The decision in principle is not a construction license. The construction and operational license has to be applied for separately.

Posiva submitted scientific and technical material for the review to authorities in connection of decision making process.

4.3 Economical aspects

4.3.1 Financial issues

All the costs concerning nuclear waste management fall upon the nuclear reactor owners. The primary alternative concerning nuclear waste disposal will cost 4.6 billion Finnish Marks and the life-span of the reactors are in this calculation forty years. The funds derive from the fees using nuclear power and they are deposited in the national nuclear waste fund. By the end of 2000 there were about 6.3 billion Finnish Marks in the fund.[2]

4.4 Sociopolitical aspects

4.4.1 The role of politicians and public opinion

The Finnish government has the authority to evaluate and accept the method and the location promoted by Posiva Oy and has therefore a major role in the process. Posiva Oy has during its activities in communities developed a system of information and communi-

[2] Posiva Oy (2000) *Nuclear waste management of Olkiluoto and Loviisa power plants. Annual review 2000.* Helsinki: Posiva.

cation, through meetings with the public and smaller discussion groups. Public involvement comprises different organizations such as neighborhood councils, the local section of the political parties, local environmental organizations and other contact persons selected by the municipalities. The citizens have in this way had a possibility to take an active part in the process. The selection of Eurajoki is a sign of the authorities accepting the public opinion and that is the case the citizens could have a say in the decision-making process.

There are no obvious institutional problems as far as we can see. Long-term plans have been put together and they seem to be implemented, together with an openness towards the public. The nuclear energy act contains requirements for local public participation and hearings. There is a public participation concerning the nuclear waste management and especially the local process of deposition. Public opinion and participation is not very clear on the national level. When the site characterization was started in 1987 it was important to gain the public confidence. No site with a negative attitude would be chosen. At the end several communities expressed their interest for site characterization within their area and the discussions were held in small groups comprising mostly of the democratically elected representatives of the community in question. A future aim is to carry on a public participation program in Eurajoki community and provide also a possibility to residents of the neighboring communities to obtain information on the project.

In addition to public participation at large, there have been local opposition groups against geological disposal but there have also been organized groups in favor for disposal. Finnish association for protection of natural environment has been active, as well as, Greenpeace. The Posiva and the STUK provide information to public, both via the Internet and through brochures and hearings. Earlier Posiva had local offices which provided information as well as open houses at the sites. The policy to build confidence has been based upon the information work. Existing underground repositories at Olkiluoto and Hästholmen for ILW/LLW have been used by effective way to build confidence. Opinion polls have measured the public confidence with good results. Reasons for this might be that the local community has accepted to host the deep repository, regulatory body has shown green light and that the Government has taken positive decision. Finnish Parliament ratified Government's positive decision by voting 159 in favour and 3 against, 37 parliament members were absent.

5 Nuclear waste management in France – Agence nationale pour la gestion des déchets radioactifs (ANDRA)

5.1 Introduction

In France there are today 58 reactors and they produce 76% of the total amount of electricity in France and 64,333 MWe. France is reprocessing spent fuel in La Hague, in the facilities of COGEMA. According to the law, the waste producers have to fund the management of the waste produced. The National Radioactive Waste Management Agency (ANDRA) is responsible for the management of the whole radioactive waste in France. The regulatory body in France is the Directorate for the Safety of Nuclear Installations (DSIN). The technical support of the DSIN is the IPSN.[1]

ANDRA was created in 1979, as a part of the French Atomic Energy Commission (CEA) and is financed by the waste producers. The main waste generators are Electricité de France Electricity state owned company, COGEMA the fuel cycle company and French Atomic Energy Commission.

The radioactive waste management is mainly under the jurisdiction of a law from 1991 for HLW management. According to the 91 law ANDRA was transformed into an independent state-owned organization under the supervision of the ministries of industry, research and environment.[2]

The government finds that only an independent state-owned organization could provide short-term as well as long-term safety, stability and independence concerning nuclear waste. The 91 law (number 91.1381) defined the three major responsibilities for ANDRA. The agency has an *inventory role* in which it has to detect all radioactive waste on French territory. The result is put in widespread annual reports. ANDRA also has an *industrial role*, which means a responsibility for designing, construction and operating of final disposal facilities. The responsibility includes all types of radioactive waste. ANDRA is today operating two different disposal facilities, one in Centre de la Manche and the other in Centre de l'Aube. The first disposal facility was operational between 1969 and 1994 and during this time it disposed of 525,000 m^3 of waste packages and is today in a post-closure phase. The activity at the facility in Centre de l'Aube started in 1992 and according to the design figures calculations it will receive 1,000,000 m^3 of waste packages (average of 15,000 m^3/year). Finally ANDRA has in its *research role* a responsibility to study and elaborate efficient and safe long-term solutions for radioactive waste management. The agency sets research programs, scientific networks and other cooperation

1 http://www.skb.se/omskb/lander/frank.htm 20000210

2 http://ourworld.compuserve.com/homepages/geodev/fran.htm 20000221

projects. It is also in charge of designing, constructing and operating underground research laboratories, one in a clay formation in Eastern France and the other in a granite formation to be determined.[3]

There are also other actors involved in the nuclear waste management process such as government representatives and the local administration. The Préfet de région, Préfet de département and the Directorate for the Safety of Nuclear Installations in charge of the licenses, and the Regional Directorate for the Industry and the Environment control that the regulations and safety requirements are implemented. There is also a national scientific assessment body (the National review board), the Parliamentary Office for the assessment of scientific an options, the local information and follow up committee consists of government officials, members of the Parliament, members of environmental groups, farm unions, professional associations among others.

France is also a part of international co operation activities, above all in the International Atomic Energy Agency – IAEA, the OECD NEA and European Union programs (DG Research). Bilateral research co-operations programs are established with the mains radioactive waste management organization such as, SKB, NAGRA, ONDRAF, Nirex, ENRESA, AECL in Canada and DOE in the USA.[4]

5.2 Technical aspects

5.2.1 Present management methods

France has many different types of nuclear waste. The amount of waste produced and to be produced by the present NPPs and other fuel cycle installations is:

- between 1 and 2 million m^3 of very low level waste,
- 1,300,000 m^3 including 625,000 m^3 already disposed of low- and intermediate level short lived waste,
- 14,000 m^3 of intermediate level long lived graphite waste,
- 56,000 m^3 of intermediate level long-lived waste,
- 3,500 m^3 of high-level long-lived waste (Glass)[5]
- 15,000 t (heavy metal) of spent fuel.

[3] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 1.

[4] http://www.andra.fr/fr/lndra/cooperat.htm 20000221

[5] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 2.

Very low level waste

Waste of this type, with an average of 10 Bq/g, will have a normal radioactivity level within a few decades, but it is necessary to design programs for each waste category and adapted to individual circumstances. This type of waste originates from:

1. The nuclear industry in general (mainly future decommissioning/dismantling waste).

2. Other industries, such chemical and metallurgical.

ANDRA has initiated a process of constructing a disposal facility for this type of waste near the Centre de l'Aube installations. The on going process is performed in total coherence with the local population.[6]

Short-lived low- and intermediate level waste

As mentioned, Centre de la Manche has been a disposal facility since 1969, accepting this type of waste and it is located in Cotentin peninsula near La Hague reprocessing plant. The facility was closed down in 1994 leaving 525,000 m^3 of waste and it was sealed in 1997. The facility is now in the institutional control period and the process of closure is the first in the world, which gives valuable knowledge on the nuclear management process. In 1984, in order to take over the Centre de la Manche facility the government of France decided to create a new surface disposal facility for low and intermediate level short lived waste and in 1992, the facility in Centre de l'Aube was operational. It is located in Soulaines-Dhuys, in the Aube Départements and close to Troyes. The site is 95 hectares and accessed through roads and a railway located in the nearest town Brienne-le-Château. It can, as mentioned, store 1,000,000 m^3, which will cover the next 60 years.[7]

High-level and long-lived waste

For this type of waste, the applicable law proclaims a research program in three parts:

1. Research on separation and transmutation of long-lived waste.

2. Research on the possibilities to construct a reversible deep disposal. This research is mainly performed in underground laboratories.

3. Research on the waste package system and on long-term interim storage.

ANDRA is in charge of research task number two and the French Atomic Energy Commission handles the two other research areas. The research is supervised by the National Review Board, consisting of French and foreign experts, which presents a report each year to the Parliament. According to the report presented by the National Review Board in 2006 the government will present to the Parliament a proposition concerning the

[6] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 3 and Answer questionnaire ANDRA 2001, p. 10.

[7] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 3.

future management of high-level long lived radioactive waste. This proposition will be discussed by the Parliament and its decision will be formalized in a new law.[8]

Apart from these concrete research activities and according to the law of 1991, research is conducted around the three areas mentioned above concerning other methods such as transmutation, and waste packages and the long-term storage process. A government decision from 1998, states that these three research areas are still the most important. Research on transmutation will continue especially on hybrid systems. The Atomic Energy Commission (CEA) will undertake studies concerning subsurface facilities and above all the technical aspects and the selection of an appropriate site. Research will continue on reversible depository, through studies in the Meuse Haute Marne clay and on a new site in granite rock.[9]

France is familiar with the concept of stepwise approach and is using it concerning the upcoming research. According to the waste act the two laboratories will keep open the possibility of choice and the local communities will have a possibility to refuse hosting geological disposal. This law defines a threefold research program:

1. research on transmutation and separation of long-lived radioactive elements,
2. research on the possibilities of reversibility of the deep geological disposal, this research will be conducted in the underground laboratories,
3. research on waste packaging and long-term surface storage processes.

All three areas are equally important and are funded equally. According to the Waste law the National Review Board will every year, to the Parliament, file reports on the research. These reports will also be available for the public. The law also states that it is not allowed to keep radioactive waste in the underground laboratories. The creation of the underground facilities and the operational costs will be covered by ANDRA. No decision regarding the high level waste may be taken before a scientific assessment is submitted at the end of a long research period.[10]

5.2.2 Research and development

Characterization and modeling of the clay formation

The confinement capacity of the clay formation is investigated and especially the hydrological condition concerning ground water flows and the confinement ability of the host rock. The same data is collected concerning gas transportation and confinement. Research is conducted to trace the chemical substances in the water, which will show how radionuclides could be soluble in that particular type of water. Based on the above-mentioned research, the retardation of the transport of radionuclides is looked into.

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[8] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000.* May 24, 2000. p. 4.

[9] French government decision, December 9, 1998.

[10] Answer questionnaire ANDRA 2001, p. 7–8.

All the data is furthermore used as a base for the design of waste packages, barriers, materials and the repository itself. The research will also characterize the geomechanical properties through holes drilled from the surface and through holes drilled in the underground galleries. These holes will provide information on the behavior of the clay at a large scale, on hydromechanical behavior and on the reaction to mining and sinking. The research will also show the response of the clay to heat and to ventilation. Hydrogeological investigations have been performed in 1994–1996 through deep boreholes.[11]

Between now and 2006, date of completion of the overall report on the feasibility of a repository, the three major phases are:

- A milestone at the end of 2001 between repository design (preliminary pilot project) safety (first safety assessment) and modeling based on available data from pre-shaft sinking operations (first disturbance-follow up boreholes, partial seismic 3D results, experiments. In 2001, it will still be possible to adjust the existing experimental program in the underground laboratory by taking into account the experience feedback from methodological laboratories and work schedules in the underground laboratory.
- 2002–2004 phase: model fitting, use of those models to design repository concepts, second safety check based on the data collected before and after the sinking of access shafts to the underground laboratory, during the digging of drifts and the beginning of the actual experiments.
- By the end of 2005 the overall data collected are consolidated in the design of a "repository pilot project" and in particular, in the safety analysis. The 2005 reference system contains measurements resulting from experiments conducted at the main level. The report to be submitted by the end of 2005 is completed.

Granitic formation

Awaiting the decision of the government concerning the second laboratory in granite, ANDRA is pursuing its R&D program on granitic formation.

The process is the following:

- Research on disposal concepts taking into account the specific characteristics of the French granitic massifs. Such a research is using the experience gained by foreign countries like Sweden with the KBS-3 concept for spent fuel disposal.
- Compilation of data from experimental programs implemented in foreign underground research laboratories, mainly concerning specific granite scientific issues such as hydrogeology, fracturation, ….
- These actions are supported by specific co-operation programs with countries like Sweden (Äspö), Switzerland (Grimsel) and Canada (Bonnet lake).

[11] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 5–6.

5.2.3 The siting process

In the 1987, ANDRA initiated the site-selection process and developed a location plan of four sites. There was an outbreak of protests in 1990 against this suggestion, from organizations, citizens and politicians. The situation was serious and the Prime Minister announced a moratorium. A parliamentary commission concluded in 1990 that is was not an acceptable situation and there ought to be created another more responsible solution. There was a need to change the methods used and the first measure was to open research for other alternatives than deep disposal. The second was to select a decision-making process in order to involve the citizens and the elected representatives. A new motto was issued: *responsibility*, *transparency and democracy*. The responsibility issue focused on the ability to take care of the French waste in France and also to solve the situation today and not to leave it up to future generations to deal with. It is vital that the process is transparent, because the nuclear issue involves all citizens. The citizens have to be able to participate in the decision-making process and to receive all relevant information. As a sign of these efforts, the law concerning research on radioactive waste management was voted in 1991, making ANDRA an independent and responsible agency. The law introduced a new collective way of looking upon the issue, stating that everyone is responsible for nuclear waste.[12]

The law, adopted by the parliament in December 1991, states that the elected representatives and the citizens have to be informed on the implementation of an underground laboratory and it prohibits waste storage in these facilities. According to the law local information- and follow-up-committees, consisting of elected representatives, representatives from the government, environmental groups, unions, representatives from other associations and from the site administrator, must be set up concerning each underground laboratory. These committees can set up public hearings and they are supported financially by ANDRA. One of the main issues seemed to be the possibility of a reversible process.[13]

In 1992, a mediator was assigned by the government in order to find a solution to the site problem. In 1993, the mediation report was submitted and it suggested four regions – départements.[14] The selection was made through two criteria. First, all applicants from geologically unsuitable regions were discarded, which left 10 alternatives. The second criteria was consensus. Out of the ten alternatives, negotiations were in 1993 initiated with the regions Gard in Southern France (clay formation), Meuse and Haute-Marne in Eastern France (another type of clay formation), and Vienne in Western France (granite formation). ANDRA received in 1994 governmental authorization to perform test drillings in these areas and the first report was issued in 1995 and the Haute-Marne and Meuse départements were regarded as one site due to geological similarities. The second report was issued in 1996 confirming geological qualities and ANDRA submitted a document called *Implementation and Operation Authorization Application* was submitted the same year to the government. ANDRA applied for the construction of laboratories in

[12] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000.* May 24, 2000. p. 7–8.

[13] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000.* May 24, 2000. p. 9–10.

[14] Answer questionnaire ANDRA 2001, p. 2.

Vienne concerning granite rock, in Gard concerning clay formations, and in Meuse/ Haute Marne regarding clay. Site evaluations were performed in 1997 with promising results. The public was involved in the process and there were also different voting procedures, with positive results. The information- and follow-up-committees issued, on a regular basis, information on the process, through various means such as newspapers, conferences, hearings and such.[15]

In December 1998, the government made a long-term decision regarding nuclear energy, which meant that this energy form would still be the main supplier of electricity. This required more research, on the three areas earlier described. The research would continue concerning transmutation, fast neutrons and subsurface facilities.[16]

The government decided to favor the construction of two underground laboratories, one in the clay formation in Eastern France and the other in a granite formation, where the site location has not yet been decided. The research program in Vienne was cancelled due partially to the sedimentary cover and to the poor quality of the granite and ANDRA is currently looking for a new site. In 1998, there was a complementary request concerning the reversibility of geological disposal and several other government decisions were taken such a concerning future energy policy. The government supported the research in the underground laboratories and these investigations started in 1999. The government and the Parliament will in 2006 decide whether to select a site or not, and if they do, it will be constructed in the vicinity of the underground laboratory. In 1999, the government issued three decrees and one of these authorizes ANDRA to construct an underground laboratory on the Bure site at the depth of 500 meters. This laboratory will gather data on geological, mechanical, hydraulically, thermal and chemical behavior of the formation. Another decree appoints the local information- and follow-up-committee, responsible for issuing information on the progress. The third decree promotes the set up of a commission of three members, with the specific task of making a first consultation on the selection process concerning one or more granite formations, where investigations can be performed. This consultation commission will initiate its work in 2000.[17] A similar decree authorizes the creation of a Local Information and Oversight Committee to be chaired by the Préfet of the Meuse Département. This committee will be responsible for ensuring that all information on the project is on the table. Its members should be granted full access at all times to the installations of the underground laboratory. In 2000 ANDRA received the authorization to start the construction of the Bure underground laboratory and in 2001 a preliminary safety report will be issued. In 2006, the National Review board will present a report to the Parliament and to the Government concerning the results resulting of the studies implemented along the three research ways. The Parliament will then discuss the future management taking into account the research results. If the Parliament decides to go ahead with the project, a repository could be built in the immediate vicinity of the underground laboratory.[18]

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[15] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 10–11 and http://www.skb.se/omskb/lander/frank.htm 20000210.

[16] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 11.

[17] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 11–12.

[18] Answer questionnaire ANDRA 2001, p. 3.

5.2.4 Safety and licensing

A safety assessment report will be issued, probably before 2005, based on evaluations on preliminary disposal facility models. The safety report will describe all the phases in the process and the models will be guidelines for other research fields. The extensive research will lead to robustness in the design, with regard taken to delays or unexpected events and it will be able to demonstrate different scenarios. The next step in the safety assessment will occur in 2001. A second safety assessment will be performed from 2001–2004, which will stabilize the safety approach and define safety scenarios. The last safety phase in 2004 has the objective to assess the feasibility of the safety demonstration.[19]

According to the government decision of 1998 it is imperative that control and transparency are connected to the safety programs of the facilities.[20]

5.3 Economical aspects

5.3.1 Financial issues

The waste producers are responsible for most of the costs of ANDRA's nuclear waste management program.[21] Different kinds of contracts have been set up between ANDRA and the waste producers. There are annual contracts covering the financial issues for the transfer of waste to ANDRA for disposal and there are pre-financing contracts, which establish financing for studies and other ANDRA future expenses for laboratories and disposal.[22]

Every potential site or region for surface studies received 5–10 millions Francs during the preliminary phase and each underground laboratory site or region receives 60 millions Francs every year up to 2006.[23]

5.4 Sociopolitical aspects

5.4.1 The role of politicians and public opinion

Decision-making process

Every party in the nuclear management process has a role when it comes to setting goals and making decisions on future management. It is the role of the government to accept or reject any suggestions by the ANDRA, as in the other countries previously described.

[19] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 12–13.

[20] The French government decision. December 8, 1998.

[21] http://www.skb.se/omskb/lander/frank.htm 20000210

[22] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 13.

[23] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 13.

The government has to evaluate all the material and research and the Parliament finally make the decision concerning site selection. The Safety Authority exercises the executive control and the Parliamentary Office for the Evaluation of Scientific and Technological Choices has the legislative control. The National Evaluation Commission makes a scientific assessment based on the research and holds hearings on its results, which it thereafter reports to the executive and legislative authorities. It gives advice to the politicians on the developments and publishes an annual report.[24]

Reversibility is a vital factor if the citizens and especially the future generations will be able to participate in the decision-making process. It seems as if almost all levels in the society have a direct possibility to be a part of the decision-making process. The individual person seems to have access to all the material but the question is if he or she can participate in the decision-making process. The regional committees do not seem to contain any ordinary citizens.

The citizens had not a direct impact on the government but ANDRA planned to put together public meetings and committees during 1999, so that the public could account for its opinion on the nuclear waste management. There were special voting sessions concerning the construction of laboratories in certain regions.

In the future the citizens will be able to enter the process on a rather early level. This will be positive for the final outcome. It is an aim of ANDRA to create a good relationship with the public by 2006.

Concerning referendums as a means for public participation in the decision-making process, they can only be organized on the national level. They can also only address certain issues specified in the Constitution. Local referendums are not legal.[25]

The role of the municipalities

The municipalities involved in the siting process, voted on the siting issue. 85% of the communes within 10 kilometers of the installation voted in favor of continued research and 84% of the communes directly involved voted in favor. 49% of the elected officials at the regional level were not in favor of an underground laboratory.[26]

Reversibility was a major issue for these communes and in a substantial part of the written questions to the ANDRA during the process. As in Switzerland, the public seems to want a stepwise approach where every phase of the process might be reversed.

The local information- and follow-up-committees constitutes an important player since they host representatives from the government, the Parliament, the regions, environmental groups, unions, other associations, site personnel etc. The committee is responsible for providing information to the citizens regarding the laboratory and it might refer

[24] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 14.

[25] Answer questionnaire ANDRA 2001, p. 7.

[26] Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 14–15.

issues to the National Review Board. ANDRA is responsible for the creation and operation fees concerning these committees.[27]

The information on the nuclear waste management process available to the public concerns information on the application for authorization for constructing and operating the underground laboratory. There is also some information on the ANDRA website. The National Evaluation Commission also publishes reports available for the public.

One experience of public participation could be extracted from the Centre de l'Aube low- and intermediate level disposal facility. Two separate funds for the local citizens have been set up, one to cover improvement of life conditions in the towns and villages and the other to promote the local economy and the tourism. This improved the relations between the locals and the facility owners. Information on all sides of the operations were handed to the local elected officials, such as information on operational results, environmental impact, potential incidents and so on. Every three months there is a package of new information and an annual report is handed over to the Local Information Committee. There are also open-house days and year-round visits. The facility also maintains good relations with the local associations, for instance the Permanent Centre for Environmental Initiatives – CPIE was given the assignment to undertake several studies on the environment around the facility. According to opinion polls, seven out of ten residents in the area, finds that the presence of the facility in the area is a positive thing.[28]

27 Information provided through personal communication with M. Jacques Tamborini, ANDRA. *French radwaste management EDRAM 2000*. May 24, 2000. p. 15.

28 Answer questionnaire ANDRA 2001, p. 9–10.

6 Nuclear waste management in Germany – BfS (Bundesamt für Strahlenschutz) and DBE (Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe GmbH)

6.1 Introduction[1]

In the Federal Republic of Germany, more than 30% of the electricity fed to the public grid is generated in nuclear power plants. As of January 2002, 19 such plants (13 PWR and 6 BWR) are in operation with a gross capacity of 22.3 Gwe. They produced a total of 169.7 TWh in 2000. One additional PWR (Mülheim-Kärlich) is out of operation for regulatory reasons. Fifteen nuclear reactors (including power reactors of Western and of Russian design as well as research and prototype reactors) and several fuel cycle facilities are being decommissioned and dismantled.

Spent fuel from German nuclear power plants is reprocessed in France and the UK or stored awaiting future conditioning for direct disposal. There are also a uranium enrichment plant and a facility for fuel assemblies' fabrication in operation. Basic and applied

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[1] The chapter is based on the following material:

Brennecke P W, Kunze V H, (BfS). Recent Developments in the German Approach to Radioactive Waste Disposal. WM'00 Conference, February 27–March 2, 2000. Tucson. USA.

Beckmerhagen I, Brennecke P, (BfS). Recent Waste Disposal Related Developments in Germany. WM '01 Conference, February 25–March 01, 2001. Tucson. USA.

Nies A, (BMU). Site selection procedure and criteria – Interim results of the German expert Group. DisTec 2000, International Conference on Radioactive Waste Disposal. Berlin, Germany.

Thomauske B, (BfS); Biurrun E, (DBE). The German repository concept – Status and Prospects DisTec 1998. International Conference on Radioactive Waste Disposal. Hamburg, Germany.

Biurrun E, Janberg K, Lempert J P, (DBE and GNS). HLW and Spent Fuel Management – Closing the Nuclear Fuel Cycle in Germany. p. 3–6. ICEM' 99. 7th International Conference on Radioactive Waste Management and Environmental Remediation. Nagoya, Japan, September 26–30, 1999.

Lempert J P, Janberg K, Biurrun E. Status of HLW and Spent Fuel Management in the Federal Republic of Germany. WM 2000 Conference. Tucson, USA.

Biurrun E, (DBE) Noak W, (BfS). Deep geologic disposal of radioactive waste – The German pioneering experience. TRU Workshop. Tokyo, Japan, 1999.

Auszüge aus der Koaltionsvereinbarung zwischen der Sozialdemokratischen Partei Deutschlands und Bündnis 90 / Die Grünen – Aufbruch und Erneuerung – Deutschlands Weg ins 21. Jahrhundert. Bonn, 20. Oktober 1998. (Excerpt of the coalition agreement between the Social Democratic Party and the Greens – Start and Renewal – Germany's path into the 21st century) Homepage of the Ministry of the Environment (BMU) http://www.bmu.de/atomkraft/fset800.php

Entwurf eines Gesetzes zur geordneten Beendigung der Kernenergienutzung zur gewerblichen Erzeugung von Elektrizität. (Draft of a law for the orderly phase out of nuclear power use for commercial electricity production.) Printed Matter 14/6890 – 4. German Parliament, 14th. election period. September 2001.

research and development in the nuclear field and/or using radioactive materials are carried out in several large research establishments. Further R&D work is conducted at universities, smaller research centers, and industrial laboratories. For interim storage of radioactive waste, some centralized and on-site storage facilities are available. Spent fuel not sent to reprocessing abroad can be stored at three centralized facilities when taken out of the plant's spent fuel pools. In the future, centralized storage away from reactor will be replaced by on-site interim storage. To this aim, a series of facilities are being currently licensed.

Thus, a broad variety of different waste types and amounts are generated in Germany. As of end of 1999, some 33,000 m^3 of unconditioned and approx. 64,000 m^3 of conditioned radioactive waste with negligible heat generation (i.e., LLW and ILW) was in storage in engineered facilities. The most recent forecast of waste arising in the future anticipates that approx. 303,000 m^3 of conditioned waste with negligible decay heat and approx. 22,000 m^3 of conditioned heat-generating waste (i.e., vitrified HLW and spent fuel) will be produced up to the year 2080.

From the very beginning of industrial nuclear power use in the early sixties, it was German radioactive waste disposal policy that all types of radioactive waste (short-lived and long-lived) were to be disposed of in deep geological formations. The 1976 amendment of the Atomic Energy Act provided the legal basis for radioactive waste disposal. Section 9a explicitly assigned the task of providing facilities for radioactive waste disposal to the Federal Government. On November 01, 1989, this competence was assigned by law to the Bundesamt für Strahlenschutz (BfS – Federal Office for Radiation Protection). Thus, BfS is responsible for providing and operating repositories, being the acting arm of the Federal Government for this specific task. BfS reports to the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU – Federal Environment Ministry) which, among other things, is responsible for nuclear safety and radiation protection.

The Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE-German Company for the Construction and Operation of Repositories for Waste) founded upon initiative of the Federal Government to this specific aim is BfS's main contractor for repository construction and operation. The Bundesanstalt für Geowissenschaften und Rohstoffe (BGR-Federal Institute for Geosciences and Natural Resources) acts as BfS's consultant for geosciences.

All other radioactive waste management activities, e.g., spent fuel storage, reprocessing, conditioning, transportation, and interim storage are within the responsibility of the nuclear industry. For so-called small producers the Federal States must provide and operate regional facilities for interim storage of radioactive waste originating from radioisotope use in industry, universities and medicine.

6.2 Technical process

6.2.1 Present method

New developments in radioactive waste management and disposal

In Germany, federal elections took place on September 27, 1998. As a result, a coalition of the Social Democrats and Alliance '90/The Greens come into power. This new Federal Government has vowed to phase use out nuclear power use for electricity generation, in a pronounced change of the previous energy policy. To this aim, in a first step so-called consensus talks were conducted with representatives of the nuclear power plant operators. Thereafter, the corresponding legislative measures were initiated.

The basic document of the nuclear consensus was initialed on June 14, 2000, and signed on June 11, 2001. According to this document, the Federal Government and the utilities agree to limit the future utilization of the existing nuclear power plants. Instead of defining fixed time limits, for each installation the total amount of electricity the plant is allowed to generate from January 1, 2000, until its decommissioning was agreed upon. To compute this total amount the average electricity production of the best 5 years out of the last ten was taken as the plant capacity basis, with an additional 7% to account for future technological improvements. Furthermore, for calculation purposes a plant lifetime of 32 years was assumed. In principle, once a plant has produced its generation quota it will be phased out. But a transfer of generation allowances from one plant to another is possible, providing flexibility for early decommissioning of older plants and longer operational life of newer ones. In total of all plants taken together, 2,623.30 TWh (net) can be produced after January 1, 2000.

Spent fuel management

Up to now, spent nuclear fuel is either shipped to the reprocessing plants of COGEMA and BNFL, stored on-site at the nuclear power plants, or at centralized interim storage facilities. For that purpose, the Gorleben (3,800 Mg heavy metal (HM); 2 x 10^{20} Bq), Ahaus (3,960 Mg HM; 2 x 10^{20} Bq), and Zwischenlager Nord (585 Mg HM; 7.5 x 10^{18} Bq) dry spent fuel interim storage facilities are available as well as the wet spent fuel interim storage facility ZAB at Lubmin (560 Mg HM). HLW originating from reprocessing abroad is stored at the Gorleben facility after returning to Germany.

According to the mentioned consensus agreement of June 14, 2000, transport of spent fuel for reprocessing abroad will be terminated as of June 30, 2005. Thereafter, spent fuel will only be bound for later direct disposal. Furthermore, and in order to minimize spent fuel transports the power plant operators must build interim storage facilities on site. After the mentioned date, spent nuclear fuel will be only allowed to be transported to the existing centralized facilities if no licensed interim storage is available at the site, and the operator is not responsible for this situation.

Correspondingly, the utilities are currently engaged in constructing new storage facilities at the plant sites or near them. As far as necessary, provisional storage places will be allowed on-site to bridge the time (up to 5 years) for licensing and erecting interim storage facilities. Until these new facilities are available, the utilities may transport spent nuclear fuel to centralized interim storage – or to France and the UK for reprocessing until June 30, 2005. With this policy, shipments of spent fuel will be considerably reduced.

Starting in 1999 and until the Fall of 2000, license applications were filed for 13 new interim storage facilities and 5 provisional storage places with capacities in the range of 120 Mg HM to 2,250 Mg HM and activities in the range of 7.6 x 10^{18} Bq to 2.7 x 10^{20} Bq. BfS is the competent licensing authority. All licensing procedures require a public hearing most of which were held in 2001. BfS issued the license for a first provisional storage place at the Neckarwestheim NPP on April 04, 2001. It is intended to issue all other licenses up to the end of 2002. Operation of all new interim storage facilities is expected up to 2005.

Radioactive waste management

As previously stated, In the Federal Republic of Germany all radioactive wastes are to be disposed of in deep geological formations. Up to now, according to the 1979 German radioactive waste management concept, two sites were considered for disposal:

- The former Konrad iron ore mine.
- The Gorleben salt dome.

The former Konrad iron ore mine near Salzgitter in the Federal State of Lower Saxony was selected for disposal of radioactive waste with negligible heat generation, i.e. waste packages which do not increase the host rock temperature by more than 3 K on an average (LLW, ILW). At a depth of 800 m to 1,300 m the emplacement of up to 650,000 m^3 waste package volume was planned. A total activity in the order of 10^{18} Bq and an alpha emitter activity of about 10^{17} Bq were anticipated for disposal in this facility. The licensing procedure started on August 31, 1982, and is still pending.

The Gorleben salt dome in the north-east of Lower Saxony is being investigated for its suitability to host at depths between 840 m and 1,200 m a repository for all kinds of radioactive waste, mainly for heat-generating waste from reprocessing and for spent fuel (direct disposal). The accumulated activity inventory to be disposed of at Gorleben was estimated to be about 10^{21} Bq for beta/gamma emitters and 10^{19} Bq for alpha emitters. Site-specific investigations started already at the end of the seventies.

Short-lived low and intermediate level radioactive waste arising from power plants and from the radioisotope use in the German Democratic Republic was disposed of at the Morsleben repository. In this site, a former salt and potash mine located near Morsleben in the Federal State of Saxony-Anhalt, disposal of waste with an alpha emitter concentration of up to 4.0 x 10^8 Bq /m^3 was carried out since 1971. After German reunification on October 03, 1990, the Morsleben repository became a Federal repository in the sense of Section 9a of the Atomic Energy Act. From 1971 until 1998 radioactive waste with a total volume of about 37,000 m^3 and some 6,100 spent sealed radiation sources were disposed of. The total activity of the waste emplaced amounts to approx. 10^{14} Bq. Pursuant to a September 25, 1998, court order BfS immediately stopped further radioactive waste disposal in the so-called eastern emplacement field of the Morsleben repository and shortly thereafter also elsewhere. Thus, last waste emplacement was carried out on September 28, 1998.

According to the coalition agreement of October 20, 1998, and the consensus agreement of June 14, 2000, the German radioactive waste management and disposal concept is being reviewed and will be updated due to political decisions, new findings, and specific evaluations. Important aspects in this regard are:

- A new national waste management plan for the legacy of radioactive waste shall be developed.
- A single repository in deep geological formations shall be sufficient for disposal of all types of radioactive waste. This repository shall be available by the year 2030 as a political objective.
- The Federal Government expressed some doubts with regard to the suitability of the Gorleben site. Therefore, its exploration shall be interrupted to allow for time to resolve the mentioned doubts. Meanwhile, also alternative sites in various host rocks shall be considered.
- The licensing procedure for the Konrad repository project shall be finished following the steps anticipated in the law. After a license, construction shall not begin immediately, to allow for objections to the project to be dealt with before the courts.
- The Morsleben repository shall be decommissioned.

The disposal of all kinds of radioactive waste in deep geological formations continues to be the only option considered. But the political objective of disposing of all waste in a single repository is likely to be reconsidered. There is namely a growing body of scientific evidence that a separate disposal of heat-generating and non-heat-generating waste would have special advantages from a safety point of view compared to disposal of all types of radioactive waste in a single repository. Among other aspects gas generation in the post-closure phase is here very important. Thus, the political aim of constructing and operating a single repository is still to be examined in detail focusing on safety-related aspects, on specific issues of the waste management concept, and on economical considerations.

Though the Federal Government has expressed some doubts about the suitability of the Gorleben site, it has been clearly stated in the consensus agreement that there is hitherto no scientific evidence pointing to its unsuitability. Correspondingly, this site shall be considered in any future site selection process (cf. chapter 2.3). Furthermore, as stated in the agreement the Federal Government believes that a further exploration of the Gorleben salt dome will not contribute to clarify the mentioned doubts. Correspondingly, exploration was interrupted for a period of three years as a minimum and ten years as a maximum; a rapid clarification of these doubts will then be undertaken. The Gorleben moratorium became effective on October 1st, 2000.

The licensing procedure for the Konrad repository project is nearly finished. Nevertheless a positive decision by the competent licensing authority, the Ministry of the Environment of the Federal State of Lower Saxony is still pending. Up to present, no fundamental legal or safety reasons have been found against a positive decision in the Konrad licensing procedure. However, a revision of the Radiation Protection Ordinance was necessary to harmonize German radiation protection regulations with European Union law. The necessary amendments of the license applications had been meanwhile carried out and the revised documents handed over to the licensing authority.

The Morsleben repository will not resume operations. A license application for the decommissioning was already filed on May 09, 1997. The assessment of the site's radionuclide isolation capability is specially important within this procedure. The original site safety assessment was based on a preliminary backfilling and sealing concept. Meanwhile, more detailed site information becoming available and the correspondingly updated safety analyses indicated that the preliminary concept would not provide best protection of man and the environment. Thus, two different decommissioning and closure concepts are being developed. Work on Morsleben is currently focussing on preparing the licensing procedure documents. Latest important issues comprise the backfilling of the so-called southern emplacement field with crushed salt from November 18, 2000, until March 09, 2001, and the statement of BfS dated April 12, 2001, that the Morsleben repository will definitely never again be used for radioactive waste disposal.

6.2.2 Research and development

The aim of German research and development (R&D) work into radioactive waste management and disposal is to protect humans and the environment from potential, particularly long-term risks of radioactive waste disposal. The responsibility for this R & D lies with three ministries: the mentioned Federal Environment Ministry (BMU), the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (BMBF, Federal Ministry of Education, Science, Research and Technology) and the Bundesministerium für Wirtschaft und Technologie (BMWi, Federal Ministry for Economy and Technology). BMU's task is to fulfil the obligations laid down in the Atomic Energy Act. Thus, BMU initiate R&D projects according to its specific needs. In addition, BfS carries out site and facility-specific R&D work on radioactive waste disposal, i.e. work that is essential for planning, construction, operation, extension, renewal, and closure of a given repository, as well as for assessing its performance after closure. The waste producers pay for such work pursuant to the Endlagervorausleistungsverordnung (Ordinance on Advanced Payments for Repository Construction). Subcontractors, on behalf of BfS, carry out the R&D projects.

BMBF R&D on radioactive waste management deals with basic research on waste disposal, independent of the realization of the German repository projects. The program is part of BMBF's energy research and development and environmental research programs. This R&D is oriented towards further developing the state-of-the-art of science and technology concerning the safety of underground disposal of radioactive waste in general. The research focus on repository post-closure safety, and has been conducted since more than 30 years. It broadens and deepens the knowledge gained by site- and facility-specific R&D work under BMU/BfS responsibility. Research establishments at Jülich and Karlsruhe carry out BMBF waste management and disposal research. BMBF finances the work either directly or within the regular budgets of the research establishments. International cooperation with almost all countries plays an important role.

6.2.3 The repository siting process

According to the new approach to waste management and disposal, further sites in various host rocks shall be investigated for their suitability. The final site shall be selected upon a subsequent comparison of potential sites, including the Gorleben site. Thus, BMU set up a special expert group, the so-called AkEnd, to develop repository site selection criteria and a site selection procedure, based on today's scientific basis. The criteria and procedures aim at finding the relatively best-suited site in different host rocks in Germany. Such a set of criteria was not available when the Gorleben site was chosen in the seventies.

The main objective of the site selection procedure under development is to identify – with public participation – potential disposal sites in a comprehensible and reliable way. Step by step and based on criteria which have to be previously defined, areas, site regions, and eventually sites shall be selected having particularly favorable conditions for later demonstrating the site suitability and confirming it in a licensing procedure.

In this context, the question in which step a decision on the host formation(s) has to be made is utmost important for any site selection procedure. According to first findings by the mentioned AkEnd, it is less this host formation but rather the integral geological setting at a site that provides for the necessary long-term isolation of the waste and for the justified assumption that even thereafter there should be no unacceptable releases. Therefore, a site selection procedure is striven for, which does not start by fixing the host formations, but rather attempts to select host formations as a result of a process based on general criteria describing an integral geological setting with favorable properties for radioactive waste disposal.

The time needed for developing the site selection criteria and the procedure is estimated to be about 3 years. Work started in February 1999; first results were presented and discussed in the Fall 2000. An in-depth discussion of the proposals with the public is planned from 2001 onwards, so that the completion of work can be expected in 2002. The recommended criteria and procedures will finally be discussed nationally (including stakeholders, environmental groups, other interested initiatives, and the general public) and internationally, before being legally implemented. During this criteria development phase, new sites will neither be selected nor surveyed.

Provided that the site selection criteria are available in 2002, and their discussion performed in 2003/2004, it seems possible to nominate potential sites, perform respective investigations, and finally select the site by 2010. Accordingly, for detailed site investigations, repository planning, licensing procedure, and construction of the repository approx. 20 years could be available in order to start operation by 2030, as is anticipated by current BMU's planning.

6.2.4 Safety and licensing

Disposal of radioactive waste in a repository is in particular governed by the:

- Atomgesetz (Atomic Energy Act).
- Strahlenschutzverordnung (Radiation Protection Ordinance).
- Bundesberggesetz (Federal Mining Act).
- Sicherheitskriterien für die Endlagerung radioaktiver Abfälle in einem Bergwerk (Safety Criteria for the Disposal of Radioactive Waste in a Mine).
- Umweltverträglichkeitsprüfungsgesetz (Environmental Impact Assessment Act).

The Atomic Energy Act and the Radiation Protection Ordinance prescribe the protection objectives for a repository. The Safety Criteria specify the measures to be taken in order to achieve these objectives, and define the principles by which it must be demonstrated that these objectives have been achieved. The Federal Mining Act regulates all aspects concerning the operation and decommissioning of a repository mine. In addition, environmental legislation including the environmental impact assessment regulations must be taken into account.

BfS is the authorized applicant within the licensing procedure. Thus, an application for initiating a so-called plan-approval procedure, i.e. a special kind of licensing procedure pursuant to Section 9b of the Atomic Energy Act, must be filed to the licensing authority of the Federal State concerned. In general terms, a plan-approval procedure shall carefully examine a project deemed important for the region concerned, weighing and balancing the interests of the body responsible for the project with public and private interests affected by the planning in a single procedure, coming up with a decision which is legally binding in relation to third parties. This instrument of German planning law is applicable to a variety of large-scale public works. The plan-approval procedure includes, among others, the involvement of all authorities concerned and a public hearing. The procedure ends, in the positive case, with a plan-approval decision, i.e. the license.

The legal competences for licensing construction and operation of a repository in a deep geological formation are such that two separate procedures are necessary: the procedure under the Atomic Energy Act on the one hand and a procedure under the Federal Mining Act on the other. Site investigations including exploration mine construction require only a license under the Federal Mining Act, as is the case at Gorleben.

In compliance with the Safety Criteria for the Disposal of Radioactive Waste in a Mine, the required safety of a repository to be constructed and operated in a geological formation must be demonstrated by a site-specific safety assessment. Thus, respective investigations and evaluations have to be carried out covering:

- Exposure of the staff and of the public in the repository vicinity to direct and scattered radiation as well as to radiation from radioactive substances released from the site via gaseous and liquid effluents, and that under normal operation and under accident conditions.
- Decay heat of the radionuclides contained in the waste package (thermal influence upon the host rock).
- Criticality safety in the operational and post-closure phase.
- Exposure to radiation in the repository surroundings due to radioactive substances released via the water path in the post-closure phase (radiological long-term effects).

This work has to be based on detailed site-specific geological and hydrogeological data, a sufficiently detailed concept of the repository including the planned mode of operation, and data concerning the types, quantities and properties of the waste packages intended for disposal. The results of such investigations provide necessary information for establishing the waste acceptance criteria and for designing the repository. Such a site-specific safety assessment was successfully performed for the Konrad repository project within the repository licensing procedure and will have to be performed for the envisaged repository to be operable by 2030.

6.3 Economical implications

6.3.1 Financial issues

Activities such as site investigations, repository design and planning, site-specific safety assessments, licensing procedures, and construction of a repository mine under Section 9a of the Atomic Energy Act involve considerable costs. Pursuant to section 21 b Atomic Energy Act, these costs must be borne by the waste producers. To this end, on April 28, 1982, the Verordnung über Vorausleistungen für die Einrichtung von Anlagen des Bundes zur Sicherstellung und zur Endlagerung radioaktiver Abfälle (Ordinance on Advanced Payments for Construction of Federal Installations for Long-term Storage and Disposal of Radioactive Waste) was issued. On the basis of this ordinance, BfS is entitled to be reimbursed for its expenses. The reimbursement is determined according to the costs having actually been incurred; budget planning covers a period of five years in advance, with two years in detail and an outline for three further years. The detailed planning for a given next fiscal year includes a description of the intended work and an estimate of costs to be incurred. This planning is made public; the corresponding moneys are part of the budget of BMU. At the end of the fiscal year, the actually incurred overall expenditure is determined and invoiced to the waste producers, apportioned to them in relation to installed capacity of their power plants.

Since 1982, the waste producers have paid for the costs of repository work on the basis of an annual invoice. From 1977 to 2000, the total costs incurred amount to about 4.8 billion German Marks. Of this amount, 2.5 billion were spent on the Gorleben project, 1.6 billion on the Konrad project and, since 1990, about 0.7 billion for the Morsleben repository.

6.4 Sociopolitical aspects

6.4.1 The role of politicians and public opinion

With respect to the coalition agreement of October 20, 1998, and the consensus agreement of June 14, 2000, it is evident that the politicians (i.e., the Federal Government) have an important influence upon radioactive waste management and disposal. Whereas the previous energy policy was in favor of nuclear power use, the energy policy is now in favor of phasing-out nuclear energy.

Public involvement in the decision-making process was already addressed with respect to the plan-approval procedure (cf. chapter 2.4), which is prescribed by law for repository licensing. In addition to that, public acceptance is considered to be of utmost importance. In the framework of the new site selection criteria and procedure under development, the public opinion is even of central importance:

- The site selection procedure will have a clear and transparent structure and will be based upon well-founded criteria in order that progress, fairness, and objectivity of the procedure can easily be followed and respective decisions are understood by the general public.

- The evaluation basis and criteria associated with the selection procedure will be fixed beforehand, to avoid decisions the public might perceive as not sufficiently justified or even arbitrary.
- Public participation is considered indispensable from the very beginning and in all phases of the selection procedure. This includes the definition of the criteria and the site selection procedure itself, the "rules of the game".

The ultimate goal of the site selection procedure being developed is that it will be generally accepted as suitable and fair before being applied, i.e. before local interests become effective.

7 Nuclear waste management in Spain – Empresa Nacional de Residuos Radiactivos (ENRESA)

7.1 Introduction[1]

Spain started to use radioactive materials in the 1950s' in the fields of research, medicine and industry. The start-up of the first nuclear reactor was in 1968. There are today seven nuclear power plants (NPP), with nine reactors (the NPP Vandellós I was shut-down in 1990). Nuclear power constituted 35% of the total electricity production in 2000. The total nuclear installed capacity is presently 7,799 MW. About 95% of the nuclear waste originate from the electronuclear facilities. Waste coming from industrial, scientific and medical applications is generated in roughly 500 installations all over Spain.

According to the Nuclear Energy Act of 1964, the producers of nuclear waste are responsible for its safe management. In 1984, Empresa Nacional de Residuos Radiactivos – ENRESA was established with the aim of taking overall responsibility of waste as to promote its disposal. ENRESA is a publicly-owned company, whose main functions are to organise and carry out radioactive waste collection, transport treatment and disposal, site selection and the design, construction and operation of storage and disposal centres. ENRESA manages also the operations related to decommissioning of nuclear and radioactive installations, manages the waste fund and, as required, conditions the tailings arising from uranium mining and milling.

The process of nuclear waste management follows the mandates included in the General Radioactive Waste Plan (GRWP) issued by the Government. The Plan currently in force is the 5th GRWP approved on 31st July 1999. It includes the necessary actions and technical solutions to be developed throughout its period of validity, aimed at the adequate management of radioactive waste. It also includes an updated economic and financial study of the costs of such actions. The Ministry of Economy (till the year 2000 this function was assigned to the Ministry of Industry and Energy) regulates the nuclear waste management area. Among its functions there are: 1. Planning of radioactive waste management, 2. Issuing of construction and operational licenses 3. Regulating the financial mechanisms to fund radioactive waste management.

The Nuclear Safety Council (CSN) is the regulatory body in charge of nuclear safety and radiological protection. The CSN is responsible for setting and ensuring compliance with current safety standards for nuclear installations and for conducting inspections at

[1] The chapter is based on the following material: *V General Radioactive Waste Plan*, July 1999, Ministry of Industry and Energy; *Technological Research and Development Plan* 1999–2003. ENRESA. March 2000; *Annual Report 2000.* ENRESA; *The role of the public and administrative mechanisms of public involvement in the development of a final disposal solution for radioactive waste in Spain*. Report to Working Group #5. International Nuclear Law Association (INLA). 1999; *Survey of the attitudes of the population to the Radioactive Waste Storage Centre of El Cabril*. 1999. Hispania Services/ENRESA.

nuclear facilities as well as for the certification of its employees. CSN has to report to the Ministry of Economy prior to granting any license, and its conditions are binding if negative. It is independent of the Administration and reports directly to the Parliament. The CSN can propose to the Ministry of Economy that fines or penalties should be imposed in the case of non–fulfilment of the regulations on nuclear safety and radiation protection.

The Ministry of Environment is responsible for the management of the process of Environmental Impact Assessment and for proposing new regulations concerning environmental issues.

Concerning RWM, there is not a specific legislation, but four major sets of regulations are applicable: 1. Regulations concerning radioactive waste management included in the legislation that rules nuclear safety as well as the process of authorisation of nuclear and radioactive installations 2. Regulations concerning Environmental Impact Assessment and Environmental Impact Statement 3. Regulations governing Land Uses and Municipal Functions. 4. Regulations concerning the activities of ENRESA and financing of radioactive waste management.

7.2 Technical aspects

7.2.1 Present management methods

According to the estimations of the 5th GRWP, the total amount of radioactive waste to be managed during the lifetime of the present NPPs will be:

- Conditioned low and intermediate level wastes: 193,600 m^3.
- Spent fuel: 6,750 tU.
- Vitrified wastes from Vandellós I: 80 m^3.

At the beginning of 1999, there were recorded some 25,435 m^3 of conditioned low and intermediate level waste and 2,249 tU spent fuel, stored in the NPPs or in El Cabril.

Low- and intermediate level nuclear waste

The disposal of low- and intermediate level waste is carried out at ENRESA's El Cabril Facility, in the province of Córdoba, which commenced operation in 1992, after a license was granted by the Ministry of Industry and Energy. In 1988, ENRESA applied for it. Reports concerning the application were ordered from the Nuclear Safety Council and the Directorate General of the Environment, the body responsible at that time for the Environment Impact Statement. In August 1989, the Directorate General of the Environment send its Environmental Impact Statement along with the positive report by the Nuclear Safety Council to the Ministry of Industry and Energy following the period of public objections and statements. In October 1989, construction of the facility was authorised by the Ministry. The construction began in 1990 following the work license issued by the Town Council based on a positive report by the Provincial Town Planning Commission. The authorisation to open the facility for operation was given by the Ministry of Industry and Energy in 1992, following the reports from the CSN, that issued a Provisional Operating Permit (POP).

The facility is of the surface type with engineered barriers. Its approximate capacity is 40,000 m^3, equivalent to the needs to be covered up to 2016.

High-level nuclear waste

The main policy on high-level waste has been to work in the disposal solutions envisaged by the scientific community while providing solutions to the short-term requirements. During the 90s, the capacity of the pools of all the NPPs was enlarged as possible by means of reracking.

After implementation of this solution two plants have sufficient capacity covering their lifetime and two plants have that same capacity minus a year. Trillo nuclear power plant did not solve its long-term capacity problem. To solve this latter situation, a temporary storage facility is being built next to the plant and will be operational by 2002. The technology is based on dual-purpose metallic casks. The Government has already granted the construction license and the construction work started in 2000.

As for the medium term, the main goal is to implement a centralised storage facility for long-lived, high level waste and spent fuel. It is intended to have this facility in operation by the year 2010. This approach has the advantage of permitting to gather high level waste, spent fuel and internals from decommissioning coming from the nuclear power plants as well as other long-lived waste produced outside the electricity sector. It is also necessary to provide storage for the vitrified waste and fissionable materials returning from reprocessing abroad. As a second solution a combination of a centralised storage facility and some storage installations, these latter at the NPP sites is also considered. The only alternative to this storage is to send more fuel abroad for reprocessing, but it would lead to a higher cost and a temporary storage would still be required in the future since vitrified waste will be returned.

The main ENRESA's strategy for the long-term high-level nuclear waste management is disposal in deep geological formations. Investigations have been made to detect suitable geological conditions and different types of formations have been examined such as salt formations, granite rock and clay layers. ENRESA is currently compiling and adapting the information material on the geological studies performed since 1986. ENRESA has also developed plans for disposal facilities and has made non site specific generic safety assessments for the three host media. Based on these documents, ENRESA has been able to initiate research in important areas, such as hydrology, geophysics, and hydrochemistry.

ENRESA has also designed a non-site-specific conceptual repository for every of the three candidate host rocks. The waste will be put in carbon steel containers and these will be deposited in horizontal tunnels and covered by backfilling material. The depth for clay is 250 meters, 500 meters for granite and 600 meters for salt. Retrievement is discussed today in Spain but it is not an official concept. According to current research it is considered feasible.

Concerning the management of spent fuel and high level wastes, the decision regarding a definitive solution has been postponed until 2010 and, in the meanwhile, there will be no siting activities. No further design work will be carried out; just the analysis of the possible impact of retrievability and new technologies, such as partitioning and transmutation (P + T). After 2010, a decision will be made on the final solution. If so, in 2035 the facility could be operational.

Decommissioning of nuclear facilities

As part of its functions, ENRESA is decommissioning the Nuclear Power Plant Vandellós I, which was shut-down in 1989. The project started after the corresponding licenses of the Ministry of Industry and Energy and the local authorities in Catalonia. The alternative chosen was immediate dismantling to Level 2, followed by a period of waiting (estimated at 30 years) for completion of total dismantling of the remaining parts of the plant (Level 3). The application was sent in May 1994. In 1997, there were issued the favourable reports by the CSN and of the Environmental Impact Statement by the Ministry of Environment. On January 1998, the Ministry of Industry and Energy issued its authorisation. The project will be completed well into 2002. Major activities of the dismantling phase (Level 2) are disassembly of the conventional components and active parts, development of the waste management plan and confinement of the reactor shroud. At the end of this phase, the facility will be prepared for the period of latency and a large part of the site will be declassified.

It is forecasted that some 2,000 t. of low and intermediate level waste will come out of the works undertaken till 2002. This waste will be disposed of in El Cabril after been conditioned in Vandellós I.

7.2.2 Research and development

The present and future research on deep geological disposal of high-level radioactive waste is divided into two periods. A first period, lasting until the year 2003, coinciding with the 5th EU Framework Programme and including the culmination of the ENRESA-2000 generic assessment exercise, which will integrate the results of the different R&D groups and involve these groups in the work performed.

A second period, lasting until the year 2010, which should include special efforts concentrating on research into especially relevant models and parameters, in keeping with the lines mapped out within the EU, and progressive closure of those whose objectives are met.

Throughout both periods attempts will be made to conserve capabilities of strategic importance for the management of spent fuel and HLW, keeping them operable within the framework of safety assessment and experimental exercises promoted by the EU.

As mentioned, research is also conducted concerning complementary methods of disposal, P + T, and concerning retrievement. The effect of these new technologies on definitive management should be periodically analysed, with studies of the entry and exit of radionuclides in the processes, expected yields, volumes of wastes of all types, the effects on deep disposal, comparative risks, costs, etc. Likewise, ENRESA will actively participate in the forums of the EU, NEA/OECD and IAEA, where the advantages, disadvantages and feasibility of these new technologies are debated. The objective of all the above is to acquire suitable experience to report to the Government on the possible influence of Partitioning and Transmutation on the definitive management of spent fuel and HLW, as well as on the best way to implement the solutions considered to be adequate.

ENRESA co-operates with many research institutions such as the Spanish Centre for Energy-related, Environmental and Technological Research (CIEMAT) and several universities. There is also co-operation with the EU Framework Programmes.

7.2.3 The siting process of radioactive waste

According to the current plan in Spain, there will be no further siting activities until 2010. In the meanwhile, there will be a gathering of the existing data on geology in order to evaluate the progress.

7.2.4 Safety and licensing

ENRESA has developed a performance/safety assessment strategy for the deep disposal and it is to be performed through systematic stages. The first performance assessment was made in 1997 on granite rock and in 1998 an assessment was made in a clay formation. The studies showed that clay and granite are suitable for a repository and through the studies a methodology was developed. ENRESA will issue another performance assessment soon. The method envisaged for a safe disposal is a multi-barrier system where the waste is protected by capsules and where the capsules are hosted by the rock.

Licenses and authorisations are issued by the Ministry of Economy as long as there are favourable reports by the Nuclear Safety Council and an Environmental Impact Statement by the Ministry of Environment. There are also other licenses that must be obtained on the local level, such as the mining licenses, licenses concerning conventional wastes and licenses on land planning and usage standards, all given by the Governments of the Autonomous Communities. To sum up, the process of licenses can be divided into three legislative blocks. The first concerns standards for nuclear installations for which authorisation is granted by the State, specifically the Ministry of Economy, the Nuclear Safety Council and the Ministry of the Environment. Licenses for applications concerning territorial planning and Land Use Management fall within the competence of the autonomous communities and the Town Councils. Thirdly, it is the responsibility of the State Government or the governments of the Autonomous Communities to issue licenses for mining, water disturbances, infliction on natural parks and so on. The Spanish legislation does not include any specific regulation just for the administrative aspects of licensing disposal facilities for radioactive wastes. The process is organised legally within the general framework of industrial legislation, to which are applicable the special conditions of nuclear safety.

7.3 Economical aspects

7.3.1 Financial issues

A fee on the electricity bills finances the management of the nuclear waste from nuclear power plants as well as its decommissioning. Other producers pay tariffs for their waste to be treated and disposed of. Moneys collected are gathered into a fund that is handled by ENRESA. There is an inter-ministerial committee that supervises and does the follow-up of the financial investments. The total cost for the waste management is revised every year, so it facilitates adjusting revenues of the Fund to the cost of unexpected events or unplanned uncertainties.

As part of its functions, the Ministry of Economy sets the annual fee to be paid by the radioactive waste producers and approves payments from the waste fund.

The total cost of the Spanish nuclear waste management program up to 2070 is estimated to be 1,630,515 millions pesetas (9,799.6 million Euro). The management of the high-level nuclear waste and the dismantling program will constitute a substantial part of this sum, around 968,943 million pesetas (5,823.5 million Euro). The waste management had by the end of 1998 used 17% of the total calculated cost. The fee on the electricity bills is today 0.8%, but the funds and the financial situation as a whole is regularly reviewed.

7.4 Socio-political aspects

7.4.1 The role of politicians and public opinion

The Government approves the General Radioactive Waste Plan where the main policies, strategies and activities concerning radioactive waste management are stated. Every time the Government approves a new Plan, this document is sent to the Parliament for information. In general, the Ministry of Economy has the overall responsibility of conducting the process of radioactive waste management. ENRESA is committed to submit every year a draft new version of the GRWP to the Ministry of Economy according to the new information on technical, economic and financial requirements. When considered adequate, the Ministry of Economy passes the Plan with its own comments on to the Government for approval.

Furthermore, the situation and forecasts of waste management are periodically discussed in the Congress and in the Senate, in the corresponding Commissions.

At present, the public has the direct opportunity to participate in the decision-making process concerning the different licenses, as it open to it to point out any allegation during the process of issuing the Environmental Impact Statement. The municipal authorisation process is also open to consider the willing of the local authorities as well as stakeholders. The applications are made public and the citizens can submit comments, complaints or statements in order to intervene in the process of authorisation. In the case of dismantling a nuclear installation, the Law states that an Information Committee has to be established under the governance of a representative of the Ministry of Economy.

Experiences in the past show that although confidence in radioactive waste management at national level is very low, at local level, where information campaigns have been systematically undertaken, public perception is quite more favourable. Some surveys carried out in the vicinity of ENRESA's facilities indicate that, although the people living close to ENRESA's installations does not like these facilities, they trust ENRESA'S work and personnel. In those cases, the siting process was successfully carried out by means of information committees, full disclosure of the projects, information centres and information campaigns and local working-force involvement. That situation happened in El Cabril, Vandellós I and in the dismantling and closure of Andújar, a disused uranium milling facility.

On the contrary, the public strongly intervened in the decision-making process when there were attempts to site an Underground Research Facility (1987) and to develop an inventory of the most favourable areas for a deep geological disposal facility for spent nuclear fuel. Both processes were halted due to social upset. Concerning the case of the inventory, the Government decided in 1996 to interrupt the Geological Research Plan and to reconsider the high level waste strategy.

Bearing this in mind, the current Government's policy highlights the necessity of better approaching the population prior to making decisions on which kind of definitive management should be implemented. Fifth General Plan states: "it should be pointed out that, in view of the obvious sensitivity of society to matters relating to radioactivity, based among other things on a lack of public understanding of the true nature of the technical solutions proposed, it will be necessary to carry out the widest possible information/educational campaigns, in order to facilitate better knowledge and understanding both of the problem to be solved and the technology to be used to achieve such a solution."

7.4.2 Information and communication

The 5th General Radioactive Waste Plan emphasises that "any action in this field (siting of an underground disposal facility) will require the furthest reaching communications campaigns possible, with a view to providing the public with whatever information might be necessary; this is especially important because of the high level of social sensitivity to issues relating to radioactive waste."

After the establishment of ENRESA, the first communication actions were taken. In 1990, the First Communication Plan was implemented with the aim of getting the most of public acceptance in the area of El Cabril. The 2nd Communication Plan, issued in 1994, targeted a wider public and tried to inform on the whole of ENRESA's activities. Current Plan, approved in 1998, is being developed upon two main axis: a) Training/Information, b) Communication with the media.

ENRESA's strategic guidelines for information and communication are:

1. Wide, transparent and truly information to the different social sectors.
2. Training on specific topics to the university students working in related matters.
3. To comply with the regulations governing the assignment of funds to the municipalities close to ENRESA's installations.
4. Co-operation with the local authorities as to improve the resources and infrastructures of those areas surrounding ENRESA's installations.

ENRESA informs by means of five Information Centres, located in those places where the company works: Madrid, Andújar Uranium Mill, Córdoba, El Cabril and Vandellós. In 2000, roughly 26,000 people visited these offices. Also, communications with the media is a major task, carried out through the release of news, reports, seminars with the journalists and participating in radio and TV debates. Last year, some 784 news were recorded in the whole of the Spanish media. The evaluation of the material released was good with most of the news (65%) approaching radioactive waste management in a positive way.

The policy of training students and young people in waste management is being mainly undertaken through courses and seminars. In the year 2000, ENRESA participated in 79, with 3,500 people attending.

Contacts with political representatives try to let them be informed about ENRESA activities and to create areas of common co-operation. Periodically, and in addition to the controls established by legislation, representatives of the company appear before the respective Commissions of the Congress and Senate of the National parliament. Meetings are also held periodically with the members of Parliament and opinion leaders most closely linked to radioactive waste management, especially those representing the areas with ENRESA's installations in the national or regional Parliaments. In addition there is an annual official meeting with the Town Councils of the areas of influence. In the field of co-operation with the local political authorities, major efforts are devoted to optimise the resources generated by the company, to implement training programs for potential site workers and to the preferential use of local resources.

8 Nuclear waste management in Sweden – Svensk Kärnbränslehantering AB (SKB)

8.1 Introduction

In Sweden, nuclear waste is handled by SKB – the Swedish Nuclear Fuel and Waste Management Company – which is owned by the four nuclear power companies. In 1977, the nuclear power companies were given responsibility for all radioactive waste generated by their plants. SKB has developed a system for managing this waste and has succeeded in siting facilities for low- and intermediate-level operational waste, as well as for interim storage of spent nuclear fuel. Over the last ten years, SKB has worked to find a scientifically and politically acceptable site for the deep disposal of spent nuclear fuel.

The legal framework of the nuclear waste management programme consists of the Swedish Act on Nuclear Activities, the Financing Act and the Environmental Code.

Originally, the Swedish nuclear programme consisted of 12 reactors (taken into commercial operation between 1972 and 1985). In 1997, however, the Swedish Parliament decided to shut down a reactor at Barsebäck, and on 1 November 1999, one of the two reactors at the Barsebäck plant was closed.[1]

The Swedish Government has the final word when it comes to nuclear waste and SKB is therefore required to present progress reports on an ongoing basis. One of the more recent reports is FUD 98[2] . The Swedish Government decided in January 2000 that the report meets the requirements specified in the Swedish Act on Nuclear Activities, but requested additional research on other alternative methods of nuclear waste management. SKB also had to present a report on feasibility studies and a clear programme and proposal for further site studies[3] , and this was done at the end of 2000.[4] These additional reports have been thoroughly examined by various government organisations and key players. The Swedish Nuclear Inspectorate (SKI), the Swedish Council for Nuclear Waste (KASAM), and the Swedish Radiation Protection Institute (SSI) are the key government bodies, and all of them have approved SKB's proposal that site investigations should be started in three municipalities in 2002.

In November 2001, the Government decided that SKB had completed the additional work connected with the FUD 98 decision and requested SKB to start site investigations in 2002. In December 2001, the municipal board of Östhammar, one of the three

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1 Lidskog R, 1999. "Towards a Postnuclear Society? Recent Trends in Swedish Nuclear Power Policy", *Environmental Politics* 8(2): 142–147.

2 RD&D-Programme 1998 (Programme for research, development and demonstration 1998).

3 Ibid., pp. 44–50 and http://www.radgiv-karnavf.gov.se/samordna/index.htm

4 *Integrated account of method, site selection and programme prior to the site investigation phase.* SKB TR-01-03 (December 2000).

proposed municipalities, decided to approve the planned site investigations. The two other municipal boards concerned plan to raise the issue in early 2002.

8.2 Technical aspects

8.2.1 Current management methods[5]

The main alternative for Swedish nuclear waste management is deposition in primary rock at a depth of about 500 metres. High-level waste is to be stored for about 30 years at CLAB – the central interim storage facility for spent nuclear fuel – before deposition in the rock. Low- and intermediate-level operational waste is disposed of at the SFR facility in Forsmark. This facility is built 50 metres below the seabed and can hold up to 63,000 m^3 of waste.

All nuclear material is currently transported by ship, since all nuclear reactors and waste facilities are located by the sea. The transport ship M/S Sigyn was specially built for this task and is used for all shipments.

At CLAB, the waste is stored in water-filled basins inside a rock facility, 25 metres below ground. CLAB currently stores about 3,400 tonnes of waste and accepts 300 tonnes a year. The maximum amount of waste is 5,000 tonnes and the entire Swedish nuclear programme is estimated to generate at least 7,000 tonnes of waste. CLAB has now been extended to enable it to handle all spent fuel from the Swedish nuclear programme.

After 30 years, the waste will be placed in canisters with an outer shield of copper and an insertion of solid cast iron. This canister is still under construction and has not yet been fully tested. When filled, the canisters will be deposited in the Swedish bedrock, about 500 to 700 metres below ground, in tunnels with deposition holes. Each canister will be surrounded by bentonite clay.

The deposition will be performed in two steps. The first deposition will consist of 400 canisters, which is equivalent to 10% of the total amount of waste. The material and the deposition method will then be evaluated. After this, either regular operation of the repository can begin or the waste will be retrieved.

The reference deposition method is known as KBS-3 and has been approved by the Swedish Government and SKI as the method on which to base upcoming site investigations. All players, however, appear to agree on the necessity of more research that will also address alternative methods.

8.2.2 Research and development[6]

Swedish research has focused, and continues to focus, mainly on the geological disposal of waste. Only to a limited extent has it been devoted to other alternatives, such as supervised deposition above ground, reprocessing and transmutation.

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[5] This section is based on information from the FUD-programme, p. 51–53.

[6] This section is primarily based on the FUD 98 report, pp. 155-176.

Direct deposition or geological deposition is the method promoted by SKB, which has found that geological disposal is the most suitable method when compared to reprocessing and transmutation, launch into space, disposal in ice several kilometres thick, abyssal disposal in or beneath the sea-bed or supervised deposition.[7] The term "supervised deposition" entails storing the spent fuel in a storage facility such as CLAB, as previously mentioned. The fuel is then kept there until a final method is proposed. The drawback of this method is that it requires constant supervision and one of the ambitions of the Swedish approach is not to leave the problem to future generations. Supervised deposition is the alternative promoted by Greenpeace[8], since the organisation does not believe that there is a suitable technical method at hand to solve the long-term safety issues.

There are different kinds of geological deposition. Research has been conducted around deep boreholes where high-level spent fuel can be disposed of in horizontal tunnels several kilometres under the ground. Another method is to place the waste in vertical tunnels that are tens of kilometres long. Research has also focused on placing the waste in a cave-like deposition below ground, known as the WP-cave system. The direct deposition method approved by SKB is the KBS-3 method of placing the waste 500–700 metres below ground in tunnels with deposition holes.

One of the most important research projects concerning deep disposal is the Äspö Hard Rock Laboratory, where a tunnel facility has been constructed. The purpose of the Äspö facility is to investigate the different variables involved in deep disposal. Research and development concerning different aspects of the KBS-3 method are conducted by SKB, various universities and other organisations. This R&D focuses on the bentonite clay, the structures of the rock, water flows and transports, ground water chemistry, the chemistry of radionuclides and radioactive substances in the biosphere. There is also ongoing research focusing on the canisters in which the waste is to be placed.

There is also some research regarding the reprocessing of spent nuclear fuel, but the official policy in Sweden is to avoid reprocessing. The reasons for this standpoint are above all political rather than the fact that it is still a very expensive process. Neither SKB, nor the governmental agencies, nor the Parliament consider transmutation to be a viable alternative.

Sweden is also involved in many projects financed by the European Union, such as projects focusing on hydrology, natural analogues and a "prototype repository".

With regard to the future, the Government has now requested SKB to conduct further research into other methods of waste management, while additional development of the KBS-3 method is also required. Now that Barsebäck 1 has been closed down, it is also necessary to conduct further research into the decommissioning of nuclear reactors and the handling of waste products.

7 *Systemanalys. Val av strategier och system för omhändertagande av använt kärnbränsle* (System analysis. Selection of strategies and system for the management of spent nuclear fuel), SKB report. See also http://www.skb.se/english/

8 See http://www.greenpeace.org for more information on the standpoint of Greenpeace.

8.2.3 The siting process for radioactive waste

The siting process for a deep repository for radioactive waste requires different types of studies, including general siting studies, feasibility studies and site investigations. These studies will also enable SKB to produce the documentation required to gain siting permission.

In 1995, SKB conducted a study on geological conditions in Sweden that focused on the quality of the primary bedrock. The purpose was to find suitable areas for deep deposition, for which gneiss and granite are considered favourable rock types.[9]

Some years before this geological study, in 1992, SKB invited the municipalities in Sweden to submit to feasibility studies on a voluntary basis. Feasibility studies take a couple of years to complete, and involve collecting information on the existing bedrock, the utilisation of the land, the impact on the environment, how transportation can be organised, and information on the municipality in general. No test drilling is carried out during a feasibility study.

Feasibility studies have been completed in eight municipalities. In two municipalities in northern Sweden, Malå and Storuman, local referendums were held (in 1995 and 1997 respectively). In them, the local population stated that they were not interested in further investigations. The results have been respected by SKB and no further work has been done in these municipalities.[10]

In six other municipalities, all located on the eastern coast of Sweden or in its vicinity, SKB has carried out feasibility studies that were presented in December 2000.[11] According to opinion polls, there is a strong majority in each of the municipalities in favour of continuing the siting process.

The plan presented by SKB in 2000 to continue the siting programme involves performing site-specific investigations in three municipalities, Östhammar, Oskarshamn and Tierp. Four main criteria were used in the selection process: the long-term safety requirements have to be met, the rock has to be suitable, the preconditions for building the facilities must be favourable, and the chosen municipality must consent. The investigations are due to start in 2002 and will take 4–8 years. All the different aspects of deep deposition mentioned in the section on research will be investigated, including the hydrological, chemical and geological implications. After 4–8 years, one final candidate site will be selected and it will then take another 6 years before the facilities can be operational in a first experimental phase. It will therefore take at least 13 years before deep deposition is finally operational.[12]

[9] FUD 98. pp. 85-91.

[10] FUD 98. pp. 91-98.

[11] The six municipalities are Östhammar, where Forsmark NPP is located, the neighbouring municipalities of Älvkarleby and Tierp, Oskarshamn, where Oskarshamn NPP is located, its neighbouring municipality Hultsfred, and the municipality of Nyköping, where the nuclear company Studsvik is located (the company treats low- and intermediate-level waste from nuclear reactors and provides services for the dismantling of nuclear facilities).

[12] FUD 98, p. 15 and answer questionnaire SKB 2001, p. 6.

8.2.4 Safety and licensing

Licensing

Pursuant to the Swedish Act on Nuclear Activities, SKI and SSI inspect both nuclear reactors and spent fuel management facilities on an ongoing basis. All such management must be both safe and useful. Another prerequisite is that the municipality involved must consent to the location of the spent nuclear fuel. The Government does have the right, under certain circumstances, to disregard the veto of the municipalities, but neither SKB nor the Swedish Parliament favours a localisation that lacks the consent of the municipality selected.[13]

The license procedure can be described in a stepwise fashion that relates to each of the relevant activities. Most of the permits are issued in accordance with the Swedish Act on Nuclear Activities and the Environmental Code.

1. The feasibility study is followed by approval of the programme for site investigations.
2. The site investigation is followed by an application for a siting and construction permit.
3. The detailed characterisation and construction is followed by an application for an initial operation license.
4. The initial operation period is followed by an evaluation and an application for a regular operation license.
5. Regular operation is followed by an evaluation, closure design and an application for a closure license.
6. The plant is then closed and the post-closure supervision phase begins.

A sequence of permits is also required for the planned encapsulation plant.

1. Studies focusing on technology, design and siting are followed by a siting application and a construction license.
2. The construction is followed by an application for an operation license.
3. The trial operation is followed by an application for a regular operation license.
4. Regular operation.[14]

Security

There are many risks involved in managing nuclear waste and these risks have different implications at different stages of the process. Research focusing on safety is relatively reliable, but due to the considerable time-span involved in nuclear waste management, it is still difficult to predict future events. Doses of radioactivity must be kept within very low levels. According to studies performed by SKB and relevant authorities, current levels are well below the limits. Long-term safety is a key issue throughout the world

[13] Ibid., pp. 26–29.

[14] Answer questionnaire SKB 2001, p. 2–3.

when it comes to highly active nuclear waste. It is also important in terms of future safety to initiate a flexible system in which retrievability is an option, for example. The Swedish nuclear waste management programme applies a stepwise approach to siting, and every step in the process requires a thorough safety analysis.[15]

One of SKB's constant concerns is with safety issues and the company presents safety analyses on a regular basis. Their purpose is to describe the deposition process and to analyse the future implications of the deposition method. In December 1999, SKB completed a major assessment of the long-term safety of a deep repository for spent nuclear fuel. Analyses were performed for three sites with different geographical and geological circumstances. The security analysis concentrates primarily on four different areas: the composition of the fuel itself, the copper canister and the cast iron insertion, the quality of the clay, and the special long-term conditions as regards the primary bedrock. These variables are investigated using four different scenarios.

The first scenario involves unchanged conditions, while the second involves studying how the repository is affected by changing conditions such as earthquakes and landslides. According to studies used by SKB, these quakes and slides are of minor importance and size in Sweden and will therefore not affect the repository. The third scenario involves changed conditions due to errors in the manufacturing process for the canisters. The many barriers prevent, or at least greatly slow down, the process whereby water reaches the surface. A new ice age constitutes the fourth scenario. This greatly increases the risk of the canisters breaking, although SKB believes that the ice cover would not destroy the rock below the top 500 metres of the surface, which means that the canisters are likely to survive an ice age.[16]

8.2.5 Stepwise implementation of nuclear waste management

Sweden has adopted a stepwise approach to its nuclear waste management. This involves both the process as a whole and the decision-making process in particular. There are a number of separate steps in the decision-making chain and they are only partly dependent on each other. The process may be described in eight steps:

1. Selection of disposal principles and repository concept.
2. Development of design, i.e. evaluation of alternative barrier materials, designs and rock types.
3. Definition of system design and safety strategy for the selected barriers.
4. Site characterisation (surface based), site comparison, system adaptation to site, design optimisation.
5. Detailed site investigations, shaft/tunnel construction, adaptation of layout and barriers to site, design of encapsulation facility.
6. System design and site utilisation.

[15] Ibid., pp. 54-56.

[16] FUD 98, pp. 147–150 and *Djupförvar för använt kärnbränsle. SR 97 – Säkerheten efter förslutning.* Huvudrapport. Sammanfattning. November 1999.

7. Re-evaluation of experience.

8. Design for repository closure/sealing.

This is a simplified model since there are many decisions, research activities, development plans etc. involved throughout the process. As mentioned before, the Swedish system is based on regular governmental reviews and approvals.

SKB also uses the term stepwise process to describe the consultation process with neighbours and affected individuals in the vicinity of the proposed facility. The information and dialogue preparation work starts very early in the process, as recommended by the Swedish Environmental Code.[17]

8.3 Economic aspects

8.3.1 Financial issues

By law (the Swedish Act on the Financing of Future Expenses for Spent Nuclear Fuel etc.), the nuclear energy companies have to cover all the costs arising from Swedish nuclear waste management. Annual fees are accumulated in the Nuclear Waste Fund and the funds are placed in interest-bearing accounts at the National Debt Office. The annual amount deposited is now about SEK 800 million, and the yield is around SEK 1,500 million per annum. The revenues of the funds are based on a special fee imposed on nuclear electricity production and set by the Government. The fee is currently SEK 0.01–0.02 per kWh and varies with the length of time that the reactors have been in operation.[18] The total cost of dealing with radioactive waste in Sweden is estimated to be SEK 46 billion. This amount will be spread over a period of more than 70 years. The largest individual costs will relate to the construction and operation of an encapsulation plant and a deep repository.

The SFR facility has operational costs of about SEK 30 million a year and the CLAB facility has costs of around SEK 100 million a year. The cost of building and operating the canister manufacturing facility will be around SEK 4 billion and the actual encapsulation facility will cost about SEK 3 billion. The deep repository, including all tunnels and staff, will cost around SEK 13 billion. A feasibility study costs SEK 10 million, a siting study costs SEK 100 million, and the final detailed study of one municipality will cost SEK 1 billion.[19]

It is the responsibility of the nuclear energy companies to ensure that they have sufficient financial resources to cover any unforeseen delays or expenses. Financial regulations stipulate that the companies are obliged to pledge securities if the expenses involved in the nuclear waste management programme should turn out to be higher than expected.[20]

[17] Answer questionnaire SKB 2001, p. 2.

[18] FUD 98. p. 27.

[19] Ibid., pp. 31, 67 and 68.

[20] FUD 98, p. 27.

8.4 Socio-political aspects

8.4.1 The role of politicians and public opinion

The siting process does not formally involve political institutions until the relatively late stages, although it is crucial to hold consultations with specific municipalities and their citizens very early in the process. The local authorities have a veto right concerning their own affairs, although the Government may, under certain circumstances, disregard this standpoint when it comes to the siting of a disposal facility for spent nuclear fuel. The policy of SKB is however to seek consensus and not to go against the wishes of the municipality. In the two municipalities in the northern part of Sweden, Malå and Storuman, local referendums showed that a majority of the inhabitants were against a deep repository, and this opinion has been respected. In the other six municipalities studied, only minor public opposition has been raised. The municipal board normally handles the public consultation and communication process and thus forms a channel for the views of the inhabitants.

The issue of nuclear waste is not currently a major political issue at the national level. Nuclear power was hotly debated during the 1970s and caused the fall of two governments. Politicians opposing nuclear power used the waste problem to formulate demands on the power industry.[21] This period ended with the nuclear power referendum held in 1980.

Greenpeace has been an important player in the nuclear power issue and also influenced local opinion in the municipalities in northern Sweden mentioned above, but it is not particularly involved in the current feasibility studies. Greenpeace is not in favour of the deep disposal method and advocates the view that it would be preferable to wait until a better solution is developed, storing the waste at CLAB for the time being. Greenpeace believes that government approval of the current KBS-3 method will make the nuclear power issue less important to both the public and politicians. It could even pave the way for new nuclear reactors, since there would then be a solution to the waste problem. All Swedish environmental organisations are currently negative in their attitudes to nuclear power, as are three of the parties represented in the Swedish Parliament.[22]

8.4.2 Decision-making process and public confidence

Referendums enable citizens to be active in expressing their opinions about the issue at hand. The most important players, however, are the leading politicians in the municipality who have initiated or at least approved the feasibility studies. It is very much up to them to create opportunities for the citizens to obtain information, share knowledge and discuss the issue. In Oskarshamn, people are highly aware of the feasibility studies and are even positive to a final repository. This municipality already has nuclear reactors, as well as the interim storage facility at CLAB, and the citizens are thus aware of the problems and controversies surrounding the issue. It has therefore not been a major problem for either the politicians or the citizens to say yes to a feasibility study.[23]

[21] Answer questionnaire Sweden 2001, p. 3.

[22] http://www.greenpeace.se 19991213

[23] Hedberg and Sundqvist. (1998). pp. 69–71 and 112–115.

Experience gained from the first two feasibility studies (in northern Sweden) show that public confidence may decrease if politicians fail to involve the public in the process and try instead to present their citizens with a "fait accompli" or ready-made decision. This may also be described as an institutional problem within this particular municipality.[24]

Another institutional dilemma is the difference between the current siting process and the one in place 20 years ago. Nowadays the public is far more involved in the process and there are also specific requirements concerning SKB's production of reports and information material. The Government, organisations and public institutions comment on these reports, and it is not until this step has been completed that the process can move forward. This means that the siting process is now a lot more time-consuming and expensive. There has been a shift during the last couple of years whereby the municipalities and their citizens are playing a more active role in the siting process. This has led to a demand for a more transparent system for research and development, critical review, licensing and decision-making with regard to nuclear waste management. The shift in the demands made by the public has contributed to an expansion of SKB and the introduction of new spheres of competence among its staff. At the local level, the confidence of the public in SKB seems to be high and the opposition groups are fairly small.

The principal cornerstone in building confidence consists of ensuring that SKB makes all its scientific and technical reports available to the public. Many of the reports are hard for a layperson to understand, although SKB also produces many reports of a less scientific and more popular nature. Not only does SKB provide the public with information, but it also enables the regulatory authorities to obtain a broader overview of the area by providing them with information as well. In addition to its written material, SKB also offers tours and demonstrations of the encapsulation laboratory, the Äspö Hard Rock Laboratory and CLAB.[25]

8.4.3 Public participation

How does public participation work in Sweden? At the national level, people participate in the process by taking part in elections. Individuals are also able to influence politicians through opinion and lobbying groups, but this participation is not as direct as participation by voting at elections. At the regional and municipal levels, citizens are closer to their elected representatives and may have easier access to them. The various opinion groups are sometimes very strong and may have more success in enlisting new members when they work in smaller communities. As we have seen, SKB is mindful of the opinions expressed in the municipalities concerned, and citizens do have a say in most parts of the process, as well as at most levels. On the other hand, this process also requires leadership and the most natural solution is for local politicians to assume such a role. Local opinion has to be analysed with regard to its size and importance. As mentioned earlier, the siting process for nuclear waste has had a positive impact on public participation in the areas concerned. SKB has spent considerable sums on information and dialogue, and has opened special information offices in the municipalities in which feasibility studies are being performed. Citizens can go to these offices to obtain

[24] Olofsson and Vedung. (1998). pp. 160–168.

[25] Answers questionnaire SKB 2001, p. 5–6.

information on nuclear waste and discuss any matters connected with it. Citizens are also invited to take part in study trips and excursions to study different types of rock.

Sweden thus adopts a democratic approach to the way the siting of radioactive waste should be handled. The different players and stakeholders involved in the Swedish siting process are well aware of the considerable demands with regard to democratic procedures imposed by the formal requirements of the Swedish Environmental Code, as well as by the stakeholders themselves in their different dialogue groups. SKB considers it important to have the support of the citizens – without their consent, no repository will be constructed.

8.4.4 Future implications

The Swedish nuclear waste programme has now reached the stage at which an Environmental Impact Assessment will be performed over the next 4–6 years. An Environmental Impact Statement must be attached to the application for siting permits for the deep repository and the encapsulation plant. As mentioned in the introduction, the County Boards will play an important part in this process, as will other players involved in environmental work. The EIA work is conducted at both local and national levels. Large-scale information campaigns will be launched at the local level to disseminate the findings of the EIA process, and there will be various forums for consultation and discussion.

The continued work of the Swedish programme is based on the following cornerstones:

- Existing facilities that are already in operation have to perform well and research and development work must also show healthy progress. This is also one of the prerequisites for ensuring public confidence.
- The siting process must be transparent and based on voluntary participation by municipalities that fulfil the geoscientific, technical and social criteria set up for each stage. An active dialogue between SKB and all parties concerned must be maintained and should focus on producing a comprehensive environmental impact assessment as a basis for decision-making.[26]

8.5 Addendum

In March 2002, the municipal board of Oskarshamn decided to approve site investigations in the municipality. The municipal board of Tierp later decided to withdraw from further investigations.

The outcome of the municipal decisions is that two of the candidate municipalities decided in favour of site investigations. This result fulfils the requirement set up by the Government of at least two investigation sites, and it means that SKB can continue the siting programme with site-specific investigations in two municipalities.

[26] Answer questionnaire SKB 2001, p. 5–7. The Ministry of Economy prior to granting any license, and its conditions are binding if negative. It is independent of the Administration and reports directly to the Parliament. The CSN can propose to the Ministry of Economy that fines or penalties should be imposed in the case of non-fulfilment of the regulations on nuclear safety and radiation protection.

9 Nuclear waste management in Switzerland – The National Cooperative for the Disposal of Radioactive Waste (NAGRA)

9.1 Introduction

Today, Switzerland has five reactors at four sites, representing 40% of the total electricity production with a capacity of 3,200 MWe (2001). According to the Swiss Atomic Act, the producers are responsible for the safe management and disposal of nuclear waste. The federal government is responsible for the low- and intermediate-level waste arising from medicine, industry and research. In 1972, the power plant operators and the federal government set up the waste management organization NAGRA – the National Cooperative for the Disposal of Radioactive Waste – with responsibility for managing all categories of nuclear waste arising in Switzerland. NAGRA is a private cooperative with six members: the federal government, Nordostschweizerische Kraftwerke, BKW FMB Energie AG, Kernkraftwerk Leibstadt AG, Kernkraftwerk Gösgen-Däniken AG and Energie Ouest-Suisse.

The entire process of nuclear waste management is supervised by the Swiss Federal Nuclear Safety Inspectorate (Hauptabteilung für die Sicherheit der Kernanlagen – HSK), as regards technical and scientific aspects, and by the Federal Office of Energy (Bundesamt für Energie – BFE); the latter is part of the Federal Department of the Environment, Transport, Energy and Communication (UVEK).[1]

There are a number of other organizations in Switzerland with responsibility for monitoring nuclear waste management activities, such as the Federal Interagency Working Group on Nuclear Waste Management (AGNEB), the Federal Nuclear Safety Commission (KSA) and the Federal Commission on Nuclear Waste Management (KNE). KSA and HSK set guidelines for nuclear safety issues and for disposal facilities. The Federal Office of Energy is responsible for the preparation and implementation of legislation relating to nuclear energy. The Radiation Protection Division of the Federal Office of Public Health (BAG) is responsible for collecting all radioactive wastes arising from the medical, industrial and research sectors and the section for radiation monitoring at BAG operates laboratories and produces data. The commission for radiation monitoring of the Federal Department of the Interior is responsible for monitoring radioactivity in Switzerland.[2]

All Swiss nuclear activities are regulated by the Atomic Act. It covers the operation of the nuclear power plants, licensing of future nuclear plants, the overall waste management concept and the licensing procedure for waste management facilities. Switzerland is also

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[1] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 1.

[2] Hugi M, Fritschi M, Nold A, Zuidima P. Monitoring. Current Status of the Swiss Programme. Paper for the 5th International Workshop on Design and Construction of Final Repositories. 1999.

involved in many forms of international cooperation and has recently ratified the IAEA treaty "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management".[3]

A new law concerning nuclear issues in Switzerland is currently in preparation and will probably enter into force in 2003.[4]

9.2 Technical aspects

9.2.1 Present management methods

Assuming a forty-year lifetime for the NPPs, Switzerland will have approximately 3,100 tonnes of spent fuel, generated by the 5 nuclear plants. The utilities (power plant owners) have set up contracts with Cogéma (France) and BNFL (UK) for reprocessing of approximately 1200 tonnes of spent fuel. Reprocessed waste will be sent back to Switzerland in conditioned form. The returned waste consists of vitrified high-level waste, cemented and bituminized intermediate-level waste and cemented low-level residues.[5]

Storage and conditioning

In the early days, Switzerland participated, together with other European countries, on 12 different occasions between 1969 and 1982 in dumping campaigns for solidified low- and intermediate-level waste in the deep Atlantic (Switzerland 5,300 metric tonnes). The campaigns were supervised by the Nuclear Energy Agency (NEA) of the OECD. Today, while awaiting a solution, the waste is held at the nuclear plant sites, each of which has an interim storage facility and facilities for treating its own low- and intermediate-level waste. In addition, centralized interim storage capacity is now available at the ZWILAG facility (Zwischenlager AG Würenlingen) – which will start operation in 2001 – for all categories of radioactive waste from the nuclear power plants. For technical reasons (cooling), the high-level waste (vitrified waste and spent fuel) has to be stored for around 40 years. Waste that can be incinerated is currently sent to the Paul Scherrer Institute in Würenlingen. Incineration will be taken over by the ZWILAG plasma oven, which is expected to start routine operation in the year 2003.

Wastes from medicine, industry and research are stored at the Federal Interim Storage Facility at the Paul Scherrer Institute and will make up around 20% of the total volume of low- and intermediate-level waste (less than 100,000 m^3).

The Swiss disposal concept developed by NAGRA foresees two repositories: one for low- and intermediate-level waste in a cavern system constructed in a mountain-side and one for high-level and long-lived intermediate-level (transuranic) waste and spent fuel in a deep geological formation. In the latter case, a multinational disposal option is also being kept open.

3 *Switzerland: Progress in the Field of Nuclear Waste Management*. NAGRA. May 12, 1999.

4 *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 1.

5 Ibid., p. 1.

Waste disposal projects

Low- and intermediate-level waste
NAGRA began as early as 1978 to evaluate sites for a low- and intermediate-level waste repository and the initial 100 potential sites were gradually narrowed down to four. Field investigation programs were performed for each of these four sites and, based on the results, the Wellenberg site (marl formation) in the community of Wolfenschiessen (Canton of Nidwalden) in the central part of Switzerland was selected in 1993. GNW – the Genossenschaft für nukleare Entsorgung Wellenberg – was founded in 1994 and is responsible for the construction and operation of the repository. The Wellenberg site is considered to be geologically suitable but, in 1995, the outcome of a cantonal referendum on the construction of a repository was negative (48% in favor), leading to a politically blocked situation. Following this decision the Swiss government together with the cantonal government started a review process with the different stakeholders (see section 9.4.3). As a consequence it was decided to adapt the disposal concept including a phase of control and reversibility and to choose a stepwise approach.

High-level and long-lived intermediate-level waste
Concerning high-level and long-lived intermediate-level waste, a site has not yet been selected, but in 1994 NAGRA applied for federal licenses for performing further field work in two investigation areas, one for crystalline rock and one for Opalinus Clay. The next step in the process is to demonstrate the feasibility and safety of a potential national repository, while leaving a multinational solution open.[6]

Crystalline basement option
Extensive field investigations started in the early 80s and provided the geological basis for the so-called "Project Gewähr" in 1985. The regional field investigations are complemented by research work carried out in Nagra's rock laboratory at Grimsel. The main regional field work, including 2D seismic surveys and boreholes, was completed in 1989 and the reports on the investigations were completed in 1994. The reports contain a comprehensive geological synthesis, a safety assessment study, an overview and a summary report. These reports are currently under review by the safety authorities and a corresponding report is expected for 2002. In 1998, field work in the crystalline investigation area came to an end, with a preferred site for an possible later continuation being identified. In a crystalline formation, a repository would be located at a depth of approximately 1,000 meters.[7]

Opalinus Clay
Regional investigations performed in the early 90s in the sedimentary layers in Northern Switzerland showed that the Opalinus Clay formation was potentially well-suited for hosting a repository for high-level waste. After a systematic regional selection process, the region of the Zürcher Weinland (Canton of Zürich) was identified as being of first

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[6] Fritschi M, Kowalski E, Zuidema P. *Developments in the Swiss radioactive waste disposal programme.* WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[7] http://www.skb.se/omskb/lander/schweiz.htm 20000221. *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 2.

priority for further investigations. A 3D seismic survey covering an area of about 50 km^2 was carried out and a deep borehole drilled in Benken in the region Zürcher Weinland, both with promising results. Important complementary work is carried out in the international Mont Terri Rock Laboratory located at a depth of 300 meters in an Opalinus Clay formation.[8]

In the 3D seismic survey in 1996/97, a massive amount of data was collected when 9,000 shotpoints were recorded over 50 km^2. The local landowners had to give permission to allow the survey to be carried out and, through an open and transparent information campaign, permission was obtained for 98% of the land plots.[9] In 1997 and 1998 the seismic data were evaluated.

The borehole at the Benken site was finalized in spring 1999. The Opalinus Clay layer was encountered at a depth of 540 to 652 meters and showed a very low hydraulic conductivity. Additional sedimentary layers with low permeability were found 100 meters above and below the Opalinus Clay.

In the investigation area, the sediments are almost horizontally bedded. The very low permeability Opalinus Clay layer in the area was found to be 100–120 meters thick at a depth of around 400–900 meters. The region has not suffered any significant tectonic movement or disruption of the Opalinus Clay since its deposition 180 million years ago. Results of rock mechanics measurements indicate that construction of a repository should be possible without too much difficulty. The investigations showed that the Opalinus Clay in the area may be well suited for the construction of a high-level waste repository.[10]

Next step in the process

Based on the investigations of both the crystalline basement and the Opalinus Clay, the next step in realizing a repository for high-level waste is to demonstrate the feasibility of constructing such a facility in Switzerland; the relevant project is called "Entsorgungsnachweis".[11]

This project will concentrate on the Opalinus Clay option. However, this does not mean that the crystalline rock alternative has been abandoned. The corresponding reports will be submitted to the authorities by the end of 2002. The review is expected to take around 3 years.

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[8] Fritschi, M, Kowalski, E. & Zuidema, P. *Developments in the Swiss radioactive waste disposal programme*. WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona. *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 3.

[9] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 3.

[10] Fritschi, M, Kowalski, E. & Zuidema, P. *Developments in the Swiss radioactive waste disposal programme*. WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[11] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 4.

Multinational solutions

Apart from the research into the Opalinus Clay and the crystalline basement, the option of a multinational project for disposal of high-level waste is being kept open. This has been a publicly accepted part of the management process since the 80s and is supported today by the government and the ministry in charge.

Parallel to further work towards a national solution following the "Entsorgungsnachweis" project, an evaluation will be made of international options. Today, there are three options for implementation: multinational repository, national repository in Opalinus Clay or in crystalline.[12] NAGRA has the task of providing the necessary information for a political decision, which could be made around 2020.[13]

9.2.2 Research and development

Besides research and development work on site selection and site characterization, additional research is being performed in two underground laboratories, at Grimsel (crystalline rock) and at Mont Terri (Opalinus Clay). Research programs are also carried out at the Paul Scherrer Institute, universities and other institutions. NAGRA places great emphasis on broad international cooperation in the field of research and development.

9.2.3 The siting process

As mentioned earlier, the evaluation regarding sites for L/ILW started in 1978 and the initial 100 sites were narrowed down to three different host rocks: anhydrite, marl and gneiss. Through an evaluation of the huge database, the Wellenberg site, in the community of Wolfenschiessen, was selected in 1993 as the most suitable site for final disposal of low- and intermediate-level waste. A political commission, with representatives from all four siting cantons, ensured that the selection process was performed in a transparent and objective way. The selection process, together with results from scientific research, was evaluated and approved by the federal safety authorities. Another independent group of experts found the selection process to be transparent and objective.[14]

The cantonal referendum of 1995 resulted in a refusal of permission for the construction of a repository in the area. 52% of the cantonal population voted negatively, whereas a majority of the host community was in favor of the project. According to NAGRA, the reason for this could be that the process moved too quickly and neither the politicians nor the population had sufficient time to gain enough knowledge on the issue. It was therefore necessary to slow down the process and to proceed in a more stepwise manner in order to achieve acceptance of the implementation process in the future.

[12] Fritschi M, Kowalski E, Zuidema P. *Developments in the Swiss radioactive waste disposal programme.* WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[13] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 4.

[14] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 4.

The field investigation programs in Northern Switzerland and studies performed at Grimsel and Mont Terri concerning high-level and long-lived intermediate-level waste and spent fuel show that there are different options for geological disposal. The Opalinus Clay and the crystalline basement both show promising signs in terms of construction of a repository. The door is also kept open for an international solution, but this does not mean that Switzerland will not fulfill the responsibility of taking care of its own waste. The reason for even discussing international options is that Switzerland does not produce large volumes of high-level waste. On the other hand, the larger volume of low- and intermediate-level waste has to be handled in Switzerland.[15]

9.2.4 Safety and licensing

According to Swiss law, the final disposal facilities should be constructed in such a way that long-term passive safety is ensured. Official policy states that final repositories have to be constructed such that no supervision is needed after closure and must be designed such that they can be sealed at any time within a few years.

There are three political levels involved in the licensing process. The federal government is responsible for granting all licenses concerning nuclear waste management, the local canton has to approve the plans and grant a concession for the use of the underground and the local community is involved in the construction process. The federal government has to approve site investigations and later issues general licenses, licenses for construction, operation and closure. The federal licensing process has five stages:

- License for preparatory measures.
- General license.
- Nuclear construction license.
- Operating license.
- Closure license[16].

The license for preparatory measures is necessary for drilling exploratory boreholes or excavating shafts and galleries for site investigation. The application has to contain detailed information on schedule, location and scope and has to outline how various other requirements are taken into account; these include protection of persons, third party property and other legally protected interests, as well as requirements relating to nature and habitat conservation and planning. The application is made public and objections can be made within a certain period. Before the federal government decision is taken, the cantons and municipalities concerned are also consulted.

The general license specifies the site, the general layout of the repository and the nature and amount of radioactive waste to be disposed of in the facility. The application has to include a demonstration of confidence in operational and long-term safety. The federal

[15] Fritschi M, Kowalski E, Zuidema P. *Developments in the Swiss radioactive waste disposal programme*. WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[16] Ibid. *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 6.

government makes a decision after hearings with the siting community, the canton and various experts and institutions. In some cantons, the response of the cantonal government to the hearings has to be voted on by the citizens of that particular canton, although the vote is consultative in nature. The application and the conclusions reached by the various involved parties are published and anyone can file written objections within 90 days. These objections are evaluated together with the application by the federal government. A positive decision has to be ratified by the federal parliament. The general license procedure is likely to take several years. [17]

The federal government will thereafter, without further need for ratification, make the decisions concerning construction, operation and closure. The construction and operational licenses are expected to take 2–3 years to obtain and only those who can be considered to be affected by the proposed repository can object. The federal government takes the application, all the reports and the objections into consideration before reaching its decision. Since the closure license is far off in the future, there are presently no legal requirements concerning post-closure monitoring and maintenance. The federal government is assumed to take over the responsibility for the facility after closure.

In addition to the federal licenses, there are a number of local licenses depending on the legislation of the involved canton. In the case of Wellenberg, a mining concession application has to be submitted to the cantonal government and approved in a cantonal referendum. The reason for this is that mining activities are covered by cantonal law. For Wellenberg, this vote is no longer consultative but binding in status. Other permits are needed for railway lines, forest clearing, environmental protection, building permits, planning issues, water protection, highway construction, nature and habitat conservation and for industrial enterprises. These permits can be appealed all the way up to the Federal Court and can result in considerable delays. Such a process can take from two to eight years.[18]

In 1994, GNW was founded and an application for a general license for a repository for low- and intermediate-level waste at the Wellenberg site was submitted to the federal government . A mining concession application was submitted to the cantonal government the same time. As already mentioned, the population of Canton Nidwalden rejected the applications and the process came to a halt.[19]

9.3 Economical aspects

9.3.1 Financial issues

To finance nuclear waste management procedures, a fund covering the cost of decommissioning the NPPs has already been established. A second fund is now being established to cover all other waste management costs subsequent to shutdown of an NPP up to

[17] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 6.

[18] Fritschi, M, Kowalski, E. & Zuidema, P. *Developments in the Swiss radioactive waste disposal programme*. WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[19] Ibid.

the closure of the repositories. Waste management costs of operating NPPs are covered by the operating budget of the relevant company. The waste producers will supply the funds based on the Swiss Atomic Act, which enforces the polluter pays principle (PPP).[20]

After closure of the repository, liability will be transferred to the federal government.[21]

9.4 Socio-political aspects

9.4.1 The role of politicians and public opinion

Because of all the different steps in the process leading to final disposal of nuclear waste, it is of greatest importance to NAGRA to maintain a strong line of communication with the public, especially the population living close to the proposed sites, the politicians and officials involved. The federal government has ongoing plans to increase communication with interested parties. The process involving pubic and politicians should be performed in a stepwise manner. Politicians, organizations, independent experts, opponents, media, safety authorities and individuals should be involved in the process and these actors should be allowed to make comments on reports and plans regarding, for example, research and development, site characterization and the actual waste disposal facility.

As mentioned before, there is a possibility to raise objections to license applications. Different concepts and strategies have been used to create public confidence; these include a forum on energy issues in 1998, an energy dialogue on disposal strategy in 1999, a symposium regarding a report on disposal concepts in 2000, exhibitions, public debates and opinion polls.

The general experience concerning presentation of waste management plans is that there is little public interest as long as no site has been selected and the actors are not directly affected. On the other hand, there has been great interest in the announcement of sites. Many actors react with a Not-In-My-Backyard(NIMBY)attitude. Many have made comments, formed groups and objected to licenses. Positive experience has been reported concerning field work, where people can experience at first hand the responsible way in which investigations are carried out, go on guided tours and attend information meetings. With this approach of direct communication with the public, trust can be enhanced in many cases. In conclusion, information should generally be structured to fit the requirements of different consumers, it should be easy to understand and it should be transparent; it should also cover issues of major concern to the public and it should create further dialogue. Important actors to be reached today are school teachers, students and women.

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[20] Radioactive Waste Management Programme. Switzerland. NAGRA 1996.

[21] *The Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 7.

9.4.2 The socio-political aspects of the Wellenberg siting project

With reference to public opinion, the federal government issued a license to start underground investigations at the Wellenberg site, but the citizens of the canton voted no in 1995 and, since then, the process has been stopped. On the community level, the repository project was accepted in 3 local votes in 1994. Public opinion plays a large role in the waste management process as the public can make a real difference in the decision-making process. It is therefore vital for NAGRA and GNW, the government and the nuclear plant owners to gain public confidence on a broad level.

According to NAGRA, the process described earlier, where the decision on final closure is put in the hands of future generations, and the general stepwise approach, are a way of letting the public play a major role in the decision-making process. The present generation cannot decide what future generation should have the right to do, but it is the duty of the generation currently benefiting from nuclear energy to prepare safe solutions and options. The repository project has to demonstrate sufficient long-term safety, based on a backfilled and sealed facility, before any waste can be emplaced. Future generations then have the choice to finally seal the repository, i.e. trusting the safety barriers, to retrieve the waste or to maintain a supervisory program.

The procedure leading up to the referendum on Wellenberg was seen by many, for example a political commission from the four siting cantons, as both transparent and objective. The results were evaluated and accepted by the safety authorities and by the federal government. Public opinion was, for some reason, more reluctant to endorse the process, perhaps as a result of a strong campaign of fear led by environmental groups and enhanced by the media.[22]

GNW has identified two main reasons for the result in an opinion poll conducted shortly after the Wellenberg referendum of 1995. The first is based on the fact that the license application covered both an exploratory drift and actual construction of the repository. If it had contained an application for an exploratory drift alone, 65.5% of the voters would have voted in favor of granting a concession. The other reason is the strong campaign led by environmental groups, such as Greenpeace. Their opinion was that a stepwise approach must be adopted and that, if the repository were backfilled immediately, the situation would be out of control for future generations. The opinion poll asked if people would vote differently if retrieving the waste was a possibility and 61% said that they would grant a concession in that case; only 25% said no.[23]

NAGRA/GNW does not see the referendum as the final decision and feels confident that it can implement measures to improve public confidence. The result of the referendum had everything to do with that confidence and little to do with actual technological implications or problems. GNW will implement the following measures:

- A stepwise approach towards implementation of the repository as proposed by the EKRA group (see below).
- Reversibility of the process at all stages.

[22] Fritschi, M, Kowalski, E. & Zuidema, P. *Developments in the Swiss radioactive waste disposal programme*. WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

[23] *Nuclear Waste Management in Switzerland – National Cooperative for the Disposal of Radioactive Waste (NAGRA)*, p. 8–9.

- Before any waste is emplaced, the long-term safety of the repository has to be ensured.
- All the necessary precautions should be taken to ensure that waste management does not burden future generations.
- After a long period of reflection, the public should be able to make a decision on closure based on solid knowledge.
- Finally, the emplacement process has to be performed properly in terms of current regulations and in accordance with government guidelines.

9.4.3 Conclusions and future implications

There are no obvious institutional problems as far as the Swiss nuclear management process is concerned. NAGRA and GNW appear to be aware of the importance of public participation and public confidence. Public participation is very important and, according to opinion polls, the majority of the public trusts the technical competence of NAGRA. There is a greater understanding for public concern regarding nuclear waste management than in some other countries, where the opinion of the public has halted the process altogether. There is not much published material on the communication process. NAGRA and GNW appear to adopt a democratic approach to future waste management issues, even though it is important to find a good solution both for the public and in the eyes of the experts.

After the referendum at Wellenberg, the federal government decided to work towards resolution of the standstill, which will meet both democratic and technical requirements. Working groups were put together and reports from these groups were published in 1998. The conclusion was that the advantages of the site considerably outweigh the disadvantages. A working group was established with representatives from national, regional and local levels, as well as representatives from interest groups such as Greenpeace, to find consensus on the waste management concept. No consensus was reached and the government therefore set up a group of experts (EKRA) with the task of comparing different concepts. Their report was published in February 2000 and was very well received by the media and the public.[24]

The report had six main conclusions:

- Geological disposal is the only method which can ensure long-term safety.
- Reversibility is necessary based on social demands.
- The legislation should be adapted to take account of the concept of retrievability.
- Safety considerations should determine when the phase of monitored long-term disposal ends and the facility is finally closed.

[24] Fritschi M, Kowalski E, Zuidema P. *Developments in the Swiss radioactive waste disposal programme.* WM'00 Conference, February 27–March 2, 2000. Tucson, Arizona, USA.

- Wellenberg fulfils the criteria for monitored long-term geological disposal and an exploratory drift should be constructed.
- The Opalinus Clay is suitable for geological disposal.
- A international option cannot replace national solutions.[25]

In late spring 2000, the federal government entered into discussions with the cantonal government, leading to an agreement in June 2000 to continue the project at Wellenberg under the condition that GNW adapts its repository concept to meet the recommendations of EKRA. A cantonal expert group (KFW) was established in July 2000 to supervise the modifications to the project and the subsequent process of implementation. KFW submitted its positive recommendations to the cantonal government at the beginning of 2001. The cantonal government has accepted an application for a mining concession restricted to an exploratory drift for evaluation and granted in September the corresponding concession. This has to be approved by a popular vote, expected in 2002/03.

The aim of Swiss nuclear waste policy today is to find a solution that is acceptable to all major stakeholders involved and to maintain an open and transparent implementation process. This stepwise process will provide future generations with a well-founded solution. It is important to stress:

- that the public should participate very early on in the process.
- that the process should be transparent and the parties should be open for dialogue.
- the important role of the decision-makers and the local authorities.
- that the media has an important role.
- that visits to sites are very helpful information tools.
- that exhibitions could develop the dialogue with the public.

The major steps or challenges still to come are, first, to obtain a positive result in the cantonal referendum regarding the exploratory drift at the Wellenberg site for low-and intermediate-level waste and, second, to create acceptance on all levels in the period 2002–2005 regarding the conclusion of the "Entsorgungsnachweis project " for high-level waste disposal in Northern Switzerland.

[25] Zuidema P, Zurkinden A, Wieland B, 2000. *Status of Radioactive Waste Management in Switzerland – March 2000.* Nea – RWMC Meeting, Paris, 9–10 March 2000, p. 2–3.

10 Nuclear waste management in the United Kingdom – Nirex

10.1 Introduction

The major sources of radioactive waste in the UK arise from the nuclear industry. Nuclear power provides some 28% of the UK's electricity. Much of the industry's waste is associated with national and commercial spent fuel reprocessing operations at Sellafield. Smaller amounts result from the nuclear deterrent capability, and hospitals and other industries.[1]

As in many other countries radioactive waste management is the responsibility of the waste producers. In 1982, with the support of Government, they created Nirex (then the Nuclear Industry Radioactive Waste Executive) which in 1985 was incorporated as United Kingdom Nirex Limited (Nirex). Nirex is responsible for proposing long-term management solutions (including disposal) for intermediate level (ILW) and some low-level waste (particularly long-lived LLW). No organisation has been given responsibility for finding a disposal solution for HLW (note that spent fuel is regarded as a resource). Nirex's shareholders are the nuclear power industry organisations and also the Government Department of Trade and Industry (DTI), as discussed later.[2]

There are a number of other government and non-government organisations involved in radioactive waste management:

- The Department of Environment Transport and the Regions (DETR) is the government department responsible for radioactive waste management policy development.
- The Radioactive Waste Management Advisory Committee (RWMAC) is an independent advisory body responsible for providing advice to government on all aspects of radwaste management, including the work of Nirex.
- The National Radiological Protection Board (NRPB) advises Government on the implementation of ICRP recommendations in the UK.
- The Health and Safety Executive (Nuclear Installations Inspectorate) and the Environment Agency regulate radwaste management issues in the UK.
- The UK is also party to a number EU and broader international agreements.

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[1] Nirex/Department of the Environment Transport and the Regions, *The 1998 United Kingdom Radioactive Waste Inventory (Main Report)* Nirex Report N3/99/01, 1999.

[2] Nirex, *Annual Report and Accounts,* United Kingdom Nirex Limited, 2000.

10.2 Technical aspects

10.2.1 Present management methods

The United Kingdom reprocesses spent fuel from its own reactors and from some other countries. As far as overseas contracts are concerned, these stipulate that waste arising from the process will be returned to the country concerned; in practice this may mean the substitution of lower volumes of high-level waste for intermediate-level waste.[3]

Reprocessing of spent fuel has been in operation in the UK since the 1950's with the original goal being to manufacture plutonium for nuclear weapons production. BNFL's Sellafield facility has up until today reprocessed some 35,000 tons of spent fuel. The operations are carried out in two main plants, the Magnox unit for spent fuel from the older UK reactors (which has to be reprocessed for chemical reasons) and the Thorp plant (thermal oxide reprocessing plant) which takes spent fuel from the later AGR reactors and LWR reactors.

Prior to being dispatched to Sellafield for reprocessing, the spent fuel is stored for a period at the nuclear power stations in water-filled ponds (or in air-cooled storage for Wylfa power station Magnox fuel). This allows it to cool to manageable temperatures. Intermediate-level waste arising from the reprocessing operation is packaged in grouted 500-litre steel drums (in accordance with Nirex specifications) which will be stored at Sellafield prior to disposal (subject to policy) in a deep facility. High level radioactive liquor from the operation is vitrified and cooled for at least 50 years and is again stored on site at Sellafield.

At the time of preparing this report (February, 2001), radioactive waste management policy is to be reviewed by the Government[4], thus the location of a final repository (if this is the method chosen for long-term management) is still to be decided.

In common with a number of other countries, low and short-lived intermediate level waste was dumped in the Atlantic Ocean during the period 1940 to 1982, but due to adverse public reaction, operations ceased. In 1982, the UK became signatories to the London Dumping Convention which prevented further disposal taking place via this route.

There are two repositories for LLW.[5] One is located at the UKAEA Dounreay site in the north-west of Scotland. This deals only with LLW which arises from onsite operations. The national disposal facility for LLW is located in Drigg in Cumbria, which is operated by BNFL; this facility takes LLW from other nuclear sites, hospitals and industry. Up until 1989, waste was loose tipped into ditches which were subsequently covered with topsoil; but since 1989 waste has been disposed of in steel ISO containers emplaced in concrete vaults.

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3 HM Government, Review of Radioactive Waste Management Policy, Command 2919, HMSO London 1995.

4 Department of the Environment, Transport and the Regions, The Government's Response to the House of Lords Select Committee on Science and Technology Report on the Management of Nuclear Waste, 25 October 1999.

5 House of Commons, "Radioactive Waste" – First Report from the Environment Committee, Session 1985–86, HMSO London, 1986.

In 1987, Nirex started a site selection exercise for a deep disposal facility for LLW and all ILW (both short-lived and long-lived). Some 30 per cent of the UK land mass was deemed potentially suitable to host a facility and by 1989 the list of sites had been reduced to 12, from which Sellafield and Dounreay were chosen to be investigated first (as they both had nuclear facilities).[6] Following two years or so of surfaced based investigations at both sites, in 1991 Nirex decided to concentrate its efforts at Sellafield where some 65 per cent of the waste to be disposed of was located at the nearby BNFL reprocessing plant.

In 1994 Nirex applied to the Cumbria County Council (local government) for planning permission to construct the Rock Characterisation Facility (an underground research facility). This permission was refused and so Nirex appealed to the Secretary of State for the Environment against that decision. This triggered a Public Inquiry into the proposal which was held between September 1995 and February 1996. The Inquiry Inspector subsequently recommended that the appeal be dismissed and the Secretary of State announced in March 1997 that he agreed with this recommendation.[7]

Since the March 1997 rejection, Government policy on disposal has been reviewed by the House of Lords Select Committee on Science and Technology which published its findings in March 1999.[8] Inter alia, this proposed that there should be a staged disposal process which could be implemented within some 24 years of starting. The Government subsequently responded to the House of Lords and announced that a consultation exercise would be held which would consider all options on long-term management of wastes, not just disposal.[9]

10.2.2 Research and development

The present Government's commitment to a period of wide-ranging public consultation clearly eliminates any immediate prospect of Nirex providing a service to dispose of waste and suggests that such a service will not be in prospect for many years. It must be recognised, nonetheless, that radioactive wastes exist now and that they will continue to be produced into the foreseeable future. These wastes still need to be recovered, packaged and stored. One of Nirex's roles is to provide expert advice to the waste producers and/or packagers on how this should be undertaken in a way compatible with disposal despite there being no repository available. It is aimed at minimising the possibility that, at some future date, waste might need to be re-packaged to make it suitable for storage, transport, handling and disposal.[10]

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[6] Nirex, Deep Repository Project – Preliminary Environmental and Radiological Assessment and Preliminary Safety Report, Nirex Report 71, 1989.

[7] House of Lords Select Committee on Science and Technology, *Management of Nuclear Waste – 3rd Report: Session 1998–99,* London: The Stationery Office.

[8] S. Barlow and J. Palmer, *The Packaging of Intermediate-Level Waste,* I.Nuc.E. Conference, Containment 2000 Windermere (UK) 2000.

[9] Department of the Environment, Transport and the Regions, The Government's Response to the House of Lords Select Committee on Science and Technology Report on the Management of Nuclear Waste, 25 October 1999.

[10] Nirex, the Proposed Nirex Forward Programme, Nirex Report N/015, 2001.

Nirex uses research and development to support the advice it gives to waste producers, to support repository design work and to underpin safety assessments, especially post-closure safety, which is associated with the most significant uncertainties.[11] The work is conveniently separated into a number of themes:

- waste packaging,
- near field chemistry,
- repository engineering research,
- geosphere development,
- biosphere research, and
- risk communication.

Waste Packaging/Near Field Chemistry

These areas directly support advice given to waste producers by providing data, models and understanding relevant to safety functions of the engineered barriers. These barriers comprise the cement grout that immobilises the waste within the waste container, the waste container itself and the Nirex Reference Vault Backfill (NRVB) another cement-based material that, in the Nirex concept, is used to surround the waste packages within the emplacement vault.[12]

Repository Engineering Development

The design concept includes the monitoring and retrievability of waste after it has been emplaced in a repository and is seen as an important aspect to the widespread acceptability of storage/disposal facilities. This is an area where proposed work will be presented for wide ranging preview via the Nirex Website.

Geosphere Research

Geosphere research considers the migration of radionuclides – in solution, as colloids and in gas – through the geosphere from the repository near field to the biosphere. The research considers a wide range of possible repository host rocks and cover rocks, in response to the needs of post-closure performance.

[11] Nirex, Development of the Nirex Reference Vault Backfill : Report on Current Status in 1994, Nirex Science Report S/97/014.

[12] Nirex, *Transparency Policy*, Nirex 1999.

Site Characterisation

Site characterisation will form an important component of a waste disposal programme. Clearly, though, it is not an activity that can be undertaken while the forward programme is wholly generic. The aim is to maintain a watching brief on the development of relevant technology, in part through participation in projects such as the Äspö Hard Rock Laboratory and the Maqarin natural analogue programme.

Biosphere Research

Biosphere research mainly investigates processes in the surface and near surface environment that might influence radiological doses and risks to man. For instance, over the long time scales relevant to radioactive waste disposal, factors such as climate change, variations in sea level and landform evolution may have a number of important effects, not least on groundwater flow. Superimposed on these are potentially important mechanisms operative on much shorter time scales, such as the bioaccumulation and biogeochemical cycling of radionuclides that may reach the surface by the upward migration of contaminated groundwaters. Such processes could lead, for instance, to the concentration of radionuclides in foodstuffs. Since the biosphere has the capacity to change relatively rapidly compared to the geosphere, biosphere investigations tend not to be site-specific, though there are some important exceptions such as the rise and fall of sea level at a coastal site.

Collaborative Research

Collaboration in international projects is an important part of Nirex's work that enables the Company to learn from, and contribute to, best practice. Such collaboration enables the UK to keep up to date with and to employ the best scientific and technical knowledge. Many collaborative projects are organised by international agencies such as IAEA and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA-OECD). These agencies provide a valuable service by promulgating and promoting best practice, drawing on the expertise of implementers (or would-be implementers), regulators and independent experts from a wide variety of backgrounds.

Participation in international projects is also seen as valuable for confidence building. By comparing individual components of the Nirex concept with the corresponding components of other disposal concepts, it is possible to establish the extent to which the Nirex concept diverges from international experience and precedent. A final attraction of such projects is that they often provide an opportunity for cost sharing with other parties such as the European Commission (via its Research Frameworks for Nuclear Fission).

Risk Communication

A significant international collaboration project is RISCOM II, a three year project funded under the European Commission Fifth Research Framework. The project represents a combined effort by 12 organisations spread across five countries to promote the development of improved processes for public participation and decision making in the area of nuclear waste management. It will use a methodology for integrating scientific, procedural and organisational aspects within a consistent framework for improved transparency. By means of a number of integrated work packages the project will:

- consider how societal values are addressed in performance assessment,
- review dialogue processes and hearing formats,
- examine the implications of organisational structures on transparency in decision making, and
- review the possibilities and limitations of the Internet as a means for communication about social issues in the context of large industrial projects.

10.2.3 Safety and licensing

The principal legislation and guidance governing health and safety in the development, operation and post-closure, of a radioactive waste repository includes:

- Health and Safety at Work, etc. Act, 1974 (HASAW Act).
- Management of Health and Safety at Work Regulations, 1992 (MHSAW).
- Nuclear Installations Act, 1965 (as amended) (NIA).
- Ionising Radiations Regulations, 1999 (IRRs).
- Radioactive Substances Act, 1993 (RSA 93).
- Construction (Design and Management) (CDM) Regulations 1994.
- Environment Agency, Radioactive Substances Act (RSA), 1993 – Disposal Facilities on Land for Low and Intermediate Level Radioactive Wastes: Guidance on Requirements for Authorisation, January 1997.

The HASAW Act places a general duty on employers to ensure, so far as is reasonably practicable, the health, safety and welfare of all their employees; and also to ensure that people not in their employment are, so far as is reasonably practicable, not exposed to risk. Also, the European Union Basic Safety Standard (BSS) Directive requires that all radiological exposures are kept “As Low As Reasonably Achievable” (ALARA), economic and social factors being taken into account. Under the HASAW Act, both general and radiological risks need to be made As Low As Reasonably Practicable (ALARP). In both cases, therefore, the safety provisions are to be optimised.

The MHSAW Regulations, which implement the European Union Health and Safety Framework Directive (89/391/EEC), build on the HASAW Act. The principal aim of the IRRs is to ensure protection of workers from ionising radiations. The NIA requires anyone, other than the Crown, to have a licence granted by the Health and Safety Executive (HSE) before constructing or operating a nuclear installation. The HSE attaches conditions to a site licence to ensure the safe operation of the installation.

On a nuclear licensed site, the RSA relates to the disposal of radioactive material including by liquid and aerial discharge, as well as by burial of solid waste.

Nirex has its own Health and Safety Policy Statement which is mandatory for all the Company's activities, in particular all design and safety assessment. It states that work shall be carried out to a high professional standard by suitably qualified, and experienced staff, good engineering practice shall be used in developing the facility. Similarly, good science and engineering shall be adopted in supporting research and development work.

As part of the design process for Type B transport packages and Industrial Packages that will be employed for transport of waste to a repository, Nirex will produce Design Safety Reports (DSRs) demonstrating compliance with the 1996 edition of the IAEA Regulations for the Safe Transport of Radioactive Material.

A post-closure safety assessment will be prepared that demonstrates to the extent reasonably practicable at the concept stage that the generic repository design(s) will satisfy the performance standards in the Nirex Radiological Protection Policy Manual, as well as all the published regulatory requirements. The requirements for a post-closure assessment include:

- All reasonably practicable measures shall be taken to preclude the build-up of localised concentrations of fissile materials in the disposal facility which could lead to a nuclear criticality.
- The safety case for a disposal facility shall demonstrate that sound engineering principles and practice and good science have been applied.
- Best practicable means are being employed to ensure that radiological detriment to members of the public will be as low as reasonably achievable, economic and social factors being taken into account.
- The effects of varying key design parameters shall be explored in order to identify those features that influence performance and to allow the design of the system to be optimised.
- The assessed risk to a representative member of the potentially exposed group at greatest risk should be consistent with an overall radiological risk target of 10–6 per year.
- If the assessed risk exceeds the target of 10–6 per year, it should be shown that the design is optimised such that any additional measures that might be taken would lead to increases in expenditure (whether in time, trouble or money) disproportionate to the reduction in risk.

10.3 Economical aspects

10.3.1 Financial issues

Nirex is financed by the Nuclear Industry under the "polluter pays" principle. Each potential customer pays an amount of the Nirex budget in proportion to the amount of waste to be disposed of in a facility. The current shareholding and financing of Nirex is shown below:

	Funding (%)	Share (%)
BNFL/Magnox	69.3	74.5
UKAEA	14.8	14.7
British Energy	7.7	10.8
MOD	8.2	0.0

Government (DTI) – 1 Special share

10.4 Socio-political aspects

10.4.1 The role of politicians and public opinion

The politicians have an important role concerning nuclear waste management in the United Kingdom, especially in the role of policy-maker. In a report from the House of Lords in 1999 many different issues are discussed and the importance of making progress is emphasised. It is important to have an open process where many actors can be involved. However it is also important to create clear roles and it has been an institutional problem in the United Kingdom that several actors may be seen to have overlapping or unclear roles. It is also important to create public confidence in the process and the actors. The ownership of the disposal company by the nuclear waste producers could potentially lead to even more problems concerning gaining public confidence. Nirex has set up guidelines[13] for how to reach the citizens:

- The disposal company should have information available for all parties on request.
- The decision-making process needs to be open within Nirex.
- Openness should be the key concept for the entire staff.
- There should be a constructive dialogue with the stakeholders.
- Constant feedback is required in every phase of the process.

There are many stakeholder groups working with this issue[13]. One organisation is Greenpeace which believes that the safest management solution is indefinite surface storage, supervised until technological breakthroughs are made. This is also the opinion of Friends of the Earth, which also believes that the construction of a larger knowledge base for future generations is necessary. It is understood that potentially affected local groups, whilst having similar views, are more focused on the local situation.

Public participation is crucial for acceptance of radioactive waste management, but it is a difficult process. It is recognised that openness and transparency in decision-making are important ways to gain public confidence, and that more measures are needed.

10.4.2 Information and communication

Nirex has an ambition to increase the general knowledge on radioactive waste management by issuing its reports, papers and other documents to reach as many stakeholders as possible. Nirex reports, for instance, will be published with an evaluation form on which the reader can provide feedback to Nirex. There will also be an opportunity to find the material on the Company's Website. Reports are divided into three categories:

- The first category will contain overviews on all different kinds of activities and the target group is the general public.
- The second report category will contain summaries of certain thematic programs and the readers might be of a general scientific background.
- Detailed results from these programs will be presented in the third category and these reports are written for specialists.

Whilst the policy of Nirex is for openness concerning its information on radioactive waste, there might exist material not suitable for public circulation. Material causing harm to national security, the personal privacy, the commercial confidentiality, or to private deliberations may not be released. If a request for information is refused, the person making the request can appeal to an independent Transparency Review Panel.

The process today seems to be focused on a step-wise approach where the public should participate in the process. The experts are still important but the whole society should gain knowledge concerning the issue because it is so important for our safety. Nirex has taken a democratic point of view and finds public participation of vital importance for the process.

[13] UK CEED, *Report of UK CEED Consensus Conference on Radioactive Waste,* May 1999, UK CEED Peterborough (UK), 1999.

10.5 Addendum

Since February 2001, the new Government department responsible for radioactive waste management policy development, the Department of the Environment, Food and Rural Affairs (DEFRA) issued a consultation document "Managing Radioactive Waste Safety: Proposals for developing a policy for managing solid radioactive waste in the UK" on 12 September 2001. The Nirex response to that consultation paper was published on the Nirex website www.nirex.co.uk in March 2002. It proposes that on the basis of lessons learned from the past the key aspects of successful policy development are:

- structure – the organisational arrangements,
- process – the way policy is developed and implemented,
- behaviour – how the different organisations involved interact with each other and with stakeholders,
- all within a framework of transparency.

11 Nuclear waste management in the USA – the Office of Civilian Radioactive Waste Management (OCRWM)

11.1 Introduction

The United States has 103 operating nuclear reactors that produce 100,000 megawatts. Nuclear energy constitutes 20% of the total electricity production, with only fossil fuel facilities producing more energy. The nuclear reactors generate approximately 1,800–2,000 tons of uranium annually. By the end of 2001 the total spent fuel production was around 45,000 tons. By 2046, taking into account the fact that some reactors will have obtained operating license extensions, the total amount of spent nuclear fuel will be around 105,000 tons, with an additional 2,500 tons of defense-origin nuclear fuel and about 20,000 canisters of defense-origin solidified high-level radioactive waste.[1]

The American nuclear waste management process is mandated by the Nuclear Waste Policy Act (NWPA) of 1982. The Act established a framework for siting, characterizing, constructing, operating and monitoring, and closing a permanent geologic repository for disposal of spent nuclear fuel and high-level radioactive waste.

The Office of Civilian Radioactive Waste Management (OCRWM) was established by the Act as the responsible entity within the Department of Energy for the management of all activities associated with the development of the U.S. spent nuclear fuel (SNF) and high-level radioactive waste (HLW) geologic repository program. OCRWM's responsibility under the NWPA was to develop site-specific information and propose facility and transportation system designs that could be used for decisions regarding the selection of sites and the development of one or more geologic repositories. OCRWM must also comply with the applicable regulations of other Federal agencies, including the Nuclear Regulatory Commission (NRC), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), and with State laws and regulations.

The NRC is the independent federal regulatory agency that develops and enforces regulations that protect public and worker health and safety at civilian nuclear facilities. Under the Act, the NRC is responsible for certifying and licensing the components of the waste management system, including the repository, storage facilities, and transportation casks. It is the licensing authority for both the construction and operation phases of the repository.

[1] Information provided by Mr. Jeff Williams. RW/DOE April 26, 2000.

The EPA is the national agency charged with the promulgation and enforcement of environmental standards, including those related to radiation protection. The 1982 Act gave EPA the authority to develop general (non-site specific) standards for the protection from offsite radioactive releases from repositories.

Department of Transportation (DOT) regulations for the transport of highly radioactive materials cover handling of shipping containers, labeling and placarding of containers and transport vehicles, and highway routing.

The NWPA requires that a regulatory framework govern certain statutory decisions related to repository development. The Nuclear Waste Policy Amendments Act of 1987 (NWPAA) and the Energy Policy Act of 1992 amended some of that framework. Since passage of the 1987 NWPAA, OCRWM was directed to focus its investigations on a single potential site at Yucca Mountain in Nevada. The NWPAA also created the Nuclear Waste Technical Review Board (NWTRB), an independent federal agency with members appointed by the President of the United States, to evaluate the technical and scientific validity of DOE's repository development effort.

In the Energy Policy Act of 1992, Congress directed the EPA to issue site-specific public health and safety standards for a repository at Yucca Mountain, consistent with recommendations of the National Academy of Sciences. The NRC was also charged with revising its licensing requirements to be consistent with the EPA site-specific radiation standards. The NRC has recently completed developing its rulemaking in parallel with the development of the EPA standards.

11.2 Technical aspects

11.2.1 Present management methods

High-level nuclear waste

The siting process for high-level nuclear waste disposition started in the 1980's when the Department of Energy in 1983 presented nine different sites in six states suitable for further investigations. In 1985 three sites were selected in a basalt geology in Hanford, Washington, a bedded salt geology in Deaf Smith county, Texas and a tuff geology at the Yucca Mountain, Nevada. The NWPA of 1982 was modified in 1987, with Congress directing DOE to characterize only the Yucca Mountain site as a potential repository. The technical rationale for the selection of Yucca Mountain in 1987 for detailed characterization is that at this site, which is an unsaturated tuff rock formation and has minor groundwater movements, there is little risk of groundwater bringing radionuclides to the surface.[2]

To ensure an appropriate site characterization process for Yucca Mountain, an 8 kilometer long Exploratory Studies Facility (ESF) was completed in April 1997. The main purpose of the ESF is to obtain data required to aid in the evaluation of the suitability of the site for the disposal of SNF and high-level radioactive waste. A Viability Assessment (VA) was initiated by DOE in 1997 as a comprehensive statement of site characterization results, and to give policy makers an assessment of the prospects for geologic disposal at

2 http://www.skb.se/omskb/lander/usa.htm 20000222

Yucca Mountain. The VA was published in 1998, and concluded that future characterization work to reduce the uncertainties about repository system performance should be performed.

In May 2001, the DOE issued the Yucca Mountain Science and Engineering Report, which describes the results of scientific and engineering studies completed to date, including studies of the geologic, hydrologic and geochemical environment; repository and waste package designs, and assessments of long-term repository performance and related uncertainties.

The NWPA requires that a final environmental impact statement (FEIS) accompany a site recommendation to the President. To prepare for this, DOE published a draft environmental impact statement (DEIS) in July 1999 for public comment. The purpose of the DEIS is to consider the possible environmental impacts that could result from the construction, operation and monitoring, and eventual closure of a geologic repository at the Yucca Mountain site. The DOE conducted twenty-four public hearings to provide the public with opportunities to comment on the DOE's evaluation of those potential impacts. The DOE is working to respond to the public comments received – the resulting FEIS will accompany a site recommendation.

In July 2001, the DOE issued for public comment the Yucca Mountain Preliminary Site Suitability Evaluation, which documents the preliminary evaluation of the site based on the DOE's proposed site suitability guidelines. (During the months of September and October, 2001, DOE held thirty-two public hearings in the vicinity of Yucca Mountain to inform residents of a possible site recommendation.) On November 14, 2001, the DOE issued a final rule amending the policies under the NWPA for evaluating the suitability of Yucca Mountain as a potential repository site. The final rule brings the DOE's site suitability guidelines into conformance with corresponding NRC regulations.

The next step would be for the DOE to recommend the site to the President. If the Secretary of Energy recommends the site, and the President recommends the site to Congress, the Governor and legislature of Nevada may submit a notice of disapproval to Congress, which will be required to decide whether to override Nevada's objection. If the site is designated, DOE will submit a license application to the NRC for authorization to construct a repository. If the DOE receives the construction authorization, it would take approximately five years to build the necessary facilities to receive initial shipments of waste. The construction will be made in a step-wise manner and only a small underground facility will initially be built. Subsequent license amendments would authorize repository operation and eventual closure.[3]

Current NRC regulations require that the DOE repository design provide for full retrievability for up to 50 years after the repository is filled with waste, but there is no reason this period can not be extended. Current DOE policy for repository closure reflects design requirements that ensure the capability to close the facility within 50 years of initiation of waste emplacement, or to be kept open for 100 years after initiation of waste emplacement, with reasonable expectation that it could be maintained open for up to 300 years.

[3] Ibid.

The sequence of OCRWM procedures, studies, milestones, and decisions leading to waste repository operation can be summarized as follows:

1. Viability Assessment (completed 1998).
2. Environmental Impact Statement (Draft/1999, Supplement to the Draft/May 2001).
3. Yucca Mountain Science and Engineering Report (May 2001).
4. Yucca Mountain Preliminary Site Suitability Evaluation (July 2001).
5. Technical Update Report (November 2001).
6. Site Suitability Evaluation Report (December 2001).
7. Site Recommendation Decision (2002).
8. License Application (Date to be determined).
9. Construction Authorization (Date to be determined).
10. Begin Initial Operations (2010).
11. Closure and Decommissioning (Date to be determined).

Other repository-destined wastes

In addition to the waste generated at civilian nuclear power plants, there is also a quantity of high-level waste (HLW), which was generated from reprocessing activities at the defense facilities. Most of this material is currently located at the Hanford facilities near Richland, Washington, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. DOE handles about 345,000 cubic meters of high-level radioactive waste.[4] In 1985, under provisions of the NWPA, the President notified DOE that a separate defense waste repository was not necessary. The HLW at these facilities is being vitrified, and will be dispositioned in the civilian geologic repository, along with the spent fuel from nuclear propulsion reactors in US Navy vessels.

There are also low-level byproduct wastes such as clothing, tools, etc. that became contaminated with plutonium and other long-lived transuranic radionuclides during the manufacturing of nuclear weapons. In 1970, the Atomic Energy Commission (predecessor to the DOE and NRC) issued a directive that these low-level radioactive wastes containing transuranics (or TRU waste) could no longer be disposed of in shallow land burial sites. The DOE strategy for managing TRU waste is through disposal in a geologic repository built in salt deposits. To this end, in March 1999 the DOE opened the Waste Isolation Pilot Plant (WIPP) located in salt beds 645 meters underground near Carlsbad, New Mexico.

[4] Information provided by Mr. Jeff Williams, RW/DOE, April 26, 2000.

Low- and intermediate level nuclear waste

Each state is responsible for its own low active civilian waste, but there is today a lack of storage facilities. There are three locations in use in Barnwell, South Carolina, in Hanford Washington, and in Clive, Utah. Seven facilities have already been filled and three sites are at the moment being evaluated.[5]

During the next 20 years, around 700,000 cubic meters of defense generated low-level waste and 100,000 cubic meters of mixed low-level waste will be generated. There are today six DOE sites for low-level waste. Waste producers currently lacking a disposal facility send the waste to one of these low-level waste sites or to commercial facilities. In February 2000, DOE decided to continue using these sites for disposal of waste generated onsite, but allowed other waste producers to send their waste to the Nevada Test Site in Nevada and to the Hanford Site in Washington State.[6] In addition, DOE decided to dispose of its mixed low-level waste at Nevada Test Site and Hanford Site, where facilities have already been constructed but to date used only for on-site generated waste.

11.2.2 Research and development

Scientific and engineering investigations at the Yucca Mountain site are currently focused on the remaining key uncertainties associated with the site. The research is concentrated around investigations on: the presence and movement of water through the repository block; the effects of water movement on waste package degradation; and the effects of heat from the decay of radioactive materials inside the waste packages on the site's geologic and hydrologic behavior.

The main task in 1999 and for most of the year 2000, has been and is to gather sufficient data to support the Site Recommendation (SR). The goal today is to obtain 80% qualified data required for the SR, and 100% qualified data by the License Application. Construction in the underground system moved forward significantly in 1999 and the work with the construction of the cross drift alcoves and niches will be finalized in the next few years.[7]

11.2.3 Safety and licensing

The problems associated with the management of radioactive waste have been identified and discussed throughout this report. In the U.S., reports and evaluations are focusing on the importance of regulating the groundwater flow in order to avoid spreading of radionuclides and corrosion of the containers.

[5] http://www.skb.se/omskb/lander/usa.htm 20000222

[6] Information provided by Mr. Jeff Williams, RW/DOE, April 26, 2000.

[7] Information provided by Mr. Jeff Williams, RW/DOE, April 26, 2000.

The state of Nevada has been one of the most critical voices in the debate around the safety of Yucca Mountain as a geologic repository. The facility is seen by the state of Nevada as extremely dangerous and should not even be investigated. (See the public opinion section).[8]

11.3 Economical aspects

11.3.1 Financial issues

The OCRWM Program is funded through appropriations from the Nuclear Waste Fund, which is financed by a 1.0 mil (i.e., 0.1 cent) per kilowatt hour fee imposed on the utilities for electric power generated and sold by nuclear power facilities. The fees constitute as much as around 650 million dollars a year. At the end of 2000, the fund had received a total of around 15.2 billion dollars, including investment earnings, and expended approximately 5.5 billion dollars. Since 1993, Congress has also made direct annual appropriations to the OCRWM Program as payment for the disposal of defense-origin wastes. At the end of 2000 these appropriations to the Defense Waste Disposal Fund have totaled about 1.2 billion dollars.

The total cost of the whole nuclear waste management program through the year 2116 is calculated to be around 44 billion dollars. Of this sum, 29 billion dollars relate to repository development, implementation and closure of the facility.[9]

11.4 Sociopolitical aspects

11.4.1 The role of politicians and public opinion

There are many opinions on nuclear energy as such and on nuclear waste disposition in general, including the state of Nevada, host state of the Yucca Mountain Project.

Other local actors such as the Study Committee are positive towards disposition of nuclear waste in Nevada, mainly because of economic reasons. A large number of jobs could be created and there could be additional economic benefits from the new kind of tourism that a repository will bring. While Las Vegas has the largest concentration of people in proximity to Yucca Mountain, other populations, although much smaller and rural, are closer and potentially more vulnerable to the risks posed by the repository. Rural communities like these are often faced with a difficult dilemma. On the one hand, they welcome the employment and economic benefits that come with growth, but on the other hand, they are reluctant to accept hazardous and other noxious facilities.

8 http://www.skb.se/omskb/lander/usa.htm 20000222

9 Ibid.

Representatives from the Nuclear Energy Institute also have a positive attitude towards the problems of nuclear waste disposition. They believe that it is the most environmentally friendly form of energy today and that the management of plants and other facilities is completely safe.[10]

On the other hand, the state of Nevada is not supportive of the Yucca Mountain project and the main issue is the right of a state to determine its own economic and environmental future. According to the state of Nevada many studies have shown that the Yucca Mountain site is not safe for nuclear waste disposal,

- due to the prospective radioactive leakage,
- due to geological and hydrological intensity,
- there are problems of earthquakes, volcanoes and hydrothermal activities in the area,

These are the opinions of the entire Nevada congressional delegation as well as the opinion of the Governor. Many organizations support this view such as medical associations and the Nevada legislature.[11]

Measures are taken by OCRWM to inform the citizens of the nuclear waste management program and to gather as many opinions as possible. The Yucca Mountain communication staff, in an effort to involve the public, has a formalized process for public participation in decision-making related to the Yucca Mountain site. This formal public participation plan was developed to fulfill the requirements of the NWPAA; the National Environmental Policy Act (NEPA) of 1969, as amended; the Council of Environmental Quality Regulations (40 CFR 1500); and the DOE NEPA implementing regulations (10 CFR 1021). These plans also consider the requirements of the Executive Order entitled “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.” The organization has prepared the “Draft Yucca Mountain Environmental Impact Statement (EIS)” concerning the disposition of spent nuclear fuel and high-level waste. It is therefore of demonstrable importance for the OCRWM to receive as many views as possible on the waste management process.

According to Section 1168 of the Nuclear Waste Policy Act, the local government in the state of Nevada and in nine counties have the right to an oversight over the repository. They are called Affected Units of Government (AUG). They may review the process at Yucca Mountain and build an opinion on safety issues, the economy and social impacts. They are also granted financial means for the reviewing process.[12] The AUG review DOE documents, attend meetings as appropriate, and conduct independent oversight programs on the YMP. The State of Nevada received oversight funds from 1983 through 1995. County oversight funds began being paid to a limited number of counties in 1989 and were later extended to all counties.

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[10] http://www.nei.org/story/high_level_main.html 19991215

[11] http://www.state.nv.us/nucwaste/yucca/state01.htm 20000223

[12] Ibid.

Due to the broad range of scientific disciplines involved in the data collection and interpretation, as well as the controversial nature of the issues such as seismology and volcanology, the YMP used an expert judgement process to define the range of data-supported interpretations that form the input to the hazard assessment. While the primary focus of these workshops was interaction among experts and facilitation teams, Project stakeholders and the public were invited as observers. Time was set aside at the end of each day for questions or comments from the observers.

OCRWM has produced information material, such as newsletters, brochures and web page information, in order to reach the stakeholders and the public. A mailing list is also established where interested citizens can get the latest information. The OCRWM has also developed exhibitions and displays as well as specific tours and public meetings.[13]

In addition to those activities listed above, outreach program initiatives include: developing audio visuals, exhibits and displays, pursuing opportunities for public presentations, planning educational activities, conducting public and special site tours, and scheduling periodic public meetings.

Interested members of the public can attend public open house site tours conducted in the Spring and Fall each year. In addition, interested groups may take tours arranged for their organizations or private clubs and civic groups.

The Yucca Mountain Site Characterization Office has science centers located in Las Vegas, Pahrump, and Beatty, Nevada, which provide visual and printed materials to visitors about the Yucca Mountain Project. The mission of the centers is to educate the local communities, national and international visitors as well as technical groups about the various aspects of science that comprise the site characterization process. Primarily focused on the needs of the general public, the science centers are a resource facility.

As part of the on-going efforts to respond to inquiries from the public relating to OCRWM and the Yucca Mountain Project, DOE maintains an OCRWM Information Center in Las Vegas, Nevada. The center operates a toll free line to operate to respond to questions from members of the public and disseminate information about the Yucca Mountain Project.

Several key messages that are incorporated into DOE communications with stakeholders and the public include:

- Public safety and environmental protection are the primary considerations in determining the suitability of Yucca Mountain as a deep geologic repository.
- The DOE is using sound science and engineering to solve a national problem.
- The DOE is an effective steward of the environment by working toward a solution to this problem now, instead of requiring future generations to find the resources and answers.

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[13] Ibid.

11.5 Addendum

After more than 20 years of scientific and technical investigations of the suitability of the Yucca Mountain site, on February 14, 2002, the Secretary of Energy gave his official recommendation to President Bush for approval of the site for the developement of a nuclear waste repository. On February 15, the President notified the U.S. Congress that he considers Yucca Mountain qualified for a construcion permit application, taking the next in a series of steps required for approving the site as a nuclear materials repository. In the course of making his decision, the President listened to the Governor of the State of Nevada, the State's Senators, and representatives of the people of Nevada and gave careful consideration to their views. He also consulted extensively with his science and environmental advisors to ensure that they concurred with the science, safety and environmental conclusions of the Secretary of Energy's recommendation.

Following the President's notification to the Congress, pursuant to the Nuclear Waste Policy Act of 1998 (NWPA), the State of Nevada on April 8, exercised a disapproval of the President's recommendation and is now before the U.S. Congress (House of Representatives and Senate) for disposition.

On May 8, the U.S. House of Representatives voted to override the Notice of Disapproval issued by the Governor of Nevada. The approval in the House of Representatives completes half the process for overriding Nevada's veto. The next and final step is a vote in the U.S. Senate. Deliberations in the Senate will begin the week of May 13, with a vote expected later this summer. A simple majority vote of approval in the Senate is required to override the State of Nevada's veto and allow the Yucca Mountain Project to proceed with license application.

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