Preface

Since the Swedish National Council for Nuclear Waste (KASAM) was established in 1985, KASAM has regularly published reports of its independent review of the state-of-the-art in the nuclear waste area. According to the terms of reference for KASAM, decided by the Government in 1992 (Dir. 1992:72), such a review must be submitted once every three years.

KASAM herewith submits its report, *Nuclear Waste. State-of-the-art Report 2004*, to the Government.

The report is the eighth in this series. The first four reports have been published in 1986 (ISBN 91-38-09767-2), in 1987 (ISBN 91-38-009938-1), in 1989 (ISBN 91-38-12264-2) and in 1992 (ISBN 91-38-12749-0). The following three reports were published in the Swedish official government report (SOU) series (SOU 1995:50, SOU 1998:68 and SOU 2001:35). English translations of the 1998 and 2001 reports were also published in the SOU-series.

None of KASAM's state-of-the-art reports can provide an entirely comprehensive view of the state-of-the-art in the nuclear waste area. This is not KASAM's aim. Instead, each report deals with current issues in the debate at the time of publication and for which there may be a need to present an accurate and accessible overview. The choice of subject areas covered is also, to some extent, affected by the competence profiles of KASAM's members. A detailed description of the structure of this state-of-the-art report is provided in an introduction.

A long-term, sustainable solution to issues concerning the disposal of spent nuclear fuel and other long-lived radioactive waste as well as the decommissioning of nuclear power plants requires co-operation between three main actors: the reactor licensees, the Government and the population of one or more municipalities where a repository or an encapsulation plant will be built. KASAM hopes that this state-of-the-art report will be studied also outside the Government offices and experts in the field, thereby facilitating the necessary dialogue between the nuclear industry, the government authorities, the municipalities, the general public and the organisations concerned.

Stockholm, June 2004

Kristina Glimelius
Chairperson, KASAM

KASAM has the following members (June 2004)

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All of KASAM's members, apart from Inga-Britt Lindblad who was appointed after the report had been finalised, contributed to the drafting of this state-of-the-art report. The following were responsible for drafting the different chapters:

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Introduction

Nuclear Power and Energy Policy

Several examples of technical projects that have been the subject of debate and discussion, not only among politicians but also among the general public, can be found during the Post-war period. The building of the Öresund Bridge, linking Sweden and Denmark, was preceded by an extensive environmental debate. The construction of railways, cell phone masts, windpower farms and genetic engineering have all been questioned by the public and by politicians. However, none of these discussions are of quite the same magnitude as the debate that nuclear power and nuclear waste has generated, starting in the early 1970's, in Sweden and abroad.

The referendum on nuclear power, which was conducted in March 1980, resulted in a majority of the Swedish parliament setting a deadline for the complete phase-out of nuclear power in 2010.

The reactor accident in Chernobyl, former Soviet Union in 1986 brought the risks associated with nuclear power into focus. In spite of this, the Swedish phase-out decision was modified as early as by 1991 – partly in order to achieve the objective of not allowing an increase of carbon dioxide emissions from fossil fuels beyond the 1988 level. In the energy policy guidelines that the parliament decided on in 1997 and 2002, a specific year was no longer given for the phase-out of nuclear power.

One reactor at Barsebäck nuclear power plant was closed down in 1999. Since autumn 2002, negotiations have been underway between the Government and the electricity producers with the aim of preparing an agreement to create favourable conditions for the commercially viable continued operation and successive phase-out of nuclear power. [1]

Conflicts between different perceptions of nuclear power and nuclear waste decreased in the 1990's and, today, there are other important environmental issues that have also come to the fore. In spite of this, the disposal of spent nuclear waste entails an important decision, at national level, on a technically and morally complex large-scale project.

Nuclear waste is the focus of this report as are the scientific conditions, consultations and decision-making processes that exist in order to find a safe disposal solution for the 200 to 300 tonnes of high-level, long-lived waste which are generated every year from the operation of Swedish nuclear power plants. Altogether, about 4,000 tonnes of such waste are in storage at the Central Interim Storage Facility for Spent Nuclear Fuel (CLAB) in Simpevarp, Oskarshamn municipality.

Nuclear Waste – a State-of-the-art Report

Most Swedes would probably recognize the claim that the nuclear waste issue is not exclusively a technical and economic issue. The nuclear waste issue has other concerns besides bedrock types, groundwater flow, mechanical strength and welding methods. Nuclear energy and nuclear waste issues also relate to moral and ethical values and priorities: Who is responsible for the safe disposal of high-level waste? Should we wait for new and improved technology to become available in the future? If not, which municipality and landowner should give up a site for the repository? What does our responsibility towards future generations require us to do?

[1] The negotiations were interrupted in autumn 2004 without a result. The second reactor at Barsebäck nuclear power plant was closed down in May 2005.

At the stage that we have reached on the nuclear waste issue today, we need broad and deep knowledge of the ways in which the selection of different technical solutions will affect society in the future. To choose between different alternatives and to prioritise always means that we must balance ethical, economic, technical, environmental, health-related and social conditions against each other. This is never easy, especially since knowledge of and values relating to these issues are not static. However, KASAM hopes that this overview can provide a good basis for reporting facts and presenting perspectives as well as for encouraging the public and decision-makers to ask relevant questions.

The report investigates some of the issues that are important for the continued consulting and decision-making process prior to the construction of a repository for spent nuclear fuel and other long-lived, radioactive waste. In this report, the nuclear waste issue is presented from a broad, scientific perspective, where findings from research in the humanities, social sciences as well as technology and science are presented in an accessible manner.

Nuclear Waste. State-of-the-Art Report 2004 contains nine independent chapters. These chapters have been grouped into three sections and each section deals with specific themes.

Section I *The Nuclear Waste Issue in Sweden and Abroad* deals with how the nuclear waste issue has so far been handled and organised. This section starts with an international overview, *Nuclear Waste Management in Some Countries.* This overview provides an indication of how, in each country, solutions are sought that are considered suitable in the country in question. The overview also clearly shows that the responsibility for nuclear waste, to a large extent, covers both private and public actors, even if this is to a varying degree. An in-depth presentation of the Swedish process is provided in the chapter – *The Municipalities – One of the Main Actors in the Nuclear Waste Issue*. Given the international overview, this chapter shows that the Swedish consultation process is based on strong and conscious efforts to achieve local participation and mutual understanding.

Section II *Handling the Risks of Nuclear Waste. An Overview of Methods, Problems and Possibilities* gives an overview of knowledge to calculate and handle different risks as well as of methods to obtain data for assessments relating to the storage of nuclear waste from a scientific perspective. This section starts off with two presentations of geoscientific methods used to calculate bedrock stability and permeability: *Some Geological, Geodynamic and Geophysical Investigation Methods Used for the Siting of a Repository in Hard Rock* and *Some Hydrogeological Methods for Determining Groundwater Recharge and Groundwater Flow*. In the next chapter, *Analysis and Fractionation of Isotopes*, the possibility is discussed of taking into account the properties of different isotopes in order to determine transport rates of different radioactive substances from a repository for spent nuclear fuel or other radioactive waste so as to obtain a basis for risk assessments and a safety assessment. The next chapter, *Copper Canisters – Fabrication, Sealing, Durability*, provides an overview of the methods used for the manufacturing and control of copper canisters which are one of the engineered barriers surrounding the waste in connection with geological disposal in accordance with the KBS-3 method. The final chapter, *An Attempt at a Comparable Classification of Radioactive Waste and Hazardous Chemical Waste*, discusses the possibility of comparing the risks of radioactive waste with the risks of hazardous chemical waste.

Section III *The Nuclear Waste Issue and the Future* is the final section. The question of the long-term responsibility that we have for the various choices that we make regarding the handling of nuclear waste is problematised. The first chapter, *Partitioning and Transmutation – An Alternative to Final Disposal. An Issue in Focus*, examines the question of partitioning and transmutation from a scenario perspective and investigates the extent to which this method is realistic. The final chapter, *Nuclear Waste, Ethics and Responsibility for Future Generations*, focuses on the question of our responsibility for future generations with respect to the choices that we make regarding the nuclear waste issue. The significance of various ethical approaches for the decisions that we make – not only with respect to this issue – is discussed more in depth. In this way, we, the members of KASAM, hope to facilitate a public discussion which is necessary as a basis for decisions that will have to be made in the next few years.

Section I The Nuclear Waste Issue in Sweden and Abroad

1 Nuclear Waste Management in Some Countries

1.1 Introduction

This chapter provides an overview of nuclear waste management in some countries. The overview is a shortened and updated version of the corresponding account presented in the previous Nuclear Waste State-of-the-Art Report (2001). Although the focus is on high-level waste and spent nuclear fuel (see *Table 1*), certain information on low-level waste (LLW) and short-lived intermediate-level waste (ILW) has also been included since a number of questions concerning repository siting etc. in many respects concern all types of radioactive waste. In addition, an overview of current activities concerning waste management within some of the major international organisations (IAEA, OECD/NEA, EU) is presented.

This account deals with countries with very different nuclear policies and many different waste management programmes. A number of European countries as well as Canada, Japan and the USA are presented here. Some of the countries (for example, Finland, France and Japan) have a growing nuclear power programme while most other countries have a more static or diminishing programme, as is the case in Sweden.

A brief evaluation shows that Finland, Sweden and the USA have come the furthest with respect to realising the final disposal of spent nuclear fuel, both with respect to method selection and the site selection process. France has a highly advanced and extensive research and development programme (R&D programme) for methods for the treatment, storage and disposal of radioactive waste which will be reported in 2006. Germany, Japan, Canada and Great Britain all have advanced research programmes although much remains to be done before concrete solutions can be presented.

Table 1.1. Quantities of high-level waste (HLW) and spent nuclear fuel for disposal

Country	*Number of nuclear reactors*		*Planned Operational time (years)*	*Spent nuclear fuel (t HM if no other information given)*	*HLW (according to specification below)*	*Remarks*
	*	**				
Sweden	11	1	Varying	ca 9 000	0	Calculated total amount for the Swedish programme
Canada	14	8	Varying	3,6 millions of assemblies (CANDU) 76 000 assemblies (other)	0	Calculated amount until year 2035
Finland	4		40–60	2 600 to 4 000	0	Calculated total amount for the Finnish programme
France	59	11		15 000	3 500 m^3	Calculated total amount from existing reactors and other nuclear facilities
Germany	19	18	Varying	9 000	22 000 m^3	Calculated total amount for the German programme. The amount includes encapsulation material
Japan	51	1		0	ca 40 000 canisters	Corresponding to accumulated amount until year 2020 (1 canister = ca 1,35 t HM)
Russia	30		30–40	n.i.	n.i.	
Switzerland	5		40 or more	ca 1 800	ca 1 000 m^3	Calculated amount for the operation time for the reactors
Great Brittain	35	10	30 to 46		ca 1 890 m^3	Calculated until year 2013
USA	103	15	Up to 40	83 500 (from commercial reactors), 21 000 (from other reactors)	640 t HM (commercial) 5 000 waste packages à 4 to 5 canisters (military)	Calculated amount from existing reactors. 105 000 t HM is expected from these including prolonged time for operation

* Reactors in operation
** Shut-down reactors
n.i. = no information
t HM = ton Heavy Metal, in this compilation equal to *tons of uranium*
CANDU = Canada Deuterium Uranium (reactor)

In many other countries, radioactive waste research is underway. Questions concerning the long-term financing of nuclear waste disposal and reactor decommissioning are also increasingly attracting international interest.

The contents of this chapter are largely based on National Profiles, which are a set of information sheets prepared by Phil Richardsson, EnvirosQuantiSci (UK) for a number of countries in the world and which are regularly updated. Additional information has been obtained from the OECD/NEA, IAEA and EU.

The information provided in *Table 1.1* is taken from IAEA-TECHDOC-1323 Institutional Framework for Long-term Management of High Level Waste and/or Spent Nuclear Fuel (December 2002).

1.2 Canada

1.2.1 Nuclear Power Programme

In early 2004, there were 22 licensed nuclear power reactors in Canada. Of these, 14 are currently in operation. One is located in Quebec, one in New Brunswick and the rest are in Ontario. The reactors are owned and operated by the federal energy utilities, Hydro Quebec, New Brunswick Power and Ontario Power Generation Inc. (OPG). The other eight reactors have been shut down.

1.2.2 Relevant Institutions

Nuclear power in Canada is regulated by the Canadian Nuclear Safety Commission (CNSC). The CNSC is a federal authority which licenses sites for radioactive waste storage and disposal and promulgates guidelines for disposal. Atomic Energy of Canada Ltd (AECL) is a government-owned company charged with the task of developing and promoting the use of nuclear power and of selling reactors abroad.

The immediate responsibility for the management of nuclear waste in Canada rests with the waste producers. New legislation for the final management of spent nuclear fuel entered into force in 2002. Under the Nuclear Fuel Waste Act (NFWA), the Nuclear Waste Management Organisation (NWMO) was formed. The NWMO is owned by the nuclear industry and will act independently of AECL and the federal government.

1.2.3 Nuclear Waste Management

LLW and Short-lived ILW

In Canada, a distinction is made between current arisings and historic waste. Historic waste originates from past uranium milling activities. Options studies for a disposal site for current LLW are being performed by OPG and operation is planned to begin by 2015.

In order to identify an acceptable disposal site for historic waste, the Co-operative Siting Process was established in 1986. A Task Force undertook extensive public consultation and invited interested communities to volunteer for site selection. Two municipalities were finally identified in 1994, although one withdrew shortly after. Following a positive referendum vote in 1995, the remaining municipality signed an Agreement in Principle to allow work to continue, but this lapsed by the end of 1996 when the federal government refused to accept the terms of the Agreement. However, there are now two possible sites which were announced early in 2004 (Port Hope Area Initiative 2004).

Spent Nuclear Fuel and/or HLW

Canada does not intend to reprocess any of its spent nuclear fuel although a certain quantity of high-level waste will be generated from the reprocessing of fuel from research projects. Over the past 25 years, commercial spent nuclear fuel has been stored at nuclear power plants.

In the mid-1990's, AECL presented a concept for the disposal of spent nuclear fuel. The concept entails placing spent nuclear fuel at a depth of 500 to 1,000 metres in the crystalline bedrock of the Canadian Shield. The repository was originally planned to be in service by 2025 and to take some 40 years to fill, before being sealed and abandoned. However, no siting-related work was permitted before concept approval. The disposal concept was reviewed in a series of public hearings before a federally nominated panel of experts in 1996 to 1997. In March 1998, the panel recommended that although the technical aspects of the concept appeared to be satisfactory, there was insufficient public acceptance to allow siting to begin.

Among its recommendations, the panel stated that the government needed to take measures to achieve a broad public support. Furthermore, in the view of the panel, AECL should not be responsible for the management of the spent nuclear fuel. Instead, a new federal unit should be set up for this task. The unit should be solely financed by the waste producers and the board of directors should include representatives from all key stakeholders. Furthermore, a strong and active advisory council should be formed, with representatives from all interested parties. Finally, the panel concluded that the search for a specific repository site should not proceed until the measures recommended above had been implemented and a broader public acceptance of the proposed management concept had been achieved.

The Ministry of Natural Resources (NRCan) issued its response statement to the panel's report in December 1998. Whilst agreeing to the establishment of a semi-independent agency (namely, an agency formally attached to a government department but with great freedom to act autonomously on most matters) to carry out future work on waste management and disposal, NRCan rejected the suggestion that siting work for a repository should be postponed. It also gave overall responsibility for establishing the new agency to the waste producers and owners, who will have total control over the makeup of the board of directors.

After a period of uncertainty, the Canadian parliament made a decision in 2002 which was based on the previous inquiry proposals. Under the Nuclear Fuel Waste Act (NFWA), the Nuclear Waste Management Organisation (NWMO) was formed. The NWMO is owned by the nuclear industry and it is to act independently from the AECL and the federal government. The legislation places responsibility with the NWMO to conduct a study within three years and to present a plan for the disposal of spent nuclear fuel to the federal government in 2005. An advisory group has been established to support the NWMO in its work. The results of the NWMO's most recent work have been reported (NWMO 2003). A special waste financing system has been set up.

1.3 Finland

1.3.1 Nuclear Power Programme

There are two commercial nuclear power plant sites in Finland, each currently with two reactors, one at Loviisa near to Helsinki, operated by the largely state-owned Fortum (former IVO), with two Russian-built VVER 440's and one at Olkiluoto, about 100 kilometres north of Åbo. The plant is operated by TVO, which is partly owned by the Finnish industry and the power companies, and has two Swedish-designed boiling water reactors. An application for a "decision in principle" was made to the government concerning a fifth reactor, to be built at one of the two nuclear power plant sites. The application was approved by the Finnish government and by the Finnish parliament in 2002. It is planned to construct the reactor at Olkiluoto by a European consortium under French management.

1.3.2 Relevant Institutions

The two energy utilities are responsible for the safe management of waste and for the necessary research and development as well as for covering the costs of the whole operation. The objectives and schedules of waste management are set out in a government policy from 1983, with the regulatory basis set out in the 1988 Nuclear Energy Act and Ordinance. The Ministry of Trade and Industry (HIM) supervises waste management activities and the R&D work. It also finances research in order to maintain independent expertise. The Finnish Centre for Radiation and Nuclear Safety (STUK) is responsible for the regulation and supervision of the safety of nuclear facilities and review and assessment of waste management plans and activities. Facilities must be licensed by the government. Every year, the HIM decides the fees that the utilities must pay into the government-controlled Nuclear Waste Fund, designed to cover the future costs of waste management.

In the past, the two utilities applied different spent nuclear fuel management strategies. Fuel from Loviisa was shipped back to Russia for storage and reprocessing, whereas at Olkiluoto, the fuel was stored on site in a water pool storage facility. After the collapse of the Soviet Union, the procedure for the fuel from Loviisa changed so that this fuel is now also stored on site in the same way as Olkiluoto. According to an amendment of the Nuclear Energy Act in 1994, no spent nuclear fuel may be exported after 1996. IVO and TVO have formed a joint company, Posiva, which is responsible for all spent nuclear fuel disposal work.

1.3.3 Management of Nuclear Waste

Waste classification in Finland distinguishes between low and intermediate level waste and spent nuclear fuel which is not to be reprocessed.

LLW and Short-lived ILW

Both nuclear utilities have developed rock cavern repositories adjacent to their existing reactor sites, using vertical silos and/or horizontal caverns. These facilities were taken into operation in 1992 and 1998, respectively.

Spent Nuclear Fuel and Long-lived ILW

Following a decision in principle by the Government in 1983, which was formally ratified in 1988 in the Nuclear Energy Act and Ordinance, HIM decided in 1991 that deep disposal would be the chosen method for spent nuclear fuel.

A list of 85 possible repository sites was prepared between 1983 and 1985. After more detailed investigations, three sites were chosen: Olkiluoto (near the nuclear power plant) in Euraåminne municipality, Romuvaara in Kuho municipality and Kivetty in Äänenkoski municipality. According to the proposal in the "TILA-99 Safety Assessment", which was published in 1999, Posiva recommended a repository in accordance with a disposal concept similar to the KBS-3 concept in Sweden. The repository is to be located at a depth of 400 to 700 metres. The exact depth is to be determined by the conditions at the chosen site.

Posiva proposed that the ultimate design of the repository at the chosen site should not be decided until the start of construction. This would make it possible to take the actual geological conditions into consideration in the design and construction work. The cost of the disposal of spent nuclear fuel is estimated at about EUR 850 million (about SEK 7,500 million).

In addition to these sites, Posiva also undertook detailed investigations near the nuclear power plant at Loviisa, on the island of Hästholmen.

In January 1998, Posiva submitted an Environmental Impact Assessment Programme to HIM. The programme was also circulated to Swedish, Estonian and Russian authorities, in accordance with the requirements of the Espoo Convention.

Following a series of public hearings in spring 1998, HIM presented its review of the programme to Posiva in June 1998. HIM required additional work to be carried out to estimate the radiological risk of a "zero alternative" (whereby the proposed facility is not built). Furthermore, HIM required that retrievability should be investigated as well as a number of alternative disposal methods. Posiva published the final Environmental Impact Assessment in May 1999 and then applied to the Government for a decision in principle concerning siting in Olkiluoto.

An international panel was appointed by STUK to review the safety assessment in Posiva's application for a decision in principle. The panel submitted its report in 1999 and, in accordance with this, STUK was recommended to conduct an additional number of review projects after the Government had made its decision in principle. The recommendation included regular reviews (every 3 to 4 years) of Posiva's research and development programme and the results achieved (as is also conducted in Sweden). The recommendation also included a review of Posiva's preliminary safety assessments as well as the application of important parts of the recommendations from independent reviews in order to increase the general public's confidence in the activity.

In January 2000, STUK issued its own report based on the panel's review and this supported Posiva's request to continue with its plans for Olkiluoto. Under the law, permission must be obtained from the municipality for a proponent to construct a repository for spent nuclear fuel. Therefore, a referendum was held in the municipal council in the Euraåminne municipality in January 2000. The outcome was 20 votes for and 7 against a facility there.

All of the review material as well as the Ministry's summary became available to the public in spring 2000.

A decision in principle regarding a repository was made by the Government in December 2000 and the parliament made its decision in spring 2001.

In June 2002, Posiva announced its opinion to construct a tunnel for the first stage of the repository (ONKALO), which includes investigations and development work. The intention is for the investigation phase to continue until 2010 and to then construct the repository part. Deposition of the spent fuel is expected to start in 2020. In 2003, Posiva submitted an application for permission to start the construction of the facility.

In December 2003, Posiva presented a research programme for the disposal of spent nuclear fuel and nuclear waste in Finland. Such a programme will be presented once every three years in the future.

1.4 France

1.4.1 Nuclear Power Programme

At the end of 2003, there were 59 PWR reactors in France and one reprocessing facility in operation on the northern coast of Cap de la Hague. Nuclear power accounts for about 70 % of the electricity generation in France.

1.4.2 Relevant Institutions

Under legislation passed in 1975, a waste producer must arrange for the disposal of the waste, at its own cost, by a body approved by the public authorities. For this purpose, the Government set up a special organisation, the National Agency for Radioactive Waste Management (ANDRA) in 1979, within the Atomic Energy Commission (CEA). ANDRA is responsible for designing, constructing and operating long-term disposal facilities as well as undertaking all necessary studies to this end, and for promoting the application of technical specifications for waste treatment to be carried out by producers prior to storage.

ANDRA is financed by the waste producers, in particular Electricité de France (EdF), the CEA and fuel cycle companies, such as COGEMA which operates the reprocessing plant in la Hague. The activities of these companies are reviewed by the safety authorities which report to the Ministry of Industry and the Ministry of Health and a few other ministries. In 2001, the regulatory function was re-organised, so that safety and radiation protection merged under "Direction Générale de la Sûreté Nucléaire et de la Radioprotection – DGSNR". Furthermore, certain support functions were re-organised by merging the institutions responsible for research and development within the areas of safety and radiation protection, through the formation of a new organisation, "Institut de Radioprotection et de Sûreté Nucléaire – IRSN".

At present, ANDRA is not responsible for managing all of the radioactive waste, especially not the waste originating from reprocessing plants or material from defence-related work. However, in a report from 1999, a member of a parliamentary advisory group recommended that ANDRA should be given such responsibility as quickly as possible.

1.4.3 Nuclear Waste Management

In France, radioactive waste is classified into two categories – short-lived and long-lived – depending on the length of time that the waste poses a hazard. Long-lived waste is also classified as B waste (corresponds to long-lived ILW in other countries) or C waste (corresponds to HLW) and spent nuclear fuel. Most spent nuclear fuel is reprocessed.

LLW and Short-lived ILW (A Waste)

These waste categories are deposited in a near-surface facility in northeastern France.

Spent Nuclear Fuel and/or HLW (B and C Waste)

Originally, the intention was to reprocess all spent nuclear fuel. The low and intermediate-level waste (B waste), high-level vitrified waste and fission product waste (C waste) as well as spent nuclear fuel that is not reprocessed would be deposited in a deep repository after interim storage. However, in 1998, in an unpublished report to the Government, it was maintained that the future strategy had to take into account the fact that as much as one-third of the spent nuclear fuel generated in France would probably not be reprocessed as was previously anticipated. It was also suggested that France would immediately attempt to return to their countries of origin a part of the plutonium which was obtained in connection with the reprocessing of spent nuclear fuel from these countries.

Four areas with different geological conditions, such as clay, granite, slate and salt were selected for investigations and the development of a deep repository. However, all work was stopped at all four sites as a result of intensive public resistance. The Waste Act was supplemented in December 1991 and, under this Act, ANDRA became a public service company reporting to the Ministry of Environment and the Ministry of Industry and was organisationally separated from the CEA. This measure was implemented in order to signal the independence of the organisation and to achieve increased transparency and openness.

Act No. 91-1381 defined the following three main areas, within which ANDRA would conduct research:

- Partitioning and transmutation
- Waste packaging and the effects of long-term surface storage
- Development of at least two underground laboratories in locations with different geologies.

A site should only be selected after local consultation with the participation of the general public. The law states that the identification of a site for an underground laboratory requires a public hearing and government approval. It should not be possible to propose a site for a repository until 15 years after the entry into force of the Act and, even in this case, public review and licensing is required. Furthermore, it is the responsibility of the ministries concerned to keep the parliament continuously informed of progress. It is ANDRA's responsibility to present a final status report in 2005 and a proposal for the siting of a repository in 2006.

A site for a facility – Installation Centrale d'Entreposage (ICE) – for long-term interim storage of spent nuclear fuel has not yet been selected. The facility will probably be of the pool-type design, like the Swedish facility, CLAB.

To follow progress in research within these areas and to report to the parliament, the law stipulates that a CNE (National Evaluation Commission) should be set up. The CNE holds regular hearings on the main topics. ANDRA supplements these hearings with presentations upon request. Reports are submitted to the Government on an annual basis and they are evaluated by the Parliamentary Commission on the Assessment of Scientific and Technological Choices (OPECST). The CNE is also responsible for the organisation and submission of the overall repository project report due in 2005.

CNE consists of 12 people, of which six are qualified experts appointed by the OPECST. At least two of these are from abroad (currently from Sweden and Spain). Two experts are appointed by the Government and four by the French Academy of Sciences.

Through the legislation passed in 1991, a new position was created – a "mediator" – in order to simplify site selection and the development of underground laboratories. The member of parliament, Christian Bataille, was appointed to the position in 1992. Bataille was given the mandate to use up to 60 million francs (about SEK 80 million) per year for support to municipalities which are positive to further investigations. Bataille's task was to consult with selected politicians, with the public and with local environmental organisations. In December 1993, he presented a report, where four areas were identified for further studies, of which three had sedimentary bedrock and one had crystalline bedrock. In 1994, ANDRA announced that a number of sites had been identified as suitable. One of them was adjacent to two of the previously identified areas. Detailed site investigations were started this year and a total of 15 holes were drilled at a depth of up to 1,100 metres at three different sites.

Since the drilling was completed, meetings have been held with public hearings between February and May 1997. In December 1998, the Government gave ANDRA permission to build an underground laboratory in a clay formation under one of the selected sites, the site at Bure in northeastern France. At the same time, two other sites were eliminated for geological reasons, one with marl bedrock near to Marcoule in the department of Gard and one with granite bedrock in Vienne. According to a government decision in August 1999, permission was obtained for the construction and operation at Bure up to 2006. However, the Government also gave ANDRA the task of locating additional candidate sites with granite bedrock before

2002. In spite of the fact that 20 such sites were investigated in Bretagne and the Massif Central, the project was terminated in June 2000, largely due to excessive resistance by the public at all sites.

Excavation of the first shaft at Bure began in early September 2001. Due to an accident in 2002, work was delayed and was later resumed in April 2003. A number of geotechnical, hydrogeological and other boreholes have been drilled and instrumented so as to allow the impact on the rock of the shaft sinking process to be studied. A number of geophysical measurements are to be conducted as the work continues and these will be correlated with measurements conducted in 1999 on the ground surface. A number of investigation niches will be established on different levels as the shaft goes deeper. Some of these will be located in clay at possible repository depth.

1.5 Germany

1.5.1 Nuclear Power Programme

In November 2003, there were 18 nuclear reactors in operation in Germany. None of these were located in the former German Democratic Republic (DDR), after closure of the nuclear power plant in Rheinsburg in 1990 and of the four reactors that were in operation (and a fifth under construction) in Greifswald.

In a coalition agreement in October 1998, the Social Democrats (SPD) and the Green Party agreed on a phase-out of nuclear power in Germany. After lengthy negotiations, an agreement was signed in June 2000 (the June 2000 agreement) between the Government and the power utilities on nuclear policy. According to the agreement, all reactors are to be shut down at the end of their expected lifetimes. Each reactor will be allocated a maximum amount of electricity which can be generated, thus allowing capacity to be added to newer, more efficient reactors, thereby extending their operation and allowing closure of the less efficient reactors. The amount of electric power agreed on roughly corresponds to an operating lifetime of 32 years. No new reprocessing contracts will be allowed and, after July 1st, 2005, all spent fuel will be subjected to direct disposal. Only reprocessing contracts effective up to that time will be honoured. A new Atomic Energy Act was passed in 2002, based on the new policy.

1.5.2 Relevant Institutions

When the Federal Office for Radiation Protection (BfS) was established in 1989, it assumed responsibility for the safe disposal of all types of radioactive waste from the Federal Institute for Science and Technology (PTB). A special company, the German Company for the Construction and Operation of Waste Repositories (DBE) was set up as a “third party” (contractor) to carry out the tasks assigned to it by BfS.

According to the new Atomic Energy Act from 2002, the waste producer is responsible for the interim storage of spent nuclear fuel at each reactor site. Applications for permission to construct such facilities have been submitted. Twelve such facilities are expected to exist by 2005 for use as storage facilities for 40 years. In the case of some of the reactors, other solutions are being planned for the storage of spent nuclear fuel.

According to the new Atomic Energy Act, the federal governments are responsible for all licensing. Previously, the intention was for all spent nuclear fuel to be reprocessed. An amendment was added in 1994 which also allowed direct disposal of spent nuclear fuel. Some utilities have already cancelled reprocessing options after 2000.

1.5.3 Nuclear Waste Management

Since the plan is to dispose of all of the waste, independent of category, in a deep repository, the waste is basically classified into two categories, namely heat-generating and non-heat-generating. According to the agreement between the coalition parties in 1998, it is enough for a single geological repository to deposit all types of radioactive waste. This repository will be located in rock, of a type that has not yet been decided, and at a site that has not yet formally been identified. This will naturally substantially affect the execution of the development programme for a repository.

LLW and ILW (Non-Heat-Generating)

Until recently, non-heat-generating waste (with alpha emitter concentrations up to 4.0 x 10^8 Bq/m^3) were disposed of in the ERAM facility (Endlager für Radioaktive Abfälle Morsleben) at the Bartensleben salt mine. According an order issued in September 1998 by the Superior Administrative Court of the state of Saxony-Anhalt, BfS must immediately stop further radioactive waste disposal in the eastern emplacement field of the Morsleben repository. In November 2001, BfS announced that measures had to be implemented to close the repository in a safe manner.

A licence application for a new deep repository for non-heat-generating low and intermediate-level waste (LLW/ILW) at the abandoned Schacht Konrad iron-ore mine near Salzgitter in Lower Saxony was submitted as long ago as 1982. After the longest Public Inquiry in German history – between September 1992 and March 1993 – the Lower Saxony government (headed at the time by the present Federal Chancellor) continued to refuse to grant a licence for the facility, against the wishes of the Federal Authorities. According to the June 2000 Agreement, the responsible authorities are to conclude the licensing procedure for Schacht Konrad as legislated. BfS withdrew the application for the immediate enforcement of the licence in order to allow a court examination on the merits of the main proceedings. The Ministry of Environment in Lower Saxony granted permission to Schacht Konrad in May 2002. A number of legal processes are underway, initiated by repository opponents. According to the agreement of 2002, only a repository for all types of waste is to be built and this also means that the future for Schacht Konrad is uncertain.

Spent Nuclear Fuel and/or HLW (Heat-Generating)

Before the 1994 amendment of the Atomic Energy Act, the only alternative for spent nuclear fuel was reprocessing which took place in France or the UK. Plans to establish a reprocessing plant in Wackersdorf were abandoned in 1989 due to intense, sometimes violent, opposition.

Repatriation of existing vitrified HLW began in May 1996, following the licensing of the interim storage facility at Gorleben in Lower Saxony in early June 1995. According to the new Atomic Energy Act, the waste producer is responsible for building the interim storage facilities for spent nuclear fuel at the reactor sites. The licence applications are currently being evaluated.

Until recently, it was assumed that Germany would develop a deep repository for HLW (and possibly also for spent nuclear fuel) in a suitable salt formation. The salt dome in Gorleben was selected as the only candidate site. However, according to the June 2000 agreement, the entire disposal problem will be re-evaluated. The deep disposal method is preferred, although more types of rock must be investigated before a decision on siting is made.

As it became clear that several potential repository sites with other types of bedrock had to be investigated, BMU formed a new committee, AKEND, in February 1999, with the task of developing a new procedure for site selection. A programme was presented in three phases in order to obtain a new siting procedure. In the first phase, proposals for the new procedure will be formulated. In the second phase, a political and legal basis for this procedure will be obtained and decided upon. The third phase will consist of implementation.

Phase 1 has concluded with AKEND, in 2002, submitting its report to the Government. Phase 2 is in progress, through discussions with different stakeholders. This discussion is expected to be completed in 2004. During Phase 3, a site selection process will be started. However, there are indications that difficulties have arisen: The waste producers want Gorleben to be included as an alternative while BMU would like to exclude it.

1.6 Japan

1.6.1 Nuclear Power Programme

Japan currently has 54 reactors in operation (2003), owned by Japan Atomic Energy Company and nine other independent electricity companies. However, several of these reactors have been closed down due to technical problems. The need for an additional 13 reactors by the year 2010 has been announced by the Japanese industry. The only breeder reactor in the country, the experimental reactor in Monju, is currently closed down due to an accident which occurred in December 1995 and which led to a loss of coolant (sodium).

1.6.2 Relevant Institutions

The Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC) determine the basic guidelines for radioactive waste management. The AEC is responsible for the planning and determination of basic policy, whilst the NSC is responsible for safety criteria and regulations.

The Ministry of Economy, Trade and Industry (METI) and the Ministry of Education, Culture, Sports, Science and Technology (MECCST) issues licences for waste management and disposal based on the Act for the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors. A new Special Radioactive Waste Final Disposal Act to deal with HLW disposal, was passed (2000). The Act includes stipulations that a plan for disposal should be presented every fifth year, with a complete re-evaluation after ten years. Through the Act, a new implementation organisation was also set up for work on site selection, construction, operation etc. of a deep repository. This organisation is known as NUMO. With the Act, a financing system for nuclear waste was also established.

The Japan Nuclear Cycle Development Institution (JNC) is responsible for work on advanced reactor designs, fuel cycle technology and R&D associated with HLW disposal. This organisation replaced the larger Power Reactor and Nuclear Fuel Development Corporation (PNC) in 1998, which was restructured after a number of incidents at several of its sites.

1.6.3 Nuclear Waste Management

The current Japanese programme includes reprocessing of spent fuel and utilisation of the plutonium and enriched uranium, including the development of Mixed Oxide (MOX) fuel fabrication. Previously, spent fuel has been reprocessed abroad, although an experimental reprocessing facility was in operation at PNC's Tokai site until March 1997, when there was an explosion and fire. The facility was restarted in November 2000.

A commercial-scale reprocessing facility has been under construction since 1993 at Rokkasho, in Aomori Prefecture, which is also the site of an operational LLW repository and a storage facility for returned HLW (from reprocessing abroad).

Japan Nuclear Fuel Service Co. Ltd (JNFL) manages both of these facilities.

LLW and Short-lived ILW

These types of waste are disposed of in a near-surface facility at Rokkasho in the Aomori Prefecture. The facility began operations in December 1992. The repository was co-sited with the reprocessing plant mentioned above and this is expected to start operation in 2005.

Spent Fuel and/or HLW

In its 1994 long-term plan, the AEC stated "some time in 2030 or no later than by 2045" as the time when a waste disposal facility would be granted an operating licence and taken into operation. The 1994 long-term plan repeated a previously presented plan to create, in around 2000, a special organisation to implement the disposal programme. In agreement with this and the new Waste Act, the Japanese utilities applied, in October 2000, to the Government for permission to establish such an organisation. The Government immediately approved the proposal and the Nuclear Waste Management Organisation (NUMO) was formed in October 2000, with its headquarters in Tokyo.

It is expected that a number of siting alternatives for a repository will be investigated starting in 2001. A number of sites for preliminary site investigations will be selected in 2004 and a few sites will then – in around 2010 – be selected for detailed characterisations. It is expected that the ultimate site will be decided upon in around 2025.

In August 1989, it was decided that an underground rock laboratory would be constructed at the disused Kamaishi mine (iron/copper) in the Iwate Prefecture, in spite of the strong local opposition which is delaying the start of the project. The work was completed in March 1998 when the contract with the municipality expired.

An experimental shaft, some 150 metres deep, in a sandstone formation containing uranium and covering crystalline bedrock has also been used since 1986 in the Tono area in the Gifu Prefecture in central Japan.

Permission to construct a new underground facility in Mizunami within the same area was granted in December 1995. Surface-based investigations started late in 1997 and it is planned that the investigations will continue for up to five years. This site will take over Kamaishi's role as the most important site for research on crystalline bedrock and like the facility it has been characterised as a facility which is only used for research.

After many years of discussion between JNC, the Hokkaido Prefecture and Horonobe city, these three parties reached an agreement in November 2000 on an underground laboratory in Horonobe on condition that it would not be used for radioactive material. A detailed research programme is being prepared and investigation drilling will start shortly. The underground laboratory in Honorobe is intended to be a centre for research on sedimentary rock types, while Mizunami has a corresponding role with respect to granite.

In Japan, as in many other countries, there is public opposition to nuclear power and nuclear waste and attempts have been made to respond to this resistance by providing information and by conducting dialogue and opening up possibilities for public influence over the work of NUMO and other bodies.

1.7 Russia

1.7.1 Nuclear Power Programme

In May 2003, there were 30 nuclear reactors in operation in Russia. 11 of these were of the RBMK type, 14 were VVER reactors, 4 were BWRs and one was a breeder reactor. Four reactors have been decommissioned. Furthermore, Russia has had 118 research reactors in operation, although many have now been shut down. Apart from the nuclear power plants, there are a number of facilities for uranium mining, fuel fabrication, reprocessing, isotope production etc. Furthermore, military activities are conducted, including plutonium production and nuclear reactor-powered ships for the Northern Fleet in the Kola Peninsula and the Pacific Fleet around Vladivostok. There is a commercial reprocessing plant at Chelyabinsk (now referred to as Ozersk). Another was under construction at Krasnoyarsk (now referred to as Zheleznogorsk), but work has now been terminated. There are also a number of reprocessing facilities for spent nuclear fuel from military activities.

1.7.2 Relevant Institutions

Previously, responsibility for radioactive waste was split between four different ministries, namely

- The Ministry of Atomic Power (Minatom) had the responsibility for waste from civilian nuclear power and from the production of nuclear weapons. It was founded in 1992. There are approximately 150 companies associated with Minatom, including 15 “closed cities”, where a total of 13 plutonium-producing reactors have been operated. Some of these are still in operation. Rosenergoatom is responsible for Minatom for operation of all nuclear power plants and management of the associated waste.

- The Ministry of Defence had the responsibility for waste from nuclear-powered naval ships.
- The Ministry of Marine Transport was responsible for waste from nuclear-powered icebreakers.
- The Ministry of Construction and Housing Policies which is managing the special “Radon” facility (for the treatment and disposal of low and intermediate-level waste) was responsible for the management of radioactive waste generated in industry, medicine, research etc.

Gosatomnadzor (GAN) is the authority that regulates activities in Russia. According to the Act on Nuclear Energy, from November 1995, this authority is responsible for the licensing and inspection of all nuclear power utilities, including military utilities. According to the Act, all companies that produce and handle active waste must apply for permission for a new operating licence. In the case of certain companies, these licences are not yet ready.

1.7.3 Nuclear Waste Management

LLW and Short-lived ILW

Proposals have been made to develop a repository for military LLW in an area in northern Russia, with permafrost, and a deep repository for industrial (non-power reactor) waste near to Moscow in salt or clay. GAN explained at a later stage that the idea of constructing a repository in permafrost is being abandoned. Russia is not currently looking for a site for the disposal of LLW and ILW waste from reactor operation. Such waste is currently being stored at the nuclear power plants.

Spent Nuclear Fuel and/or HLW

From the start, Russia planned to only reprocess spent nuclear fuel from certain reactor types, namely VVER-440, VVER-1000, BN-350 and BN-600. No plans exist to reprocess RBMK fuel. VVER-440 fuel is being reprocessed in the RT-1 facility, operated by the Majak group Ozersk in southern Ural. It was taken into operation in 1948 and was used for military fuel but was modified in 1976 so that civil fuel could also be reprocessed. The construction of RT-2 facility in Zheleznogorsk for the reprocessing of VVER-1000 fuel was interrupted in 1989 and was completely stopped in 1998, for technical and financial reasons.

RBMK fuel is stored for three to five years in the reactor hall pools and then transferred to special interim storage pools at the nuclear power plants. Such interim facilities only exist at the stations in Leningrad, Kursk and in Smolensk.

Liquid waste, including HLW of different origins has been injected into deep boreholes in Ozersk, Zheleznogorsk, Dimitrovgrad and Seversk for many years.

The Institute of Geology, Ore Deposits, Petrography, Mineralogy and Geochemistry (IGEM) is responsible for developing a strategy for the treatment and disposal of spent nuclear fuel and HLW. Furthermore, the Khlopin Radium Institute in St. Petersburg has been given the task of developing a better system for waste treatment from the reprocessing in Zheleznogorsk (if RT-2 is put into operation).

Several different deep disposal concepts are currently being studied. Since the authorities do not consider that retrievability is desirable, both mining shafts and deep boreholes may be used for disposal.

Since, as before, the aim is to concentrate the activity and to site it geographically near the sites where waste is produced, interest has centred on the areas around the Zheleznogorsk and Ozersk facilities.

The Khlopin Radium Institute in St. Petersburg has investigated sites around Zheleznogorsk. Other institutes have studied basal and granite bedrock in the Baltic Shield. Of the eight sites which were originally considered suitable for further investigation, two candidate sites remained in 1996. One of these has been selected and will be further studied on condition that the activity can be financed. The work has been supported by the IAEA's Expert Contact Group and funds have been made available from PNC in Japan, DOE in the USA and authorities in Finland.

The work at Ozersk has been financed by the former USSR Academy of Sciences. A site within the boundaries of the complex was selected and four holes were drilled to a depth of at least 900 metres. The aim is to build an underground laboratory to conduct experiments and in-situ characterisation. However, recent studies show that it can be difficult to site a repository there due to uncertainties concerning the tectonic conditions. The work in this project is being conducted as part of an EU-supported PHARE programme and contains technical contributions from several organisations in the west. So far, IGEM has identified three possible disposal zones at the same time that it was dubious to the suitability of the originally selected site.

The treatment and disposal of spent fuel and other waste from repository-related industry, especially the large quantities from reactor-powered submarines, have also become an urgent problem. Much of this waste – in the from of spent fuel and different types of liquids – is stored under unsatisfactory conditions, either at the bases of the Russian Northern Fleet on the Kola Peninsula around Murmansk and Arkangelsk or at the Pacific Ocean bases near to Vladivostok. At the Northern Fleet bases, it is expected that up to 48,000 fuel elements with spent nuclear fuel have been deposited in storage facilities that are leaking and in poor condition.

In February 1998, an IAEA working group, the Contact Expert Group, reported that the waste management in the

Russian northwestern area was in such poor condition that the area had been prioritised for global co-operation projects.

Three alternatives have been examined: A new wet storage facility, a new dry storage facility or renovation of the existing wet storage facility. In the case of a dry storage facility, according to an agreement in February 1998, about USD 50 million would be placed at the disposal of Sweden, Norway, France and Russia. To this must be added EU support, which was confirmed in May 1998.

In July 1998, the USA stated that it was prepared to pay for the cost of the transport of spent nuclear fuel from Vladivostok to Ozersk since it was concerned about the inadequate safety at the existing facilities.

The Kola Mining Institute has conducted a number of studies concerning the development of underground repositories for the Northern Fleet HLW. A proposal was presented already in 1994, which included a four-year programme for a deep repository on the Kola peninsula. This would be of the conventional type and would be located in hard crystalline bedrock. An experimental facility would first be constructed although it seems as though only very limited work has been conducted so far.

In April 1999, it emerged that a US company, Non-proliferation Trust, Inc. (NPT) had been formed to develop an international interim storage facility for spent nuclear fuel at Zheleznnogorsk. This facility was intended to have a capacity of about 6,000 tonnes of uranium and a lifetime of at least 40 years. The earnings from this activity would be used to clean up Russian's military defence facilities in order to secure the handling of up to 50 tonnes of plutonium which exist and to support the defence project that is under way. However, for this project to be realised, Russian legislation must be amended to allow the import of foreign waste.

In July 2001, President Putin signed an act that allows the import of foreign spent nuclear fuel to Russia. The fuel can be stored there until 2021, when reprocessing can start in the reprocessing facility that is under construction at Zheleznogorsk. The imports must be approved by a special commission set up in 2002.

1.8 Switzerland

1.8.1 Nuclear Power Programme

There are currently five nuclear reactors in Switzerland, divided into four power stations. Furthermore, there are six research reactors. A moratorium means that no new reactors will be built for the time being. However, this situation may change if a revised Atomic Energy Act is passed.

1.8.2 Relevant Institutions

In Switzerland, nuclear power producers are responsible for the nuclear waste generated. In 1972, the power utilities and the Swiss state which is responsible for waste from medical, research and industrial activities formed NAGRA, which is responsible for radioactive waste disposal and related treatment. ZWILAG in Würenlingen is responsible for the central interim storage and the Co-operative for Nuclear Waste Management Wellenberg (GNW) runs the project which aims at building a repository for LLW and ILW in Wellenberg (see below). The utilities are themselves responsible for transport, reprocessing of spent nuclear fuel and for waste preparation and interim storage at the plants.

The federal government receives support from the Federal Interagency Working Group on Nuclear Waste Management (AGNEB), from the Federal Commission for Safety in Nuclear Installations (KSA) and by the Federal Commission on Nuclear Waste Management (KNE) which, in turn, is a sub-committee of the Federal Geology Commission (EGK).

The responsible authority for radioactive waste in Switzerland in the Swiss Federeal Nuclear Safety Inspectorate (HSK), which reports to the Federal Energy Office (BEW). In turn, BEW is part of the Federal Department of the Environment, Transport, Energy and Communication (UVEK).

Due to the fact that public acceptance for the siting work is slow to obtain, the federal government has appointed several working groups over the past few years. The question of "indefinitely monitored retrievable storage" or "passively safe geological disposal" has been discussed. For this reason, the federal government discussed, in June 1999, the appointment of an expert group (EKRA) which would work with different disposal concepts for radioactive waste. This group has developed a concept based on monitored long-term retrieval storage.

EKRA came to the conclusion that geological disposal, which isolates the waste, is the only method that meets the requirements on long-term safety. However, the general public's requirements that the waste must be accessible (retrievable) must also be taken into account. Therefore, EKRA suggests a stepwise process which includes a phase of monitoring and a higher degree of accessibility before the geological repository is closed. In addition to the large-scale repository, the concept also includes a pilot facility, where a small part of the waste is placed in a small but representative copy of the full-scale facility. The facility is designed allow the waste to be retrieved from the pilot facility if its performance does not meet expectations. Naturally, the idea of a monitored long-term geological repository must be adapted to the geology at the site and to the waste types that occur in a certain repository.

1.8.3 Nuclear Waste Management

Until the repository for different types of waste has been built, most of the waste will be stored in the ZWILAG facility in

Würenlingen in Canton Aargau in northern Switzerland. ZWILAG was taken into operation in April 2000.

LLW and Short-lived ILW

Due to the high population density in Switzerland, there are no plans to construct repositories near the surface for short-lived LLW or ILW. According to the plans, this type of waste will be disposed of in bedrock in a suitable rock formation at a depth of several hundred metres and with repository access possibilities via a horizontal tunnel. NAGRA found a suitable site in 1993, namely Wellenberg in Canton Nidwalden in central Switzerland. The municipality accepted the project in two different referendums in 1994 with 63 % and 70 % of the votes, respectively. In spite of this, a referendum in the Canton – concerning the mining concession required by law in the Canton – led to a vote of rejection.

Since this, the geological suitability of the site has once again been evaluated, which was also confirmed by the Federal Safety Inspectorate. GNW decided to limit its application in the first step, to include an extended period of monitoring and to apply a stepwise process for repository closure. Bearing in mind this, the federal government started a new discussion with the Cantonal government. The discussion led to an agreement in June 2000.

According to the agreement, an expert group from the Canton (KFW) was established to prepare and subsequently monitor the project. The KFW started its work in July 2000. After a series of negotiations with GNW, with NAGRA (which functions as a scientific and technological competence centre from GNW) and with the Nuclear Safety Inspectorate (HSK), the modifications that would be achieved in the project were agreed. These were described by GNW in a report that was submitted in November 2000. In December 2000, KFW stated that it expected that the report was satisfactory and the Cantonal government stated that it was willing to receive a new application from GNW for a mining licence, limited to the research tunnel.

However, in September 2002, a referendum in Canton showed that there was strong resistance, also to this project. The Government therefore explained that Wellenberg was no longer under consideration and that no new attempts to site a repository at Wellenberg would be made.

Spent Nuclear Fuel and/or HLW

For about one-third of the spent nuclear fuel, the utilities have a contract with reprocessing facilities in France and Great Britain. However, a new Atomic Energy Act does not allow any reprocessing to be conducted beyond the contracts that already exist. Vitrified HLW will be returned to Switzerland for interim storage in ZWILAG and ZWIBEZ (storage facility adjacent to the Beznaureaktorn). The first transport from France arrived in 2001. Spent nuclear fuel will also be put in interim storage at the two facilities just mentioned, pending disposal.

Swiss law requires that radioactive waste should be permanently disposed of in a geological repository. As a condition for the continued operation of existing nuclear power plants or the construction of new plants, a Government ruling of 1979 called for a project demonstrating the feasibility of the safe disposal of all waste generated in Switzerland to be submitted by 1985. This project, Project Gewähr, was submitted to the federal government by 1985.

In June 1988, the project was approved. The project was based on the use of a crystalline host rock, was approved by the Government. Although the safety case and the technical feasibility of repository construction were fully accepted by the safety authorities, the authorities did not consider that the existence of a sufficiently extensive body host rock with the required properties for making the safety case was adequately shown. Since Project Gewähr was based exclusively on crystalline bedrock, the safety authorities requested that future work should also include other alternatives.

NAGRA follows a strategy with three phases. Phase 1 comprises regional studies based on a series of deep boreholes with accompanying geological general studies. Phase 2 comprises a detailed characterisation (from the ground surface) of small areas. Phase 3 includes underground investigations.

Crystalline Basement Alternative

The regional fieldwork (Phase 1) was completed in 1989 and the report was presented in 1994. The most important parts of the report include a summary of geological information and a performance assessment.

At the end of 1994, NAGRA applied for federal permits to conduct two site investigation programmes, one for opalinus clay in Zürcher Weinland and one for crystalline basement in Böttstein/Leuggern. The programme proposals were examined by the federal authorities and their experts.

An underground laboratory in crystalline basement – the Grimsel facility in central Switzerland – has been in operation since 983. When this laboratory was constructed, a horizontal tunnel system was constructed from an existing hydro power facility at the Grimsel pass. An extensive test programme including geology, rock mechanics etc. has been conducted since 1984 with wide international participation.

Opalinus Clay Alternative

The Opalinus Clay (OPA) had been considered as a potential host formation prior to Project Gewähr, in 1979. Desk studies carried out in 1986/87 had also evaluated six other potential sedimentary formations and the options were narrowed down to two final candidates, namely the OPA and the Lower Freshwater

Molasse (USM). The latter can reach a thickness of up to 4 km and contains units of high clay content and low permeability. *(Molasse is a sedimentation of soft rock types along a newly formed mountain chain).*

Two areas were selected for studying OPA. These, like the crystalline basement areas are in the northern parts of Switzerland. As a part of the Phase 1 programme, a regional two-dimensional seismic study, extending over 230 kilometres, was conducted from 1991 to 1992.

Based on these investigations, in 1994, a preliminary evaluation of the sedimentary alternatives was conducted in co-operation with the authorities. USM was given second priority and, since then, has been considered as a reserve option. The eastern OPA area was given first priority. After additional selections in the region, the area at Zürcher Weinland in the Zürch Canton was identified for further investigation.

These further investigations (Phase 2) comprised a three-dimensional seismic study of an area of about 50 km^2 and a deep borehole at Benken. In Zürcher Weinland, sedimentary rock types are almost horizontally contained and the opalinus clay is of an adequate thickness (100-200 metres) at a suitable depth (400-900 metres below the surface). Since these sediments were formed, the region has almost not been exposed to any tectonic movement at all and the original sedimentation are still undisturbed, which means that the site seems to be an ideal candidate site.

Another important information source with respect to the properties "in situ" at the opalinus clay and clay in general is the work conducted at the Mont-Terri rock laboratory in the Jura Canton within the framework of an international project under the management of Switzerland's hydrological and geological surveys. This facility is located near to an investigation tunnel (for a motorway) which intersects the clay at a depth of about 300 metres.

The Next Milestone in the Swiss HLW Programme

The next milestone in the Swiss HLW programme will be the conclusion of a project called "Project Entsorgungsnachweis". The aim of the project is to be able to demonstrate the feasibility of disposal of HLW in Switzerland. This means that it must be possible to show that there are sufficiently large rock volumes with suitable properties for constructing a repository, and that the requirements on safety and constructability can be met. Due to the good accessibility from the ground surface and the positive results so far obtained, this project will be conducted focusing exclusively on constructing a repository in the Opalinus Clay. However, this does not mean that crystalline basement has been excluded as an alternative for the ultimate construction of a repository for HLW.

The most important reports from Project Entsorgungsnachweis will, together with other relevant information, be submitted to the safety authorities for evaluation. A decision from the authorities regarding how to proceed is not expected until around 2006 at the earliest.

1.9 United Kingdom

1.9.1 Nuclear Power Programme

The UK currently operates 19 Magnox reactors, 14 advanced gas cooled reactors (AGRs) and one pressurised water reactor (PWR). British Energy Generation is responsible for the operation of the AGR and PWR reactors. British Energy Generation comprises the formerly state-owned companies, Nuclear Electric and Scottish Nuclear Corporation. These companies merged in January 1999. The Magnox reactors are still state owned and operated by Magnox Electric which, in turn, was taken over by British Nuclear Fuels Ltd (BNFL) in 1998. BNFL has announced that it intends to successively by

2012, shut down the Magnox reactors. BNFL and British Energy have also started a study on the phase-out of the AGR reactors.

1.9.2 Relevant Institutions

The regulatory authority in the UK is the Nuclear Installations Inspectorate (NII), assisted by the Environment Agency (EA) and the Ministry of Agriculture, Fisheries and Food. Since July 1997, NII has also been responsible for regulating waste held on sites operated by the Ministry of Defence. In Scotland, the EA's responsibility has been assumed by the Scottish Environmental Protection Agency (SEPA).

The Government is advised on waste management issues by the Radioactive Waste Management Advisory Committee (RWMAC), whose members are appointed by a minister. These come from the nuclear industry, academia, public bodies (health authorities etc.) and, more recently, a number of independent experts have been appointed. In 2003, a new Committee on Radioactive Waste Management (CoRWM) was appointed to advise the Government on issues relating to disposal of radioactive waste. It seems that both of these committees will exist in parallel but with different foci of activities.

A major commercial reprocessing facility run by BNFL exists at Sellafield. A smaller facility is located in Dounreay in northern Scotland (where the now shut down experimental breeder reactor was located). The operation of the Dounreay facility was managed by the United Kingdom Atomic Energy Authority (UKAEA), built to reprocess specialist fuels and highly enriched uranium from research reactors. The facility in Dounreay will successively be taken out of operation.

Currently, spent nuclear fuel from the AGR and Magnox reactors are placed in pools at the nuclear power plants to cool off. This will also apply to the fuel from the pressurized water reactor at Sizewell. The fuel will then be transported to Sellafield for a long period of interim storage and possible reprocessing.

Dry storage of Magnox fuel has only been conducted at one of the plants. Design problems led to the corrosion of the fuel canisters.

The Thermal Oxide Reprocessing Plant (THORP) in Sellafield was taken into operation in 1994 and its purpose is to reprocess about 7,000 tonnes of spent oxide fuel (from AGRs, PWRs, LWRs etc.) by the year 2005.

The Government has taken the initiative to clarify the responsibility for existing spent nuclear fuel and nuclear waste, "Managing the Nuclear Legacy". A new authority, the Liabilities Management Authority, has been created. The authority will be responsible for waste from previous activities at BNFL, UKAEA etc. A new organisation, National Decommissioning Agency, will start to work in 2004 on issues concerning the nuclear power plant decommissioning.

1.9.3 Management of Nuclear Waste

LLW and ILW

The responsibility for short-lived LLW and HLW lies with the producer of the waste. The Nuclear Industry Radioactive Waste Management Executive (called UK Nirex), is responsible for the disposal of long-lived ILW (since 1982), future LLW and short-lived ILW. NIREX was formed in 1981 by all of the companies in the nuclear power industry and each of these is represented on the board. Nirex has never been responsible for HLW.

A commercial repository near to the ground surface for LLW and short-lived ILW has been operated by BNFL in Drigg, near Sellafield, since the 1960's. Nirex originally proposed that, when this repository was full, disposal should be continued near to the ground surface for these types of waste at another site and that an abandoned anhydrite mine for a deep repository for long-lived waste should be used as a repository for long-lived ILW.

However, due to opposition from the local population, the mine project was abandoned in 1985.

When three other sites were proposed in 1986 for an LLW repository near to the ground surface, as a complement to the originally exclusive candidate, there was once again intense local opposition with extensive civil disobedience. These site proposals were abandoned in 1987, just prior to the general elections. It was then suggested that a disposal solutions should be found for all LLW and ILW. This proposal was then soon modified and the alternative deep proposal for long-lived ILW was taken up again, while LLW and short-lived ILW would be sent to Drigg.

After two years of nationwide mapping, two sites for further investigation were selected in 1991, both near the existing nuclear facilities at Sellafield and Dounreay. A list of a further ten sites were established but these have not been published.

The investigation work focussed on Sellafield in 1993 and over GPB 250 million was used for characterisation from the ground surface. In 1992, Nirex announced its attention to construct a Rock Characterisation Facility (RCF). This would allow a limited development and experimental activity to be conducted before a large-scale repository could be constructed. Nirex requested permission to start construction of the RCF in 1994. However, this request was rejected after a hearing in 1995. The inspector granting the licence announced that Nirex had not been able to convince him that their geological interpretation was correct. Furthermore, he considered that the design was poor and not well thought through. Nirex immediately stated that they would withdraw from Sellafield but retained the right to return in the future.

In November 1997, the UK House of Lords Select Committee on Science and Technology, HoL) announced that an extensive, independent hearing would be conducted concerning all issues relating to the handling of nuclear waste, including the future role of Nirex. The verbal hearing started in February 1998 and the final report was published in March 1999.

The report concentrated on the development of waste management in phases, especially for LLW and ILW and resulted in a proposal to at least develop a repository for long-lived ILW. The report also emphasised the need, within 15 to 25 years for a facility near the ground surface as a replacement for Drigg.

Spent Fuel and/or HLW

According to current plans, domestic HLW is to be stored at Sellafield for cooling for 50 to 100 years, after which time the Government is to make a decision concerning how it will be disposed of. In the past, the only certainty as regards disposal was that it would involve deep disposal, in a rock type yet to be determined, at a site yet to be determined.

Until 1981, investigation work was conducted with trial drilling and other research for a possible disposal. A certain investigation into crystalline basement and sedimentary rock occurred at the end of the 1970's, including detailed studies close to Dounreay. This system was abandoned due to wide opposition on the part of the public and now only general research is conducted. Concepts concerning waste disposal at great depths were once again included in proposed legislation which was abandoned by the Government in 1995, although no special programme was presented. A timetable for the development work for the repository was presented to the Government in 1999 although no significant work has so far been conducted.

As was previously mentioned, a new committee was appointted, "Committee on Radioactive Waste Management", CoRWM, in 2003. This committee is to provide advice to the Government on questions concerning the final disposal of radioactive waste and prepare a programme. The programme is to be presented in 2005.

1.10 USA

1.10.1 Nuclear Power Programme

The USA currently has 104 nuclear power reactors in operation, located at over more than 80 sites. In 2001, the Department of Energy, DOE) invited the nuclear power facilities to show their interest in the construction of new nuclear power plants in the USA (which would be the first for more than 25 years). Several companies have evinced interest in this.

1.10.2 Relevant Institutions

In the USA, nuclear waste disposal is paid for by the nuclear power producers. However, the responsibility for implementing the disposal of spent nuclear fuel and HLW lies with the DOE, and more specifically, the Office of Civilian Nuclear Waste Management (OCRWM). According to contracts with the nuclear utilities as a result of the 1982 act on nuclear policy (Nuclear Waste Policy Act, NWPA), the OCRWM was to have managed and disposed of the nuclear utilities' spent fuel for final disposal in January 1998.

The Nuclear Regulatory Commission (NRC) is the main regulatory authority for the disposal of HLW. With respect to transport of HLW, the NRC shares the responsibility with the Department of Transportation (DOT). The US Environmental Protection Agency (EPA) plays an important role in that it promulgates general regulations that set standards, also for the disposal of HLW.

1.10.3 Nuclear Waste Management

Since commercial reprocessing of spent nuclear fuel was stopped in 1977, HLW from non-military sources is only a fraction of the quantity of waste for which a management solution must be found. More than 95 percentage by volume originates from military-related reprocessing under the DOE's jurisdiction and is stored in tanks at different sites under DOE control pending vitrification. Two facilities were taken into operation in 1996, one of which is located in South Carolina and the other in New York State.

In the USA, waste which contains small quantities of plutonium and other long-lived radionuclides is called transuranic or TRU waste. The waste must contain more than 100 nanocurie per gram (corresponding to 3,700 Bq/g) of transuranic elements (namely, substances with atomic weights that are higher than those of uranium) with half-lives exceeding 20 years to be classified as TRU waste. All other waste, including spent nuclear fuel, is either LLW or HLW.

LLW

In the USA, the waste producers are responsible for the management of LLW and the federal states are responsible for waste disposal. Co-operation between individual states has been established in certain cases and in many states attempts have been made to find suitable sites for disposal facilities. The latest development is that a commercial facility (Envirocaire) for toxic waste in Utah recently received permission. This facility may only receive naturally occurring and class A LLW. An application for permission to also receive class B and class C waste has been preliminarily accepted but final permission has not yet been applied for by the company (2003).

TRU Waste

Since 1999, the DOE has been disposing of TRU waste from nuclear power production in the Waste Isolation Pilot Plant

(WIPP) in New Mexico at a depth of about 650 metres in a salt formation.

Spent Nuclear Fuel and/or HLW

Spent nuclear fuel from civil nuclear reactors is currently stored at nuclear power plants. The available pool area is not adequate for the volumes that are likely to be generated in all existing and planned reactors in operation (estimated quantity, about 87,000 tonnes). If we assume that no repository is in operation, an additional 80,000 tonnes of storage capacity will be needed in 2030. At present, there are about 35,000 tonnes stored at the different nuclear power plants and the quantity is increasing by about 2,000 tonnes per year. In 2046 the quantity of spent nuclear fuel could be about 105,000 tonnes.

As indicated in Section 1.10.2, according to the 1982 Act on Nuclear Power Policy, the DOE would be able to receive spent nuclear fuel from 1998. In 1993, when the federal states and nuclear utilities realised that the goals that were written into their contracts with the DOE would not be realised in time, a series of legal processes started. The aim was to force the DOE to take responsibility to start receiving spent nuclear fuel for disposal in 1998 and to try to find ways of obtaining damages if the DOE did not take responsibility. After a number of legal processes, it emerged in 2000 that if the utilities and the DOE could not reach an agreement, the DOE would have to carry out legal processes in at least 20 different cases to establish the damages that would have to be paid. These damages can (according to calculations conducted in March 2003) amount to a total of several tens of billions of USD if a repository is never constructed.

During 1998, 1999 and the first part of 2000, an attempt was made to get the senate to introduce new legislation which would entail an amendment of the original nuclear waste policy situation (NWPA) from 1982. Several proposals have also been put forward concerning constructing a central interim storage facility for spent nuclear fuel. The pressure on the utilities to construct their own interim storage facility at the nuclear power plants would therefore be reduced. The bill also proposed removing the upper boundary of 70,000 tonnes of capacity at the proposed repository.

A site selection process for the repository had previously been initiated where a large number of sites and geological media were included as possible candidates. However, through an amendment to the NWPA (1987), the instruction for the site selection procedure was eliminated. This meant that a number of sites had to be investigated, before a final candidate site could be appointed. The DOE could thereby select a site in Yucca Mountain, Nevada near to the DOE's investigation site, as the only candidate.

Through the 1987 amendment (NWPAA) to the NWPA, the Office of the Waste Negotiator was also established with the task of locating a site that affected parties could voluntarily make available for the siting of Monitored Retrievable Storage Facility (MRS). In addition, the Nuclear Waste Technical Review Board, NWTRB) was established to evaluate the scientific and technical work that the DOE was conducting on the disposal of spent nuclear fuel and HLW, including transportation issues and the waste canister design.

The latest conceptual design for an underground repository in Yucca Mountain includes one primary area that is crossed by parallel emplacement drifts that will be used for final disposal. The repository will be constructed in a geological formation comprising lithophysal welded tuff, some 300 metres above the water table.

Through surface investigations, it has been possible to identify and characterise most of the properties of the ground structure. Extensive research is underway at the Exploratory Studies Facility (ESF) which is a spiral-shaped tunnel construction completed in 1997. The main project is the Drift-Scale Heater

Test, in which rock temperatures of up to 200ºC. The experiment is not expected to be completed before 2004.

Other work focuses on testing, analysis, models and designs that are needed as a basis for supporting the suitability of the site. The current timetable anticipates licensing in 2002-2005, construction in 2005-2008 and commissioning in 2010.

The actual design is somewhat different from the design that was presented as a basis for a preliminary evaluation in 1998 (Viability Assessment). At that time, a strategy was presented, based on an average temperature load, according to which the waste containers were located near to each other. The heat from the fuel would raise the temperature of the surrounding mounted to over 100ºC. Water, which would otherwise corrode the containers and expose the waste in the short term, would boil away. The DOE is now planning to study a strategy, based on low temperature loads which is recommended by NWTRB. In this case, heat production is about 25 % of the amount envisaged in the previous concept (about 40 kW/hectare).

It is proposed that the repository should be kept open and available for 100 years from the time when the waste is deposited. Future generations would therefore make decisions concerning backfilling and closure. The repository is therefore referred to as a “monitored, geological repository”.

Through a decision in congress and by the president, in 2002, it was decided that Yucca Mountain would be accepted as a repository site. The DOE will now apply to the NRC for permission to construct the repository. The NRC’s approval is required before construction can start and for the subsequent operation of the repository. The NRC is preparing for an extensive review which will include a number of review groups.

1.11 International Organisations

1.11.1 Nuclear Energy Agency, NEA

At OECD/NEA, the Radioactive Waste Management Committee, (RWMC) is supervising the work within the nuclear waste area. The work is mainly divided into three areas, each of them supervised by a Working Party:

- The Integration Group for the Safety Case (IGSC).
- Forum on Stakeholder Confidence (FSC).
- Working Party on Decommissioning and Dismantling (WPDD).

In addition to these groups, there is also a Co-operative Programme on Decommissioning Projects (CPD) and a Regulators Forum.

The RWMC has initiated discussions on a common approach to issues such as retrievability, the benefit of underground laboratories, stepwise decision-making, etc. The RWMC has also organised international peer reviews which have reviewed various national programmes. On behalf of the Swedish Nuclear Power Inspectorate, such a group reviewed SKB's SR-97 safety assessment in spring 2000.

The Integration Group for the Safety Case (IGSC) works in a discipline-oriented way on technical safety for repositories with questions such as, for instance, the development of performance assessment and how this can be used to communicate technical information and develop confidence between concerned stakeholders, how safety assessments may be used as a basis for decision-making, scenario development etc.

The purpose of the FSC is to formulate questions on the decision-making process and its structure, on the organisation and on trust as well as to develop principles for how different stakeholders can be involved.

The WPDD's task is to work with policy issues on decommissioning and dismantling. Experience from the Co-operative Programme on Decommissioning Projects (CPD) and other projects is compiled and reported.

In CPD, more than 20 years of experience from decommissioning and dismantling of nuclear facilities has been collected. In total, around 40 projects are included. In addition to the exchange of experience and technical collaboration, the CPD also publishes reports on radiological data from the dismantling of reactors.

Based on information from consultants and experts in the member countries, the NEA has published a number of status reports on the state-of-art in deep geological disposal. The material is based on work in different countries over the past ten years.

"Progress towards the Geological Disposal of Radioactive Waste: Where Do We Stand?", published in 1999 (ref. 2, also translated into Swedish in 2000, see list of references at the end of this chapter) formulates a number of claims on which the specialists in the area appear to agree. These include:

- Deep geological disposal is the most appropriate means of long-term management of the various disposal options considered.
- Significant progress has been made in relevant scientific understanding and in the technology required for geological disposal in the past ten years.
- The technology for constructing and operating repositories is mature enough for deployment.
- The time-scales envisioned in the past for the implementtation of geological disposal were too optimistic.
- There is a high level of confidence among the scientific and technical community engaged in waste disposal that geological disposal is technically safe.
- However, the broader public does not necessarily share the high level of confidence of the scientific and technical community.

- There is a need for continued high-quality scientific and technical work.
- There is a need for a consistent policy and strict regulatory licensing, with clear decision points which also allow for public dialogue.

The report points to a number of specific areas where it suggests that significant progress has been made over the past ten years in terms of the technical activities required to implement disposal. These are:

- The development and construction of facilities for the treatment and interim storage of waste.
- Experience from laboratory and field experiments, including studies of natural analogues.
- Construction and operation of underground rock laboratories.
- Experience in site characterisation.
- Development of the design of engineered barriers.
- Improved safety assessment methods.
- Improved co-ordination between site characterisation, design and safety assessment.
- Development of regulatory frameworks, including requirements, on safety and radiation protection reporting.

In a report from the Forum on Stakeholders Confidence (Strategic Directions of the RWMC Forum on Stakeholder Confidence, May 2002), the importance of the decision-making process and certain basic elements are emphasised:

- A clear strategy for a long-term solution and support from the Government and policy-creating organisations, based on responsibility and needs.
- A flexible decision-making process which incorporates influence from the public and the needs of those concerned.
- Involvement from all of those concerned, including municipalities and authorities.

- A well-structured process for dialogue/interaction between industry, authorities, politicians and the general public.

1.11.2 International Atomic Energy Agency, IAEA

In 1995, the IAEA published "Principles of Radioactive Waste Management". This is the IAEA's main document in the Safety Standards Series. Since this time, the IAEA has put considerable effort into developing the principles presented in the document. A consensus statement has been prepared by the member states on safety issues in all important areas relating to the management of radioactive waste. This important document is also a basis – with respect to technical issues – for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management), which was adopted at a diplomatic conference in 1997.[1]

The International Conference on the Safety of Radioactive Waste Management was held in Córdoba, Spain, in March 2000 within the framework of the IAEA's safety programme for 2000. The main purpose of the conference was to facilitate an open dialogue between different interested parties – scientists and representatives from waste producers, for companies responsible for waste management, for units with regulatory functions and for the general public. Conclusions and recommendations from the conference were compiled in a document that was submitted to the IAEA's Board of Governors General Conference in September 2000. The document contains a proposal for the development of a form of Roundtable on Stakeholder Consensus. The following text has been taken from the document.

> The evolution, under the aegis of the IAEA, of a "de facto" international radiation and nuclear safety regime was noted. In the area of radioactive waste safety, this regime consists of the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" (which, it is hoped, will

[1] Sweden ratified the Convention in 1999. The Convention entered into force in 2001.

enter into force soon), the body of international waste safety standards published by the IAEA and other international organisations, and the IAEA's mechanisms for providing for the application of those standards.

Progress has been made in the development of technology and disposal alternatives for the radioactive waste, but further R&D work is still necessary. Regardless of which alternative a country finally chooses for high level and long lived waste, it will be necessary to continue the development and assessment of deep geological disposal. This type of alternative will most certainly be utilized in the future.

International co-operation is important for reaching a common understanding among technical experts and the general public and support for the national programs. The following tools are especially important in this aspect:

- "Joint Convention", an important legal instrument that presupposes engagement on a high level of the contracting parties concerning safe management of radioactive waste
- International standards, already existing
- International systems that will help to implement the standards

The first review conference for the "Joint Convention" has now taken place and some of the conclusions are summarized below:

- The main purpose of the convention is to support the safe management of radioactive waste and spent fuel
- The convention has already contributed to this, e.g. by the work to produce the national reports that has helped in identifying needs for increasing nuclear safety
- The need to develop long term plans for waste management and disposal is underlined
- The need for planning for decommissioning of nuclear facilities is also underlined
- The need for consultation between stakeholders in the process is underlined.

1.11.3 The European Commission

In September 2000, responsibility for nuclear safety issues in the European Commission was largely transferred from the Environment Directorate (DG-Env) to the Transport and Energy Directorate (DG-Tren), although radiation protection matters will be unaffected.

Research work on Radioactive Waste Management and Disposal has been part of the European Atomic Energy Community (EURATOM) for more than 25 years, supervised by the Research Directorate. This is part of the general research and technological development (RTD) programme of the EC. The programme covers activities in major fields of science and technology, organised in five-year framework programmes. The programme is performed through 'shared-cost' contracts by national laboratories of the Member States of the European Union (EU) with financial support from the EC (normally up to 50 % of the total costs) or through and in conjunction with the Joint Research Centres (JRC).

Since the publication of KASAM's state-of-the-art report in 2001, the sixth framework programme (2002-2006) has started. The sixth framework programme will contribute to creating a "European Research Area (ERA). The European area for research is a vision of the future of European research, an internal market for science and technology. The aim is to promote state-of-the-art research, competition and innovation through improved co-operation and increased co-ordination between all of the different levels. Economic growth is increasingly dependent on research and individual countries can no longer, on its own, solve many of the problems that industry and society is faced with today or which can be predicted for the future. At a summit meeting Lisbon in March 2000, the heads of states and governments called for a better use of Europe's research work. This would be achieved through the creation of a European area for research activities. The framework programme is the financial instrument that is to contribute to the realisation of the European area of research.

So far, the framework programmes have almost exclusively been conducted with the help of projects for research co-operation. This was highly effective when the project started, but has two disadvantages:

- Most often, co-operation in the project consortium ceased when the project was finished.
- In many cases, the projects were not large enough to achieve a "critical mass" and to have more far-reaching effects from the research standpoint or from the industrial or economic standpoint. In order to remedy this and to contribute to the creation of a European area for research activity, two new instruments have been created which will be applied in the sixth framework programme, namely, the network of excellence and *integrated projects*.

The principle behind both of these instruments is to finance coherent programmes for research rather than many small projects while, at the same time, the European research consortia will be allowed as much freedom and flexibility as possible.

The aim of the *network of excellence* is to integrate the activities of the network partners in stages in order to promote virtual research centres. *Integrated projects* consist of very large projects which will lead to goal-oriented research with clearly defined scientific and technical objectives for the critical mass that is required.

The sixth framework programme will include research on the disposal of radioactive waste in the sub-programme, Fuel Cycle Safety, and the total available budget is EUR 60 million.

Research priorities for radioactive waste are

1. Research on geological disposal.
   a. Improvement of basic knowledge and development and testing of technology.
   b. New and improved tools.
2. Partitioning and Transmutation (P&T) as well as methods that lead to smaller waste quantities in connection with nuclear energy production.

1.12 Conclusion

All countries described in this chapter share the fact that increasing attention has been paid to issues relating to the treatment and disposal of spent nuclear fuel and nuclear waste from the operation of nuclear reactors, by both representatives from society's institutions (parliament, governments, regulatory authorities) and by the nuclear industry. This applies in countries with a growing nuclear programme (such as Finland, France and Japan) as well as in countries, such as Sweden, which have a more static or declining programme.

In most of these countries, there is a common view to how nuclear waste issues should be solved, even if concrete technical solutions, timetables etc. are different. This joint approach is manifested through the Joint International Convention on Nuclear Waste which most countries with a substantial nuclear power programme as well as countries without their own programmes have ratified. Sweden was one of the first countries to ratify the Convention.

An overall evaluation shows that Finland, Sweden and the USA have come the furthest in realising the disposal of spent nuclear fuel, both with respect to choice of technology and site selection. In France, a highly advanced and extensive research and development programme is underway on methods for the treatment, storage and disposal of radioactive waste. The final report for the programme will be submitted in 2006. Germany, Japan, Canada and Great Britain also have advanced research programmes although much remains to be done before concrete solutions can be presented. In many other countries, research on radioactive waste is also underway. Issues relating to the long-term financing of nuclear waste management and the decommissioning of reactors are attracting increased international interest.

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Abbreviations

General

AGR, advanced gas-cooled reactor
PWR, pressurized water reactor
LLW, low level waste
ILW, medium level waste
HLW, high level waste
MOX (mixed oxide fuel), mixed fuel containing both uranium- and plutonium oxide
R&D, research and development

Canada

OPG, Ontario Power Generation Inc.
NFWA, Nuclear Fuel Waste Act
CNSC, Canadian Nuclear Safety Commission
NWMO, Nuclear Waste Management Organisation
AECL, Atomic Energy of Canada Limited
NRCan, Ministry of Natural Resources Canada

Finland

Fortum (earlier IVO, Imatran Voima), state-owned power enterprise
VVER, Russian type of reactor
TVO, utility, owned by Finnish industry and power enterprises
STUK, Radiation safety central (Finnish authority for nuclear safety and radiation protection)
ONKALO, the first stage of the deep repository (used for R&D)
Posiva, Finnish company (corresponding to SKB in Sweden)

France

ANDRA, organisation responsible for disposal (corrresponding to SKB in Sweden)
EdF, Electricité de France (state-owned company with a main responsibility for electric energy supply in France)
CEA, Commissariat à l'Energie Atomique (a state organisation responsible for the development of nuclear energy)
COGEMA, (a state organisation operating the reprocessing facilities in la Hague)
DGSNR, Direction Générale de la Sûreté Nucléaire et de la Radioprotection
IRSN, Institut de Radioprotection et de Sûreté Nucléaire
ICE, Installation Centrale d´Entreposage (a planned central facility for the intermediate storage of spent fuel)
CNE, Commité National d'Evaluation (national commission for the evaluation of nuclear waste research activities)

Germany

BfS, the federal radiation protection authority
PBT, federal institute for science and technology
ERAM, Endlager für Radioaktive Abfälle, Morsleben, final disposal for LLW and ILW
BMU, the federal ministry for the environment
AKEND, committee responsible for proposing a new procedure for site selection

Japan

AEC, Atomic Energy Commission
NSC, Nuclear Safety Commission
METI, Ministry of economy, trade and industry
MECSST, Ministry of education, culture, sport, science and technology
NUMO, an organisation responsible for work on site selection, construction, operation etc. of a deep geologic repository
JNC, an institute responsible for work related to advanced reactors and nuclear fuel cycle technology and research and development related to disposal of HLW
JNFL, Japanese Nuclear Fuel Ltd

Russia

Minatom, Atomic power ministry
GAN, Gosatomnadzor" (nuclear power authority)
RBMK, Russian reactor type
VVER-440, VVER-1000, BN-350, BN-600 Russian reactor types
IGEM, Institute for Geology, Ores, Petrografy, Mineralogy and Geochemistry
CEG , Contact Expert Group (expert group within IAEA)
PHARE, a support program financed by EU
NPT, Non Proliferation Trust, Inc. (an American enterprise)
(NPT, Non-Proliferation Treaty, an international agreement)

Switzerland

NAGRA, organisation responsible for final disposal of nuclear waste (corresponding to SKB in Sweden)
ZWILAG, a company responsible for central intermediate storage of spent fuel
AGNEB, Federal advisory group for nuclear waste
KSA, Federal commission for nuclear safety
HSK, Swiss Federal Nuclear Power Inspectorate
EKRA, an expert group for development of a disposal concept for radioactive waste
GNW, an organisation corresponding to SKB in Sweden

UK

BNFL, British Nuclear Fuels Ltd
NII, Nuclear Installations Inspectorate
EA, Environment Agency
SEPA, Scottish Environmental Protection Agency
RAWMAC, Radioactive Waste Management Advisory Committee
CoRWM, Committee on Radioactive Waste Management
UKAEA, United Kingdom Atomic Energy Authority
THORP, Thermal Oxide Reprocessing Plant in Sellafield
LMA, Liabilities Management Authority
National Decommissioning Agency, a new organisation for issues related to decommissioning and dismantling of nuclear reactors
UK Nirex, Nuclear Industry Radioactive Waste Management Executive, works with issues related final disposal of long lived ILW and LLW and for short lived ILW

USA

DOE, Department of Energy
OCRWM, Office of Civilian Nuclear Waste Management (part of DOE)
NWPA, Nuclear Waste Policy Act
NRC, Nuclear Regulatory Commission
DOT, Department of Transportation
WIPP, Waste Isolation Pilot Plant i New Mexico
NWTRB, Nuclear Waste Technical Review Board

OECD/NEA

RWMC, Waste Management Committee
IGSC, Integration Group for the Safety Case
FSC, Forum on Stakeholder Confidence
WPDD, Working Party on Decommissioning and Dismantling

International organisations

IAEA, International Atomic Energy Agency
OECD/NEA, OECD Nuclear Energy Agency
EU, European Union