SAND2014-18223R

Progress in Siting Nuclear Waste Facilities

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Nuclear Fuels Storage and Transportation Planning Project

Laura L. Price
Rob P. Rechard
Sandia National Laboratories

September 2014
FCRD-NFST-2014-000628
SAND2014-xxxxx

Sandia National Laboratories

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EXECUTIVE SUMMARY

Shortly after the United States Department of Energy (DOE) requested to withdraw the Yucca Mountain license application in 2010, the Blue Ribbon Commission on America's Nuclear Future was chartered to recommend a new strategy for managing the back end of the nuclear fuel cycle. The Blue Ribbon Commission issued its final report in January 2012 [1], and one of its recommendations was that the United States should pursue a consent-based approach to siting future nuclear waste management facilities.

To implement this recommendation, the DOE established a database of the experience that has been gained and relevant documentation that has been produced in efforts to site nuclear waste facilities, both in the United States and abroad. This database, the Siting Experience Database, can be found online at curie.ornl.gov. The DOE has also asked for reports to be prepared regarding the status of siting nuclear waste facilities throughout the world. Previous reports focused on how various countries had answered key questions applicable to the United States about siting; this report focuses on the siting programs of three countries that are furthest in the siting process (Finland, France, and Sweden) and summarizes the siting status of several other countries, not only for radioactive waste disposal, but for waste processing and storage facilities as well.

For the three countries looked at in some detail, the following questions are addressed: 1) Who participated in the design of the process? 2) What were important elements of the siting process (principals, steps, inclusion of various stakeholders, means of obtaining consent)? 3) What information and expertise was required (what kind of information was required and developed for communities, were screening criteria provided up front, were grants provided)? 4) How was consent-based siting implemented (time necessary, inclusion of community in oversight)?

This study identified some factors that all three countries (Finland, France, and Sweden) had in common: they all have a defined method for public participation, they all have an underground research laboratory, they all require disposal to be reversible or that the waste be retrievable, and the siting process has taken a long time (decades). It is also noted that, in the two countries in which affected municipalities have a right to veto the siting of the repository, the consenting municipalities already had nuclear power plants.

In addition to addressing the above questions, in Appendix A this report also summarizes the types of additions made to the Siting Experience Database in the last year.

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ACRONYMS

AKA	Använt Kärnbränsle och radioaktivt Avfall Committee (Sweden)
ANDRA	French National Radioactive Waste Management Agency
BRC	Blue Ribbon Commission on America's Nuclear Future
CLIS	Local Committee of Information and Monitoring (France)
COVRA	Central Organization for Radioactive Waste (Netherlands)
COWAM	Community Waste Management
DOE	United States Department of Energy
ENRESA	Empresa Nacional de Residuos Radiactivos, S.A (Spain)
HLW	High-Level Waste
IEER	Institute of Energy and Environmental Research (France)
ILW	Intermediate-Level Waste
KASAM	Swedish National Coucil for Nuclear Waste
LLW	Low-Level Waste
NUMO	Nuclear Waste Management Organization of Japan
NWMO	Nuclear Waste Management Organization (Canada)
OECD	Organization of Economic Co-operation and Development
ONDRAF/NIRAS	National Agency for Radioactive Waste and Enriched Fissile Materials (Belgium)
ORDIMIP	Regional Observatory of Industrial Waste of Midi-Pyrénées
SKB	Swedish Nuclear Fuel and Waste Management Company
SKI	Swedish Nuclear Power Inspectorate
SSI	Swedish Radiation Protection Institute
SSM	Swedish Radiation Safety Authority
SNF	Spent Nuclear Fuel
STUK	Finnish Radiation and Nuclear Safety Authority
UK	United Kingdom

NUCLEAR FUELS STORAGE AND TRANSPORTATION PLANNING PROJECT
PROGRESS IN SITING NUCLEAR WASTE FACILITIES

1. INTRODUCTION

Shortly after the United States Department of Energy (DOE) requested to withdraw the Yucca Mountain license application in 2010, the Blue Ribbon Commission on America's Nuclear Future (BRC) was chartered to recommend a new strategy for managing the back end of the nuclear fuel cycle. In its final report of January 2012 [1], the BRC recommended that the United States pursue a consent-based approach to siting future nuclear waste management facilities.

This report supports the development of a consent-based siting process for radioactive waste management facilities by examining in detail three countries (Finland, France, and Sweden) that are the furthest along in their consent-based process for siting a repository for spent nuclear fuel (SNF) and/or high-level waste (HLW). As defined by the BRC, a consent-based siting process is one that is flexible, adaptive, staged, transparent, patient, responsive to public concerns, and based on the consent of the community in which the facility is to be located [1]. It is recognized that implementing the BRC's recommendations will require changes to the Nuclear Waste Policy Act that currently governs the back end of the nuclear fuel cycle in the United States, as well as corresponding regulations. Such a discussion is beyond the scope of this report.

This report also supports the development of a consent-based siting process by discussing improvements made to the Siting Experience Database, an online database that was developed by the DOE in response to recommendations by the BRC. The online Siting Experience Database can be found at curie.ornl.gov.

1.1 BACKGROUND

In response to the BRC's report, the DOE issued a strategy report in January 2013 that provides a "…framework for moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel and high-level radioactive waste from civilian nuclear power generation, defense, national security and other activities" [2]. As a part of this strategy, the DOE plans to implement a program over the next 10 years that [2]:

- Sites, designs and licenses, constructs and begins operations of a pilot interim storage facility by 2021 with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advances toward the siting and licensing of a larger interim storage facility to be available by 2025 that will have sufficient capacity to provide flexibility in the waste management system and allows for acceptance of enough used nuclear fuel to reduce expected government liabilities; and
- Makes demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048.

To implement these goals, the Nuclear Fuels Storage and Transportation Planning Project was created to, in part, support the development of a consent-based siting process that directly engages stakeholders and potential host communities through deliberations regarding appropriate criteria and siting conditions [3]. This report supports the consent-based siting process by examining in detail three countries that are furthest along in their siting process for a SNF/HLW repository, and by discussing improvements made to the Siting Experience Database.

1.2 APPROACH

The approach here is a case study approach, based on an evaluation of waste management programs throughout the world. Specifically, this report summarizes the status of consent-based siting processes that have been implemented abroad. Although a few waste management facilities are completed, most are at various stages of completion but show promise of reaching consent to proceed with the project. The hazard in using case studies is that unless all the nuances about the conditions of application are known it can be difficult to discern whether the case study is directly applicable to the United States situation at this particular time. Provided, however, that the process of consent-based siting has been tailored to the United States situation, the advantage of examining case studies is that they provide examples of how to implement various elements of the siting process. The information presented here represents but a small sampling of the vast amount of information that will have be collected and made available to the key parties in order to support their deliberations for a consent-based siting approach.

First, the progress of siting waste disposal, storage, and treatment facilities is summarized for several countries (Section 2). This is followed by a discussion of the three countries that were examined in detail (Section 3): Finland, France, and Sweden. For these three countries, the following questions are addressed: (1) Who participated in the design of the process? (2) What were important elements of the siting process (principals, steps, inclusion of various stakeholders, means of obtaining consent)? (3) What information and expertise was required (what kind of information was required and developed for communities, were screening criteria provided up front, were grants provided)? (4) How was consent-based siting implemented (time necessary, inclusion of community in oversight)?

Appendix A of this report also lists the additional documents added to the online Siting Experience Database.

2. STATUS OF SITING NUCLEAR WASTE FACILITIES IN VARIOUS COUNTRIES

This section summarizes the status of the siting of radioactive waste facilities in various countries, first discussing the siting of radioactive waste processing and storage facilities, followed by a discussion of the siting of radioactive waste disposal facilities.

2.1 SITING OF WASTE PROCESSING AND STORAGE FACILITIES

The status of siting radioactive waste processing and storage facilities in Australia, Spain, and Ukraine is as follows.

2.1.1 AUSTRALIA

2.1.1.1 SYNROC PLANT IN SYDNEY

In September 2012, the Australian Nuclear Science and Technology Organization announced plans for an intermediate-level waste (ILW) treatment plant at their campus in the Sutherland Shire of Sydney. The plant will process waste from the co-located nuclear medicine production facility. The treatment uses Australian Synroc, a durable solid rock-like material, to encapsulate the waste. In May 2014, the Australian Radiation Protection and Nuclear Safety Agency approved construction of the treatment plant after a review that included expert assessment and public consultation. The Australian Nuclear Science and Technology Organization plans to begin plant construction in 2015 and complete construction by the end of 2017 [4].

2.1.1.2 AUSTRALIAN NATIONAL RADIOACTIVE WASTE MANAGEMENT FACILITY

In May 2014, the Australian federal budget allocated $22.6 million to develop detailed design options for the National Radioactive Waste Management Facility [4].

In 2007, a km^2 section of the 2241 km^2 Muckaty Station in the Northern Territory was nominated by the Northern Land Council, an official body that represents Aboriginal interests, to store low-level waste (LLW) and ILW. The Council negotiated with the Aboriginal Ngapa clan. But four other clans with claims to the land opposed the nomination. In June 2014, the Australian federal government decided it would not proceed, and the legal case between the Northern Land Council and the four other clans was dismissed.[5]. Because the case was dismissed, issues were not answered related to (1) how to apply the process of obtaining consent from several Traditional Owner clans represented by the Northern Land Council and (2) how to manage disagreements.

The Northern Land Council may make a second nomination on behalf of Traditional Owners from the Muckaty Aboriginal Land Trust. The Federal Minster for Industry has given the Northern Land Council three months to develop a second nomination [6].

2.1.2 SPAIN

2.1.2.1 NUCLEAR WASTE STORAGE FACILITY

The Spanish government spent ~6 years from April 2006 to December 2011 identifying a host community to site a centralized interim storage facility. The community selected, Villar de Canas, is 135 km from Madrid. The primary impetus for interim storage was the necessary return of HLW from France after processing Spanish SNF to avoid penalties specified in the bilateral agreement. The Spanish government, through ENRESA (the Spanish agency responsible for radioactive waste management and nuclear plant decommissioning), proposed an interim storage facility for SNF, HLW, and ILW from nuclear power plant decommissioning that included a technology center with a research laboratory and an industrial park. The Spanish Association of Municipalities in Nuclear Areas led efforts to communicate with local stakeholder through diverse approaches and encourage involvement of stakeholders following the guidelines of COWAM (Community Waste Management). The Ministry of Industry created an Inter-ministerial Commission to communicate with stakeholders on a national level and design and implement a site selection process. Following a ~3.5 year program of outreach to municipalities, the Inter-ministerial Commission, in rapid succession, issued a call for volunteers, ranked the 8 eligible municipalities, and identified 4 preferred sites to the Council of Ministries of the executive branch. However, the lack of consent by the regional provinces stalled the final selection for 1.5 years. Local, regional, and national elections finally resolved the impasse in 2011.

In April 2013, detailed design of the centralized interim storage facility began by a consortium of Westinghouse Electric Company, TRSA S.A. and GHESA S.A, the major partners of EMPRESARIOS AGRUPADOS, a leading international provider of engineering and consulting services from Spain. The target date opening for the facility is the end of 2017, following regulatory approval. The facility will store ~13×10^4 m^3 of radioactive waste (10^4 m^3 is SNF and remainder is HLW and other ILW not suitable for disposal in the El Cabril repository in southern Spain for LLW and ILW)[7].

2.1.2.2 MODIFICATIONS TO LLW AND ILW REPOSITORY

In 1992, the El Cabril disposal facility for LLW and ILW, near Cordoba in southern Spain, began operations. In July 2013, ENRESA awarded a contract for design modifications and preparation of technical and licensing documentation [8].

2.1.3 UKRAINE

In April 2014, the Ukrainian government chose a 45 hectare site for its central nuclear fuel storage facility in the Chernobyl exclusion zone, southwest of the Chernobyl nuclear power plant. The 11.5 hectare facility is to be completed in late 2017 by Holtec International, which won the design-license-build contract in 2005. The planned capacity is 16,530 fuel assemblies, 12,010 from VVER-1000 reactors and 4520 from VVER-440 reactors from the South Ukraine, Rivne, and Khmelnitsky nuclear power plants after being processed at Russia's Krasnoyarsk and Mayak fuel cycle facilities. The capacity of the first stage is 3,620 assemblies, with 2,510 assemblies from VVER-1000 reactors. SNF from Ukraine's Zaporizhia nuclear power plant is in a dry storage facility, commissioned in 2001, at the Zaporizhia nuclear power plant site [9].

2.2 DISPOSAL FACILITIES

The status of siting of radioactive waste disposal facilities in Belgium, Canada, the Czech Republic, Germany, Japan, the Netherlands, Spain, and Switzerland is as follows.

2.2.1 BELGIUM

The National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) is charged with preparing a plan for the long-term management of the radioactive waste for which it is responsible, which has to be accompanied by a strategic environmental assessment and submitted for public consultation. ONDRAF/NIRAS prepared such a plan and the accompanying strategic environment impact assessment, and submitted both to the federal government on September 26, 2011. It also organized public consultation and information processes through public dialogues and a citizen's forum. ONDRAF/NIRAS is currently waiting for a decision in principle from the government regarding its plan [10].

The plan calls for disposal of the waste in poorly indurated clay (Boom clay or Ypres Clay) within one underground facility constructed on a single site located in Belgium. The facility is to be reversible, such that the waste can be retrieved after complete or partial closure of the disposal unit. Belgium began studying clay formations as a potential host rock for disposal of long-lived waste (low-level, medium-level, and high-level) in 1974, and subsequently constructed an underground research laboratory in the Mol-Dessel area at a depth of 220 m. Research and development continue in the underground research laboratory, and the findings will be used to support the decision of the government to start the siting phase, assuming the government approves the plan. It is assumed that all spent fuel will be reprocessed, such that spent fuel rods will not be disposed of directly. The high level waste will be allowed to cool for at least 60 years before it is disposed of in the repository [10].

2.2.2 CANADA

In 1972, the Atomic Energy of Canada, Ltd., which was formed in 1952, proposed geologic disposal for SNF and HLW. In 1978, the Canadian government established geologic disposal as national policy. In 1984, Atomic Energy of Canada, Ltd. opened an underground research laboratory in crystalline rock, but by 1988 public opposition led to a request for an environmental assessment of geologic disposal. In 1989 the "Seaborn Panel," named after its chairman, began deliberations and in 1998, the Seaborn Panel concluded that geologic disposal had failed with regard to public acceptability. Hence in 2002, the Canadian Parliament mandated the formation of the Nuclear Waste Management Organization (NWMO), financed by the nuclear industry, to study alternatives for managing radioactive waste from ethical, social, economic, and technical viewpoints and recommend an approach. After engaging many subgroups using diverse formats over ~3 years between late 2002 and 2004, summarizing results in 2005 and 2006, NWMO formally proposed its Adaptive Phased Management plan in 2007, which the Canadian Parliament adopted. The Canadian government then asked NWMO to implement the Adaptive Phased Management plan. In turn, NWMO reorganized, which included reforming the governing board with new members and greatly expanding the natural science and engineering functions.

The reconfigured NWMO then began developing a consent-based process for siting a geologic repository. Over ~2 years between 2007 and 2009, NWMO involved the public in developing a consent-based siting process through advisory citizen panels, an internet dialogue, and information sessions. In 2008, NWMO released its proposed selection principles and consent-based siting process [11]. New citizen's panels were formed to discuss the proposed principles and process. In January 2010, the results of the citizen input were reported and modifications incorporated "…for identifying an informed and willing host community for a deep geological repository for the long-term management of used nuclear fuel in Canada" [12, p. 3].

The nine-step Adaptive Phased Management process of selecting and building a repository and center of expertise for CSNF was initiated in May 2010 by NWMO. In September 2010, NWMO suspended the first 2 steps (outreach and detailed briefing) after 21 communities had expressed interest, and moved to Step 3.[12, p. 21]. By November 2013, NWMO had completed Step 3, the preliminary technical assessments, for 8 of the 21 volunteered communities and had eliminated 4 (2 in Saskatchewan and 2 in Ontario Province). Of the 4 having strong potential, 1 was in Saskatchewan (Creighton) and 3 were in Ontario (Ignace, Hornepayne, and Schreiber). One community, Nipigon, chose to withdraw in June 2014[13]. NWMO expects to complete the preliminary Phase 1 technical assessments for the remaining 12 communities, all located in Ontario, in 2014 and begin the more detailed technical assessments of the 4 communities with strong potential (Phase 2 of Step 3) [14].

NWMO expects to begin Step 4, detailed characterization sites near one or two communities around 2018. Tentative plans are for a repository opening in 2035, with a capacity 3.6 million fuel bundles. Currently, ~2 million fuel bundles are stored [14].

2.2.3 THE CZECH REPUBLIC

The Czech Republic is planning to place its SNF and any HLW generated from reprocessing (should it occur) in a deep geologic repository, which is expected to start its operation in 2065. The waste is currently in dry storage in dual-purpose transport/storage containers at the generators' sites and is expected to stay there until the repository opens. The repository siting program is in its early stages; it has been delayed because the municipalities at the preliminary selected sites rejected the detailed geologic survey. The generic conceptual design was updated in 2012 to account for changes in regulations, technology, and the economy since it was first issued in 1999. The state organization Radioactive Waste Repository Authority is responsible for development of the geologic repository; and supports research and development projects connected with site characterization, the development of materials for use in a repository, the development of disposal casks, etc. [15].

2.2.4 GERMANY

In its 2013 proposed rulemaking, the United States Nuclear Regulatory Commission summarized the status of siting of a SNF disposal facility in Germany as follows [16]:

> In Germany, a large salt dome at Gorleben had been under study since 1977 as a potential spent nuclear fuel repository. After decades of intense discussions and protests, the utilities and the government reached an agreement in 2000 to

suspend exploration of Gorleben for at least 3, and at most 10 years. In 2003, the Federal Ministry for the Environment set up an interdisciplinary expert group to identify, with public participation, criteria for selecting new candidate sites. In October 2010, Germany resumed exploration of Gorleben as a potential spent nuclear fuel repository. In March 2013, Germany announced plans to form a 24-member commission to develop siting criteria. The Commission will hold public meetings through 2015 on the issue of a permanent repository for HLW.

The 24-member commission will also work on proposals in relation to issues such as safety requirements and exclusion and selection criteria for each type of geology. The Bundestag will adopt legislation as needed to execute individual phases of the selection procedure, including decisions regarding locations for surface and underground exploration. The procedure will include the following phases, with 2031 being the expected decision date for a repository site [17]:

- Review of legal provisions and definition of basic criteria
- Identification of suitable regions, surface and underground exploration, site comparisons and proposals, selected site to be written into federal legislation.
- Creation of plan approval procedure for the safety assessment of the selected site
- If possible, construction of the repository after judicial review of the plan approval procedure

2.2.5 JAPAN

The Nuclear Waste Management Organization of Japan (NUMO) is charged with disposing of HLW generated from reprocessing SNF and transuranic waste. These wastes are to be disposed of in a stable geologic formation at a depth of at least 300 meters, after a 30- to 50-year long period of interim storage to allow for cooling. NUMO is also responsible for conducting research and development related to safe disposal of radioactive waste. Among its other research and development efforts, NUMO has opened two underground research laboratories, one in crystalline rock at Mizunami and one in sedimentary rock at Horonobe [18, 19].

The repository site selection process is specified by the Act on final Disposal of Specified Radioactive Waste of 2000. It is a three-stage process involving the selection of Preliminary Investigation Areas, Detailed Investigation Areas, and finally the selection of a repository construction site. NUMO is currently in the first phase, conducting open solicitation of municipalities nationwide and seeking areas in which feasibility studies can be conducted. One of the early steps is to determine whether the sites that express interest are subject to volcanic activity, active faults, or other geological phenomena that would make them unsuitable for a geologic repository. NUMO is to keep the public informed, and selection is to proceed on the basis of respecting local opinions, obtaining stakeholder agreement, and obtaining approval of the government. If a municipality or prefecture opposes the siting of a repository in their respective municipality or prefecture, it will not be located there. The selection of a disposal site is expected to occur in around 2026, with repository operations beginning around 2040 [20, 21].

2.2.6 THE NETHERLANDS

The Central Organization for Radioactive Waste (COVRA) is responsible for managing the radioactive waste generated in the Netherlands. Currently, SNF is sent to either France or the United Kingdom (UK) to be reprocessed, and the resulting HLW is sent back to the Netherlands for storage. The current plan is to store the HLW in the storage building specifically designed for storage of such waste (HABOG) for at least 100 years and to prepare financially, technically, and socially for deep geologic disposal after the 100-year storage period. Money is being collected in a capital growth fund so that it will be available in 100 years to fund the disposal effort [22, 23].

In 1993 the Netherlands government adopted a radioactive waste management policy that requires any underground disposal facility to be designed such that each step of the process is reversible. Thus, it would always be possible to retrieve the waste that had been disposed of [22, 23].

2.2.7 SPAIN

The Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA) is the body responsible for radioactive waste management activities in Spain. Spain has been working on deep geologic disposal of SNF and HLW since 1985 through its Site Selection Plan, which was stopped in 2006; through its development of conceptual designs for granite, clay, and salt formations; through its safety assessment exercises, and through its research and development plans [24].

Currently, SNF is stored on the site of each nuclear power plant, with the exception of Vandellos 1, whose spent fuel was reprocessed in France. However, Spain is getting ready to construct a Centralized Interim Storage in Villar de Canas (see Section 2.1.2.1). The construction contract is expected to be awarded in February 2015, construction is expected to take about 5 years, and the waste is expected to be stored for 60 years, at which time a repository for deep geologic disposal should be available [25].

2.2.8 SWITZERLAND

In its 2013 proposed rulemaking, the United States Nuclear Regulatory Commission summarized the status of siting of a SNF disposal facility in Switzerland as follows [16]:

> In Switzerland, after detailed site investigations in several locations, the Swiss National Cooperative for Radioactive Waste Disposal proposed, in 1993, a deep geologic repository for LLW and ILW at Wellenberg. Despite a 1998 finding by Swiss authorities that technical feasibility of the disposal concept was successfully demonstrated, a public cantonal referendum rejected the proposed repository in 2002. Even after more than 25 years of high quality field and laboratory research, Swiss authorities do not expect that a deep geologic repository will be available before 2040.

2.2.9 UNITED KINGDOM

In its 2013 proposed rulemaking, the United States Nuclear Regulatory Commission summarized the status of siting of a SNF disposal facility in the UK as follows [16]:

> In 1997, the United Kingdom (UK) rejected an application for the construction of a rock characterization facility at Sellafield, leaving the country without a path forward for long-term management or disposal of either ILW or SNF. In 1998, an inquiry by the UK House of Lords endorsed geologic disposal but specified that public acceptance was required. As a result, the UK Government embraced a repository plan based on the principles of voluntarism and partnership between communities and implementers. This led to the initiation of a national public consultation and major structural reorganization within the UK program. The UK Nuclear Decommissioning Authority envisions availability of a geologic disposal facility for ILW in 2040 and a geologic facility for SNF and HLW in 2075; however, there have been changes in societal acceptance in the UK for the siting of a geological disposal facility. In 2007, the Scottish Government officially rejected any further consultation with the UK Government on deep geologic disposal of HLW and SNF. This action by the Scottish Government effectively ended more than 7 years of consultations with stakeholders near Scottish nuclear installations. In 2013, the Cumbria County Council voted to withdraw from the UK process to find a host community for an underground radioactive waste disposal facility and to end the site selection process in west Cumbria.

In September 2013, the Department of Energy and Climate Change proposed a new approach for engaging communities regarding hosting a repository. The new approach would provide more information at an earlier stage in the process, require a demonstration of support by the community, and allow continued right to withdraw from the process. The site selection process could take ~15 years. The period of consultation on the new approach was to occur between September 12, 2013 and December 5, 2013. In 2014, the Department of Energy and Climate Change plans to implement the new approach [26].

3. DETAILS OF SITING NUCLEAR WASTE DISPOSAL FACILITIES IN FINLAND, FRANCE, AND SWEDEN

This section presents detailed information regarding the history and status of siting of SNF and HLW disposal facilities in Finland, France, and Sweden. These three countries are examined in detail because they are the furthest along in the siting process. For each country, first the current status of the HLW disposal facility siting/licensing process will be presented, followed by a more detailed discussion of the siting process that was established for that country, how it was implemented, the important elements in that process, and any information and expertise that was required.

3.1 FINLAND

In December 2012, Posiva Oy, jointly owned by the Finnish utilities TVO and Fortum, submitted a construction license application to the Finnish Ministry of Employment and the Economy for disposal of SNF in a proposed repository in Olkiluoto. This ministry will conduct hearings and invite several other ministries, authorities, and organizations to comment on the application. The Finnish Radiation and Nuclear Safety Authority (STUK) will review the license application and make a safety assessment. The Ministry of Employment and the Economy plans to submit the license to the government at the end of 2014. The Olkiluoto repository, with a planned opening in ~2020, is in crystalline rock and will have a capacity of 9000 tonnes of uranium in CSNF, enough capacity to dispose of waste produced by four existing nuclear power plants (i.e., Olkiluoto 1&2, Loviisa 1&2) and two future nuclear power plants (Olkiluoto 3&4). Some 3000 tonnes of uranium in SNF from the planned Hanhikivi nuclear power plant, owned by Fennovoima, is not currently included in the inventory planned for the proposed Olkiluoto repository [27].

Finland's LLW/ILW repository, also at Olkiluoto, has disposed of 5500 m^3 (half its capacity) from the Olkiluoto nuclear power plants and some waste from the health care sector, industry, and research institutions. The Olkiluoto LLW/ILW repository is 60-100 m deep. In the past, 100 to 180 m^3 of waste has been disposed every year with 66% LLW and 33% ILW, but TVO, owner of the Olkiluoto nuclear power plants, plans to reduce the volume of ILW by 20 to 30% in the future [28].

3.1.1 THE FINNISH SITING PROCESS

The process for siting and licensing a SNF repository is stipulated by the Nuclear Energy Act of 1987. The process outlined in that act applies to reactors as well as a SNF repository. The steps in the process for nuclear facilities are, assuming success at each step: 1) Assess environmental impact, 2) apply for a decision-in-principle from Parliament, 3) obtain construction license, 4) obtain operating license.

Under the same act, the Ministry of Trade and Industry (now the Ministry of Employment and the Economy) was designated as being responsible for supervision of nuclear power operation and for waste disposal. It is assisted by an Advisory Committee on Nuclear Energy in major matters and also an Advisory Committee on Radiation Protection. The country's Radiation and

Nuclear Safety Authority (STUK) is responsible for regulation and inspection. It operates under the Council of State (effectively the Government), which licenses major nuclear facilities. STUK is administered by the Ministry of Social Affairs and Health, is funded by the State, and is assisted by an Advisory Committee on Nuclear Safety in major matters [29].

The mission of Posiva Oy is to manage the spent fuel from the nuclear power plants owned by TVO and Fortum and, thus, is responsible for final disposal of the SNF including the process for siting and licensing a SNF repository. The Nuclear Energy Act established the State Nuclear Waste Management Fund, which collects assets from Finnish nuclear power companies for future nuclear waste management purposes. The Ministry of Employment and the Economy administers the State Nuclear Waste Management Fund [30].

3.1.2 HOW THE SITING PROCESS WAS IMPLEMENTED

As a part of its 1999 application for a decision-in-principle to locate the repository in the municipality of Eurajoki, Posiva Oy wrote up an overall report on the final disposal project, including a description of the facility, and distributed it to every household in the municipality of Eurajoki (population in 2009: 5872; area: 458.77 km^2 [31]) (Figure 1) and its neighboring municipalities. Notices regarding the project were posted on notice boards in nearby municipalities, and announcements were placed in a number of newspapers. In addition, a public hearing was held in Eurajoki.

Figure 1. Location of Eurajoki in Finland [32]

The Environmental Impact Assessment process helped to produce and disseminate information, and to create a discussion platform. In the Environmental Impact Assessment process there were three ways for the public to participate: 1) public hearings, 2) written opinions to the Ministry of Employment and the Economy, and 3) direct contact with the Environmental Impact Assessment contact person of each candidate municipality. One of the concerns raised during the development of the Environmental Impact Assessment was whether the waste was retrievable. In March 1999, the government required that the SNF be retrievable even after repository closure [33].

Posiva Oy began taking an active role in in shaping the opinion of Eurajoki by creating cooperation groups between itself and the municipality and addressing comments. However, some characterized the public participation rate as "negligible," and attributed this low level of participation to the lack of participatory traditions, the lack of confidence in the effectiveness of participation, the tiredness and exhaustion of some stakeholders, and the uneven distribution of resources among stakeholders [33].

STUK was responsible for a public information program to address the concerns, expectations, and information needs of local residents. STUK has implemented a policy of providing "the best information available" to the public and will go to a municipality to provide information when asked to do so [33].

In addition, as a part of the application for a decision-in-principle to locate the repository in the municipality of Eurajoki, the Ministry of Trade and Industry obtained statements from the municipal council of Eurajoki and the neighboring municipalities of Eurajoki, the Ministry of the Environment, other Ministries, and other local councils and boards. STUK provided a preliminary safety assessment report on the project, along with a statement on the project. The Advisory Committee on Nuclear Safety, which advises STUK, also provided a statement.

It is important to note that the Nuclear Energy Act requires that, before the government takes the decision-in-principle, it shall ascertain that the municipality in which the nuclear facility is located is favor of such construction, as documented in the statement the municipality provides in the application for the decision-in-principle. This gives the host municipality veto power with respect to the application for a decision-in-principal. In addition to holding public hearings in connection with the decision-in-principle, the government must also ascertain that nothing has been found to indicate that the disposal facility would not be safe, that it would inflict injury on people, or that it would damage the environment or property [33].

The municipal council of Eurajoki voted 20 -7 in favor of construction, and no factors were found that would indicate that the disposal facility could not be built safely, so the Government took a favorable decision-in-principle regarding the project in 2000 and Parliament subsequently ratified that decision in May 2001 by a 159 – 3 vote, finding that siting the repository in Eurajoki was in the overall interest of society. These decisions allowed Posiva Oy to perform detailed site characterization and to construct an underground research facility, ONKALO, in 2004, that has been the site of research performed to verify the site selection. ONKALO will become the repository site, assuming the license application is approved [34]. The decision-in-principle would have expired if a construction license had not been applied for within 15 years after the

decision-in-principle became valid. Posiva Oy submitted its license application in December 2012, and it is still being evaluated by STUK. STUK expects to finish its review in December 2014, at which time it will submit its report to the Ministry of Employment and the Economy (which has the responsibilities that the now-defunct Ministry of Trade and Industry once had). This ministry will then forward the license application and report for consideration by the government. The current plan is for the repository to open in 2020 [35].

Prior to Posiva Oy submitting its application for a decision-in-principle, four different locations were investigated in some detail regarding their technical suitability as a repository location. All four were technically suitable. Eurajoki was selected as the final site because of the high level of local consent and because it already had the majority of the waste destined for disposal in the proposed repository. Locating the repository close to where most of the waste is stored minimizes transportation costs and risks.

3.1.3 IMPORTANT ELEMENTS IN THE SITING PROCESS

In identifying important elements in the siting process, it should be noted that Eurajoki twice rejected the idea of locating a spent fuel disposal facility in their community, once in 1993 and once in 1994. Some of the factors that served to change the negative vote into a positive vote a few years later were amending the Nuclear Energy Act such that nuclear waste could not be exported from Finland, nor could nuclear waste be imported from other countries for disposal, the development of Environmental Impact Legislation, and the founding of Posiva Oy. Amending the Nuclear Energy Act to ban exporting spent fuel from Finland made it clear that disposal of spent fuel was Finland's responsibility, while amending it to ban importing spent fuel from other countries allayed fears that Finland would be disposing of spent fuel from other countries.

Public opinion regarding nuclear energy tends to be favorable in Finland. In January 2010, a TNS Gallup survey (N=1000) commissioned by Finnish Energy Industries) showed that 48% of Finns had a positive view of nuclear power, and only 17% were negative. The gap between the two was the widest since polling began 28 years earlier [34]. It has been speculated that the Finns, because the extremely harsh winters that they experience, appreciate an assured energy supply more than other nations. They are "aware of what their quality of life would be if their energy supply declined, if not ceased, for any reason…It is a living condition where the refrigerator is expected to keep water in liquid state" [33]. It may be that this appreciation of energy security leads to a generally favorable opinion regarding nuclear energy.

A workshop was held in November 2011 after the decision-in-principle was ratified by the Parliament [33]. The purpose was to discuss the step-wise decision making process that had led to ratifying the decision-in-principle. Some of the conclusions of the roundtable discussions are as follows.

1. What influenced the process and the outcome?

- The institutional framework (decision-in-principle, Environmental Impact Assessment, and STUK), the step-by-step decision process, the simple organizational structure, the political decision to prohibit the export of fuel, and the early introduction of the concept of geological disposal.

- Broad political consensus, on a national and regional level, regarding the site of the disposal facility. There was a high level of public confidence in the host community, and competition among potential host communities.
- Participation of stakeholders and transparency of the process

2. What are the lessons learned regarding the step-wise decision-making process?

- It is important to recognize that a problem exists, and that the problem needs to be solved and can be solved
- Confidence and trust in the regulatory body and in the implementers is crucial
- The municipality is a major stakeholder, and its veto right is a very important element
- Differences between risk perception by experts and lay people have to be understood and public concerns need to be taken into account
- The following elements were key factors of success:
  - Decision-in-principle as part of a step-wise procedure and as principal decision for implementation
  - Environmental Impact Assessment as a structure and guide for public involvement and participation
  - STUK as a regulatory body that created confidence

3. Was the stakeholder involvement process sufficient?

- A majority of workshop participants shared the view that the Environmental Impact Assessment process provided sufficient opportunities for stakeholder participation. The leader of a local protest movement, however, claimed that chances provided for various stakeholders to participate and influence decisions were far from equal.
- The participation of STUK was especially acknowledged by a majority of participants.

4. Did you receive all the information you needed for your involvement?

- A majority of the Finnish participants found that sufficient information was available. Some claimed that there was too much information.
- Some claimed that information provided about alternative waste management methods was insufficient.
- It was mentioned that due to the lack of resources, opponents could not hire independent experts.

5. What are lessons learned regarding stakeholder involvement?

- It is important that the role of the Environmental Impact Assessment in the siting process, as well as the role of stakeholder involvement in the Environmental Impact Assessment, be clear from the beginning.
- Stakeholders should be allowed to participate from the very early stage of the siting process
- Public interest in participation can be maintained only if stakeholders believe that they can have an influence on key decisions.

- Continued dialogue between the implementers and local people is crucial.

6. How could your involvement be improved in the future?
- The complexity of the Environmental Impact Assessment should be simplified and public participation should be made easier.
- More attention should be paid to informing people
- More attention should be paid to listening to people and responding to their concerns
- Resources should be provided for less powerful stakeholders to assure that they have fair chances for effective participation

7. What was important for developing confidence? How would you rank the various measures?
- In general, the fairness and transparency of the decision-making process were emphasized as key factors of trust and acceptance
- For the municipality, the right of veto, the clear government strategy, and public participation as defined by the Environmental Impact Assessment were most significant.
- Some participants considered institutional measures as most important, followed by the social and technical measures
- Some emphasized the importance of maintaining the dialogue between various stakeholders throughout the whole duration of the project

8. What were negative experiences in gaining confidence and trust?
- Some parties (e.g., Ministry of Trade and Industry, research organizations) were criticized for not being neutral or sufficiently competent
- Some tools (e.g., Posiva Oy's information campaign, public surveys) were criticized as unfair or inappropriate
- Concerns were expressed over the past changes of policy regarding the export of waste, the lack of control by Parliament after approving the decision-in-principle, and Finland's being the first country to establish a repository.

9. What should be done to improve confidence and trust?
- Openness, honesty, early and continuous participation of a variety of stakeholders are key factors
- Adopting a step-wise approach with public outreach increases the chances of success
- The process is not over yet, the dialogue needs to be continued
- The lessons learned from the Finnish process are only partially transferrable to other countries.

3.1.4 REQUIRED INFORMATION AND EXPERTISE

The information and expertise needed to produce an Environmental Impact Assessment was required. This would require expertise in several technical areas. In addition, STUK carried out a program for cooperation and direct communication with the public media, including oral and written materials, seminars, and discussion meetings. The program was based on the needs of the

local public and their representatives (e.g., elected representative, municipal administration, civic organizations, environmental organizations) as communicated to STUK. The objective was to build credibility and public confidence in the high quality and transparency of the decision process of the disposal project itself; it was not to gain public acceptance for disposing of the waste [33].

3.2 FRANCE

In 2012, France placed the first contract for managing the conceptual phase of their HLW repository, Cigéo. The next phase includes public consultation in 2013. Depending on the progress of the consultation phase, ANDRA (the French National Radioactive Waste Management Agency) might submit the license application in 2015.

3.2.1 THE FRENCH SITING PROCESS

The radioactive waste disposal siting process began in 1991 with the passage of the Bataille Act, which defined three research fields in the area of radioactive waste management: separation and transmutation of long-lived radionuclides contained in radioactive waste, storage of radioactive waste, and disposal of radioactive waste in deep geologic repositories. This act also established ANDRA as the National Radioactive Waste Management Agency and provided for the creation of underground research laboratories to study deep geologic disposal of radioactive waste. This Act prescribed a 15-year period of study, after which ANDRA was to recommend a site for deep geologic disposal of long-lived HLW and ILW. The report documenting the basis for its decision is to be reviewed by the Nuclear Safety Authority, which is the French nuclear regulator; the National Review Board, which is an advisory body; and a group of international experts under the aegis of the Nuclear Energy Agency [36]. In addition, the French Parliament plays a role in the process in that it passes laws, sets policy, and must vote on a "Reversibility" act before granting the repository construction license and a "Closure" act before granting the repository closure license [37], [36].

The 1991 Act also provided for the creation of a Local Committee of Information and Monitoring (CLIS) associated with each underground research laboratory. Each CLIS was to monitor the progress of the research being done at its associated underground research laboratory and of the information given to the local public, is chaired by the Prefect of the local representative of the State, and is funded through a public interest group. Each CLIS was also authorized to commission audits or studies by registered laboratories [38]. The Nuclear Safety and Transparency Act of 2006 (Article 22) also discusses local information committees. This Act specifies who is to be on the committee and who is to chair the committee, the legal status of the committee, the scope of its activities, and how it is to be funded.

In 2006, the Planning Act [39] was passed by Parliament. Section 12 of this act specifies that, with respect to a deep geologic repository:

> Any deep geological repository shall be considered as a basic nuclear installation. By derogation to the rules applicable to all basic nuclear installations:

• Any license application to create such an installation shall only concern a geological formation that has been investigated through an underground laboratory;

• The submission of any such application shall be preceded by a public debate on the basis of a case report prepared by the National Radioactive Waste Management Agency (ANDRA);

• Any such application shall give rise to a report of the National Review Board, to a notice of the Nuclear Safety Authority, and to the collection of the opinions of the various territorial communities located totally or in part in the consultation zone prescribed by decree;

• Any such application accompanied by a summary of the public debate, the report of the National Review Board, and the notice of the Nuclear Safety Authority, shall then be submitted to the Parliamentary Office for Evaluation of Scientific and Technological Options who shall in turn assess it and report to the relevant committees of the National Assembly and of the Senate;

• Afterwards, the Government shall table a bill prescribing the relevant reversibility conditions. Once the act is promulgated, the license to create such a facility may be granted by State Council decree after holding a public debate on the issue;

• No license to create a deep geological repository for radioactive waste shall be granted, if the reversibility of such a facility is not guaranteed in accordance with the requirements prescribed by the said Planning Act.

During the review of any such application, the safety of the facility shall be assessed throughout the different steps of its management, including its final closure. Final closure shall only be authorized by passing a new act. As a precaution, the license shall prescribe the minimum period for which the reversibility of the disposal process must be guaranteed. In any case, that minimum period shall not be less than 100 years.

Section 3 of the Planning Act stipulated that the license application for a deep geologic repository for radioactive waste be submitted in 2015 and that the repository be commissioned in 2025, subject to approval of the license.

The public debate referred to in the second bullet is organized by an independent administrative authority, the National Commission on Public Debate. This commission is responsible for ensuring that public participation is consistent with the National Preparation Process for Development and Equipment Projects for the State, territorial communities, public establishments, and private individuals. Public participation may be organized in the form of a public debate on the relevancy, the objectives, and the main characteristics of the project. Public participation shall be guaranteed throughout the development phase of the project, and the National Commission on Public Debate shall ensure that the public is kept informed and shall encourage public consultation throughout the development of the project [39].

Section 13 of the Planning Act of 2006 [39] also stipulates that:

> In any district where the total or partial perimeter of an underground laboratory or deep geological repository is located, a public-interest group shall be constituted with a view to:
>
> • Managing any equipment designed to favor or facilitate the implementation and operation of the underground laboratory or repository;
>
> • Performing, within the boundaries of the relevant district, any regional or economic development actions, particularly in the proximity zone of the underground laboratory or of the repository, the perimeter of which has been set by decree after consultation with the relevant general councils;
>
> • Supporting training initiatives as well as actions relating to the development, including business-wise, and diffusion of scientific and technological knowledge, notably in the fields investigated within the underground laboratory and in the framework of new energy technologies.

Besides the State and the license holder, the relevant regions, districts, municipalities or their groups located totally or in part within the proximity zone referred to in the second bullet shall have the right to be members of the public-interest group.

The ex-officio members of the public-interest group may decide to accept the membership of municipalities or their groups located within the same district but outside the proximity zone referred to in the second bullet above, provided that those municipalities or groups are effectively concerned by the daily operation of the underground laboratory or repository.

The actions referred to in the first two bullets shall be financed from part of the income resulting from the additional tax, known as "outreach tax," to the tax on basic nuclear installations. The actions referred to in the third bullet shall be financed from part of the income resulting from the additional tax, known as the "technological diffusion tax." Any person accountable for any of the additional taxes shall publish an annual report on its economic activities in all relevant districts referred to in the first paragraph above.

3.2.2 HOW THE SITING PROCESS WAS IMPLEMENTED

In the case of France, it may not be accurate to call the siting process "consent-based" siting, as the sites did not actually consent to having a deep geologic repository sited near their municipalities. They were able to participate in the process, but their consent was not required for the process to move forward.

After the Bataille Act was passed in 1991, ANDRA initiated a research program to define methods for disposal of radioactive waste in a deep geologic repository. During 1992 and 1993, ANDRA searched for regions of country in which to build underground research laboratories to

study disposal of radioactive waste. Four regions were selected: Gard (clay formation), Meuse (clay formation), Haute-Marne (clay formation) and Vienne (granite formation). ANDRA conducted geologic investigations in these regions, which were in favor of such investigations. The investigations revealed that the Callovo-Oxfordian clay formation underneath Meuse and Haute-Marne was continuous, so these were combined into a single study area. The other clay formation that was studied, Gard, posed a scientific challenge related to its long-term geodynamic evolution and faced strong local opposition, so further studies were not conducted. For the granite site (Vienne), no scientific consensus on the possibility of building a safe repository could be reached, so further studies were not conducted there either [40]. ANDRA looked for another granite site in which it could perform geologic investigations, but was unable to find one and eventually ceased looking for a site in granite. ANDRA was able to learn about the behavior of granite, however, by building on work done in underground research laboratories in other countries, such as Sweden and Canada.

In 1998, the French Government authorized the construction of an underground research laboratory in Meuse/Haute-Marne. Construction of the underground research laboratory began in 2000 in Bure, a small village located in northeast France (population density: 5 people/km^2 [41]; see Figure 2), and in 2004 the drilling shaft reached the layer of clay that is the focus of experiments to study the rock and its behavior. ANDRA published a report, Dossier 2005 Argile [42], that described its research regarding geologic disposal of radioactive waste. In 2009, ANDRA proposed to the French Government that it be allowed to study in detail a 30 km^2 underground zone located within the clay layer that it had been studying. This zone was selected on the basis of safety and geology, as well as integration of the project with Meuse/Haute-Marne (e.g., deciding where the ramp would be sited, deciding where the access shafts would be sited, avoiding siting the facility under inhabited areas). The proposed zone was approved by the Government, the Nuclear Safety Authority, the National Assessment Board, and was accompanied by consultation with the CLIS for Bure. If licensed, the repository will be sited in this zone. In accordance with the Planning Act of 2006, ANDRA is to submit a license application in 2015 and the repository is to be commissioned in 2025, assuming it is successfully licensed.

While ANDRA was setting up the underground research laboratory in Bure, the CLIS of Bure was created and began a process of independently assessing ANDRA's research program. The CLIS of Bure asked the Institute of Energy and Environmental Research (IEER), an independent institute, to evaluate the adequacy and scientific thoroughness of ANDRA's research program; to identify gaps and deficiencies that may exist in ANDRA's research program; to propose modifications to ANDRA's experiments and approach; and to recommend additional research to complement ANDRA's program.

The conclusion of the IEER study, presented to the Bure CLIS in January 2005, was that it was not possible to determine the feasibility of deep geologic disposal of radioactive waste because not enough information had been gathered, because the research program was not transparent enough to formulate an independent opinion, and because of gaps in information. The IEER report with these conclusions was sent to the residents of Meuse and Haute-Marne, and has been used in the public debate regarding the repository.

The Government approved further development of the repository in 2009 in spite of the IEER report and even though the Bure CLIS made a direct call to members of the Parliament not to approve such further development. However, the conclusions of the IEER study appeared to have influenced the national policy process [38]. ANDRA seems to have integrated some of the recommendations into its current work program, the Parliamentary Office for the Evaluation of Scientific and Technological Choices considered some of the points made by the IEER, and the report helped mobilize the national press on the issue of deep geologic disposal of radioactive waste.

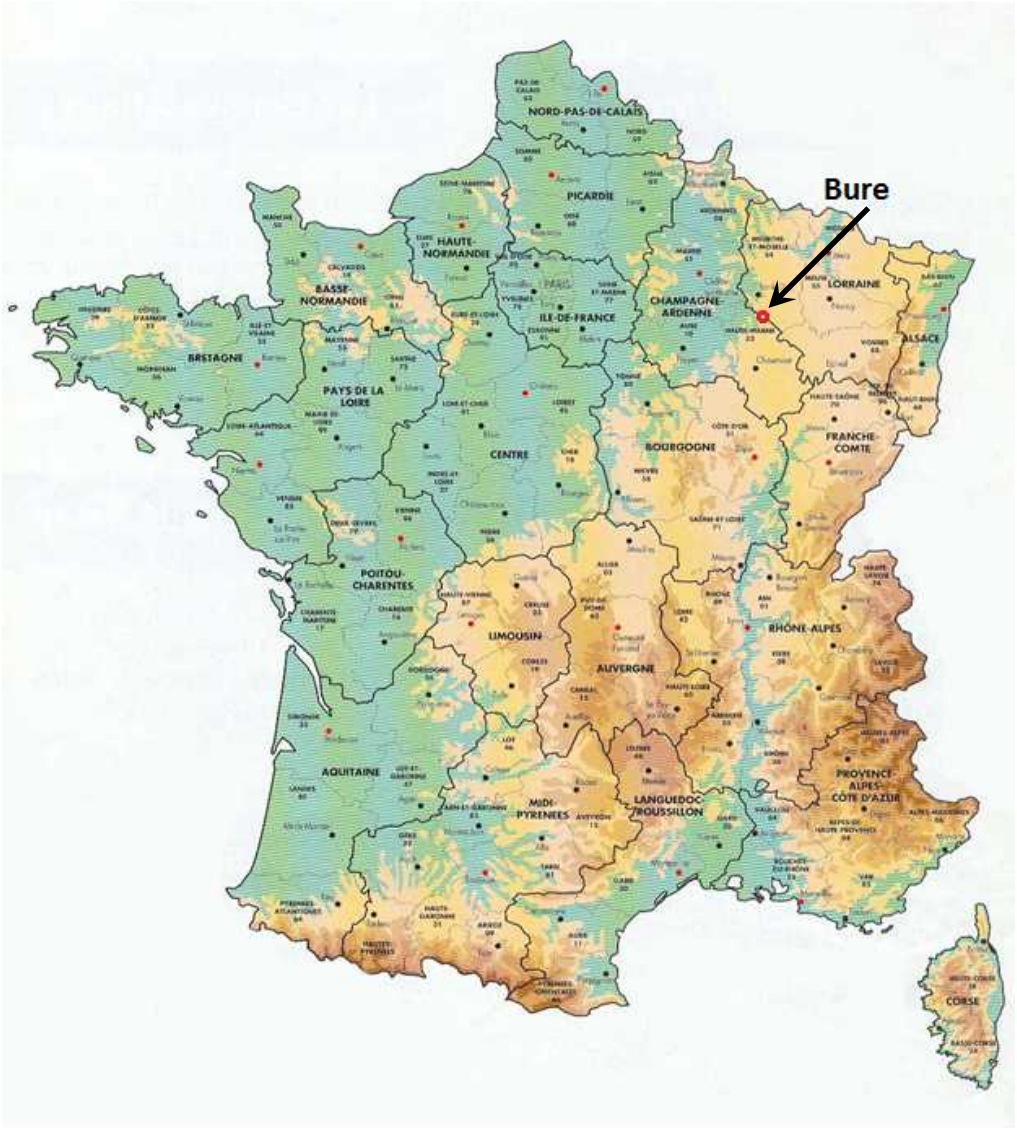

Figure 2. Location of Bure in France

ANDRA calls the reversible geological disposal facility for radioactive waste at Meuse/Haute-Marne "The Cigéo Project" and produced a report regarding The Cigéo Project in preparation for the public debate required by the 2006 Planning Act [40]. The public debate was originally scheduled to begin May 2013 and to end October 2013, but opponents to the project disrupted the meetings, forcing the National Commission on Public Debate to reschedule the meetings. A revised method for public interaction was developed as well. The Public Debate ended on

December 15, 2013 [43] and the State will take the input from the public into consideration when it makes a decision regarding the creation of the Cigéo Disposal facility [44].

ANDRA is scheduled to submit the license application in 2015, and it will be reviewed over the course of several years by the National Assessment Board, the French Nuclear Safety Authority, the local authorities, and Parliament. The license will be granted only after passage of a new act stipulating that the repository be reversible and after a local public inquiry is held [40].

It is worthwhile to note that in 2008, France and ANDRA began a search for volunteers to host a disposal site for low-activity long-lived waste, such as radium-bearing waste and graphite waste. About 40 towns volunteered, and two were chosen by the government, based on ANDRA's assessment of suitability, but these two towns withdrew their support under pressure from opponents. A working group was then set up to obtain feedback and propose recommendations. ANDRA will use the recommendation as it moves forward with a new solution for disposing of low-activity long-lived radioactive waste. ANDRA is currently conducting scientific studies and consulting with various sites, and will deliver a report with the results of the studies and consultations to the Government in 2015.

It is also worthwhile to note that France has experienced the successful siting of a repository for industrial waste. In the French Mid-Pyrenees, the development of a Regional Plan for Elimination of Special Industrial Waste (as required by law) and the implementation of a repository for industrial waste was supported by an extensive dialogue process that went well beyond that required by law. An *ad hoc* body that had no decision powers, the Regional Observatory of Industrial Waste of Midi-Pyrénées (ORDIMIP), helped steer the decision process from 1993 to 2000. It gathered stakeholders in the region and managed the dialogue process for different tasks, such as formulating recommendations for a regional policy for industrial waste management and following up the implementation of a repository. The ORDIMIP was involved from the preparatory phase until the repository was implemented, and played a key role in the evaluation of the six proposed repository projects. The ORDIMIP was also able to participate in defining the evaluation criteria, requirements, and specifications that were to be used in analyzing the various proposals. In this process, all stakeholders had a common goal of not having to depend on another region for disposal of its chemical waste [45].

3.2.3 IMPORTANT ELEMENTS IN THE SITING PROCESS

The retrievability/reversibility issue is important to the public and is mandated in the 2006 Planning Act. "Reversibility" allows for an operational stepwise disposal process driven by a political decision-making process, and provides flexibility in repository construction and operation with the possibility of design evolution at all steps, including the option of going backwards one or more steps, during the whole process of construction and operation. Before the 2006 Planning Act was passed, when the government authorized the creation and operation of an underground research laboratory at Bure in (Meuse district) in 1998, retrievability was to be considered as part of the R&D program. This requirement was the result of the various opinions expressed by the local municipality and district councils during the 1997 public inquiry associated with the underground research laboratory license application filed by ANDRA [37].

The consent of the municipalities located near the proposed HLW repository is not required for a construction license to be issued. Those opposed to the repository have opportunity to express their opinion during the public debates that are mandated by law prior to issuance of a construction authorization, and ANDRA has made some changes to its approach as a result opinions expressed during the public debate [46].

3.2.4 REQUIRED INFORMATION AND EXPERTISE

ANDRA provided its research program to the Bure CLIS in November 2001 and provided updates as needed. CLIS also established a person to act as a liaison to the Bure CLIS when the CLIS was first established [38]. The Bure CLIS was also able to contract with the IEER to perform an independent study of the work that ANDRA was doing, and had the necessary funding to place the contract. ANDRA cooperated with the Bure CLIS and the IEER by providing the documents that allowed these organizations to perform their independent assessment, and ANDRA commented on IEER's report.

The Bure CLIS worked to develop its technical expertise so that it would be able to understand the issues related to the Bure site, and to understand and challenge the work of ANDRA. The CLIS has set up a scientific secretariat so that it can have a permanent scientific capacity [47].
ANDRA has involved the Bure CLIS in the process of deciding the location of the surface facilities for Cigéo, and recently has set up a liaison committee to interact with the Bure CLIS. Through this committee, ANDRA will transmit technical documentation once it is published, and the Bure CLIS will provide questions asked by the public. ANDRA also occasionally invites local town councils to tour its Underground Laboratory, and has a traveling exhibition titled "Radioactivity from Homer to Oppenheimer" that provides easy to understand and comprehensive information on the subject of radioactivity. In addition, in 2009 ANDRA opened The Technological Exhibition Facility near the underground laboratory for the purpose of presenting the Cigéo project to the public. It has, for example, prototype waste containers and the robots developed for remote handling of the waste containers [48].

The Basic Safety Rules for repository safety were issued in 1991 by the Nuclear Safety Authority. These rules are 1) absence of seismic risks in the long term, 2) absence of significant water circulation inside the repository, 3) rock suitable to underground installation excavation, 4) confinement properties for radioactive substances, 5) sufficient depth to keep the waste safe from potential aggressions, and 6) absence of nearby rare exploitable resources. The dose threshold established by the Basic Safety Rule is 0.25 mSv/year [42].

3.3 SWEDEN

In March 2011, the Swedish Nuclear Fuel and Waste Management Company (SKB) submitted a license application to the Swedish Radiation Safety Authority and to the Environmental Court for a repository for SNF at Forsmark near Östhammar [49]. The Forsmark repository is to be ~500 m deep in granitic bedrock, and full construction is expected to start in 2015. In November 2006, SKB submitted a license application to build an encapsulation plant in Oskarshamn [29].

3.3.1 THE SWEDISH SITING PROCESS

The Nuclear Power Stipulation Act of 1977 was passed against the backdrop of a struggle between pro-nuclear and anti-nuclear groups in Sweden. This law dictated that before any new reactor could be fueled, the reactor owner had to show how and where the waste from the reactor could be disposed of with absolute safety. This act forced reactor owners and developers to focus on developing a long-term solution to the problem of how to dispose of SNF or HLW from reprocessing long before the waste was generated [50].

SKB, which is owned by the nuclear power producers, is responsible for both the short- and long-term management of the waste. It should be noted that Sweden owns one reactor, and is, thus, part of SKB. Regulation of nuclear energy was overseen by the Swedish Radiation Protection Institute and the Swedish Nuclear Power Inspectorate until 2008, at which time the two organizations merged to form the Swedish Radiation Safety Authority (SSM) [50].

The Nuclear Power Stipulation Act was replaced by the Nuclear Activities Act in 1984. This law stipulated that the licensing process for nuclear waste facilities is based on the safety case submitted by SKB to what is now SSM. Thus, SSM is the licensing authority for Sweden.

The Environmental Code, passed in 1999, stipulated that the licensing process for nuclear waste facilities is also based on the review of the Environmental Impact Assessment submitted by SKB to the appropriate regional Environmental Court in Sweden. In addition, according to Chapter 17, Section 6 of the Environmental Code, the Government may permit nuclear waste facilities only if it has been approved by a municipal council, or if it "…is of the utmost importance with regard to the national interest" and no other sites are considered more appropriate or another site is likely to approve of such a facility. This law also required that consultations be made with those affected by the repository and the general public, creating opportunities for the public to influence the design and layout of the facilities, as well as the scope and content of the Environmental Impact Statement. During the siting process, 60 meetings were held at the local level, involving municipalities and regional organizations. The Environmental Code also provides a legally binding set of rules on the information flows that are part of the decision-making process. See Figure 3 for an illustration of the Swedish licensing procedure.

Nuclear generators are responsible for the costs of managing and disposing of spent fuel, and must provide for those costs as they go, the "polluter pays principle." They pay a fee set by the government to the Nuclear Waste Fund, which is administered by SSM to cover waste management and decommissioning. Funds from the Nuclear Waste Fund have also been made available to environmental and other non-governmental organizations so that these organizations can participate in the evaluation and public auditing of Swedish nuclear waste management policy. Municipalities involved in the siting process described below availed themselves of this funding to facilitate their involvement in the process [29], [50]. National non-governmental organizations receive money to support their participation from the Nuclear Waste Fund while local non-governmental organizations receive it from the municipality. The prerequisite for receiving money is to participate in the Environmental Impact Assessment process. The decision on a budgetary request from a non-governmental organization – as well as for concerned municipalities – is made by SSM [51].

The 1984 Act on Nuclear Activities also stipulated that SKB submit a report on research, development, and demonstration every three years to be able to apply for funding from the Nuclear Waste Fund. This report is to be reviewed by SSM, the municipalities that SKB is investigating, environmental groups, and the Swedish national Council for Nuclear Waste. SSM collects all the review statements and submits a final audit document to the government. SKB then responds to these review statements, and the reviewers are allowed to provide comments again on SKB's response before the government decides whether to approve further support of the KBS project [50].

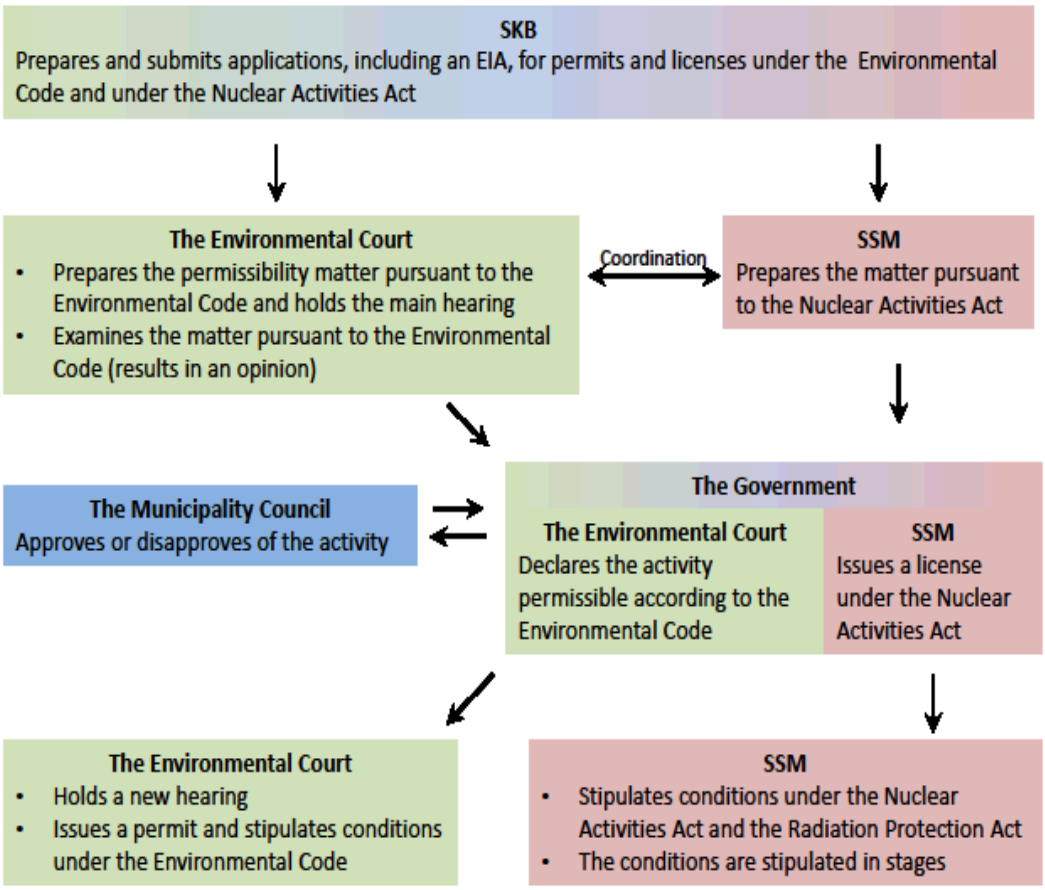

Figure 3. The Swedish Licensing Procedure [52]

3.3.2 HOW THE SITING PROCESS WAS IMPLEMENTED

Sweden's first attempt to address the nuclear waste problem consisted of a committee established in 1972, the AKA (Använt Kärnbränsle och radioaktivt Avfall). This committee's 1976 report was primarily concerned with the security of the nuclear fuel supply, and only secondarily concerned with disposal of radioactive waste. At the time, the approach to disposal of SNF was to store the fuel at a central interim storage facility prior to reprocessing, reprocess the fuel, vitrify the resulting waste, encapsulate the vitrified waste in canisters, and dispose of the

canisters at a depth of at least 200 m in bedrock, surrounded by clay. The two sites suggested for interim storage, reprocessing, and disposal were Oskarshamn and Forsmark/Östhammar, municipalities where nuclear reactors were already operating. However, growing disenchantment with nuclear power in Sweden and with reprocessing, and the passage of the Nuclear Power Stipulation Act in 1977 made nuclear waste management a high technical and political priority, and led to developing the current approach to waste disposal: direct disposal of spent fuel at a depth of 500 m in crystalline bedrock, buffered by bentonite clay [50].

Studies of the Swedish bedrock began in 1975, before the Nuclear Power Stipulation Act was passed in 1977. These studies had the goal of gathering knowledge about the Swedish bedrock and what properties the rock must have to be able to dispose of SNF safely. The strategy was to locate the repository in one of the crystalline rock types that dominate Swedish bedrock. Studies were conducted at 17 sites all over the country with the objective of identifying areas for more detailed investigation. The criteria were [53]:

- Flat bedrock topography
- Low fracture frequency on exposed rock surface
- Widely spaced major fracture zones
- Uniform composition and structure of the rock mass
- Areas with low seismic activity
- Documented low water flow rate in the rock mass

In conjunction with gathering knowledge regarding the Swedish bedrock, hard rock was tested in realistic environments. The Stripa Mine in Bergslagen was used from 1976 to 1992 to develop methods for investigating and characterizing the bedrock and to study the thermomechanical properties of the rock mass and the function of the bentonite buffer, borehole plugs, and tunnel plugs. In addition, the Äspö Hard Rock Laboratory near Simpevarp in Oskarshamn was used to develop, demonstrate, and test the KBS method of SNF disposal [53].

One of the conclusions of this step was that the local characteristics of the bedrock were the greatest importance in identifying suitable and less suitable sites. Another lesson was that the siting work had to be based on the acceptance and confidence of the local populations. Some of the investigations were met with local resistance and protests, and SKB did not see the point of continuing siting work in a hostile community [53].

In the fall of 1991, SKB began a siting project that included feasibility studies. In this siting project, SKB focused its efforts on municipalities with both suitable conditions and a population that was willing to participate, or that at least showed an interest, in further exploring the idea of hosting a SNF repository [53].

Between 1992 and 2000, SKB discussed the possibility of conducting feasibility studies with about 21 municipalities. Feasibility studies were actually conducted in eight of the municipalities; in the remaining 13 municipalities, discussions were discontinued either because SKB found that a feasibility study was not warranted or because the municipality chose to decline [53].

The feasibility studies had two objectives. One was to identify areas with bedrock that was suitable for safe disposal of SNF, and that had suitable technical, environmental, and societal conditions. The other was to give the municipality and its residents an opportunity to form an opinion on the final repository project and consider their possible further participation, without any commitment on their part. With this second objective in mind, SKB had active dialogues with private citizens, the municipality, and the country administrative board [53].

During the feasibility studies, the following questions were investigated and answered [53]:

- What are the general prospects for siting a final repository in the municipality?
- Where could suitable sites exist for a final repository with reference to geoscientific and societal conditions?
- How can transportation be arranged?
- What are the most important environmental and safety issues?
- What are the possible consequences, positive and negative, for the environment, the economy, tourism, and other business enterprises in the municipality and the region?

The procedure used was as follows [53]:

- Study the general conditions in the municipality with regard to the above questions.
- Exclude those areas that did not have sufficiently good chances of satisfying the requirements for the bedrock.
- Rank remaining areas based on an overall assessment where technical and environmental siting aspects were also considered. Select areas for geological field checks.
- Present the results in a preliminary final report, which was circulated for comment by the municipality along with other study material.
- Perform geological field checks and other supplementary work.

- Compile results, taking into account viewpoints offered during the review process. Evaluate siting alternatives and rank in order of priority, and present a final report on the whole feasibility study.

As a result of local referendums after the feasibility studies, two of the eight municipalities declined further participation in the siting process. In one of the remaining six municipalities, SKB concluded that the probability of finding sufficient volumes of suitable bedrock was too low to warrant further investigation. In the five remaining municipalities, SKB identified eight siting alternatives that were judged to be sufficiently promising to warrant further study, and to be of sufficient breadth and quality such that the selection process could move toward prioritizing a smaller number for site investigation [53].

SKB then ranked the eight siting alternatives based on the bedrock, the industrial establishment (e.g., available infrastructure, environmental impact, land availability), and societal aspects (e.g., political and popular support). With respect to societal aspects, SKB conducted option surveys to evaluate the prospects of proceeding with site investigations. Some sites were more open to the idea than others; some had groups actively opposing further involvement in the process. At some sites, SKB decided that the uncertainties in obtaining the necessary local support were great enough that it was not worthwhile to carry out further studies. SKB noted that "confidence in SKB's activities is deemed to be most stable in those localities where nuclear activities have long existed" [54]. The top two sites selected for further investigation (Simpevarp and Forsmark) both had nuclear facilities already; the interim storage facility is located at Simpevarp .

In 2000, SKB announced it had selected Forsmark in the municipality of Östhammar, Simpevarp (later designated Laxemar) in the municipality of Oskarshamn., and the northern part of Tierp Municipality for test drilling and further site investigations. It had also decided to conduct additional studies of the prospects for the Skavsta/Fjällveden area in the municipality of Nyköping. This decision was subject to regulatory review and a Government decision. SKI (the Swedish Nuclear Power Inspectorate) agreed with the decision to commence site investigations in Forsmark and Simpevarp.[a] SKI did not object to SKB's conducting site investigations in Tierp as well, but thought that there were some weaknesses in the arguments for selecting Tierp. KASAM (the Swedish National Council for Nuclear Waste) supported SKB's choice of sites for site investigations and, for the most part, the arguments for those choices as well [53].

The Nyköping Municipality decided not to let SKB continue with its investigations in the municipality, as did Tierp in April 2002. The municipal council of Östhammar decided to consent to the site investigation in December 2001, and the municipal council of Oskarshamn made a similar decision in March 2002. Thus, SKB was able to initiate site investigations in

[a] Prior to 2009, the Swedish Radiation Protection Institute (SSI) developed radiation protection standards and the Swedish Nuclear Power Inspectorate (SKI) handled implementation. In 2009, these functions were merged into the Swedish Nuclear Power Authority (SSM)

Forsmark in the municipality of Östhammar and in Simpevarp in the municipality of Oskarshamn [53].

The overall goal of the site investigation phase was to prepare a license application for a repository. The most important activities were to [53]:

- Carry out investigations in Oskarshamn
- Carry out investigations in Forsmark
- Produce descriptions of the investigated sites as a basis for site-adapted repository solutions, safety assessments, environmental studies, and environmental impact assessments,
- Design facilities, systems, and infrastructure for final repositories on the investigated sites to a level that can serve as a basis for the facility descriptions and safety assessments that are to be included in the application.
- Produce safety analysis reports for the long-term safety of the final repository and the operation (including transportation) of the facility on the investigated sites,
- Carry out studies as a basis for assessing the impact on environment, human health, and society of planned facilities and activities,
- Carry out the prescribed consultations and other communication with concerned parties and the public,
- Devise a program for the construction phase
- Produce the Environmental Impact Statement that should accompany the applications.

After these activities were carried out, SKB performed an integrated evaluation of all the information collected to select and justify a site for the final repository choice and to compile a license application. After several years of investigation and evaluation, on June 3, 2009 SKB chose Forsmark in the municipality of Östhammar as the site for the repository, and chose to place the encapsulation plant adjacent to the central interim storage facility for SNF in Oskarshamn [53]; see Figure 4 . It should be noted that, before this decision was made, both municipalities adopted comprehensive plans to begin physical planning for a possible final repository in their respective municipalities. The license application for the repository in Forsmark was submitted on March 16, 2011.

Figure 4. Forsmark, Östhammar Municipality in Sweden [53]

3.3.3 IMPORTANT ELEMENTS IN THE SITING PROCESS

SKB is the organization that implemented the siting process and submitted the license application for both the repository and the encapsulation facility. It is jointly owned by the owners/licensees of the nuclear power plants operating in Sweden.

One of the roles of the SSM is to collect fees that go into the Nuclear Waste Fund, as well as to approve reimbursements from the Fund, perform audits, and control the use of fund assets. SSM decides the fees based on information from SKB, suggests the fee to the government, which then decides on the fee that the nuclear power plant licensees must pay. The Fund covers costs associated with management and disposal of waste from nuclear activities, spent fuel management, construction of new facilities, research and development, decommissioning and dismantling of all nuclear facilities, waste management, management of legacy waste, regulatory supervision, and the involvement of local communities and non-governmental organizations in the site selection process.

The Environmental Court, which was established by the Environmental Code of 1998, reviews the Environmental Impact Statement prepared by SKB for permissibility and provides an opinion to the Government with respect to permissibility. If the Government finds the activity to be permissible, it returns authority to the Environmental Court, which holds a new hearing and issues a permit [52].

The municipalities of Östhammar and Oskarshamn played significant roles in the siting process. A municipality is smaller than a county but incorporates several distinct communities in cities or villages. Östhammar municipality is part of Uppsala county and the 2010 census counted 21,389 residents. Oskarshamn municipality in Kalmar county in 2010 counted 26,235 residents. They are situated respectively in the central eastern and south eastern part of Sweden and cover respectively 3,508 and 2,295 square kilometers. Each contains nuclear energy installations [51]; three reactors in Oskarshamn and three reactors in Forsmark [29].

During the siting process described above, Oskarshamn insisted on funds being made available from the Nuclear Waste fund to support local engagement in the siting process, and also insisted on having veto power such that they could pull out of the siting process if they so desired [50]. The municipality of Oskarshamn is now involved in reviewing the application for the encapsulation plant. It has established a strategy group, which focuses on social planning, spatial planning, and infrastructure; and a review group, which considers radioactive protection and other environmental issues. The municipality of Oskarshamn must approve the license application for the encapsulation plant if it is to be built. Elected leaders of Oskarshamn will make the decision [51].

The municipality of Östhammar, where the repository is planned to be located, established three different committees: the long-term safety committee, the environmental impact assessment committee, and the consultative committee working party. The municipality is reviewing the license application for the repository, considering long term safety, environmental impacts, health effects, and socio-economic impacts. The municipality of Östhammar must approve the license for constructing the repository if it is to be built. This decision is made by the elected leaders of Östhammar [51].

Various non-governmental organizations played an important role in the siting process as well. National non-governmental organizations received money from the Nuclear Waste Fund while local non-governmental organizations received funds from their local municipality. The prerequisite for receiving money was to participate in the Environmental Impact Assessment process, which is the vehicle that the non-governmental organizations used to involve themselves in the siting process.

SKB and the two municipalities (Oskarshamn and Östhammar) created an Added Value Program in April 2009, before SKB had decided on a location for the repository, but while both municipalities were being investigated. The two municipalities felt that SKB should acknowledge the effort expended by the two municipalities in trying to solve an important national issue, and that an added value program would enable the municipalities to partner with SKB and create synergies. In the Added Value Program, 75% of the additional value is to go for the benefit of the municipality where the repository was not to be constructed, 25% was to go for

the benefit of the municipality hosting the repository. The Added Value Program differs from the Nuclear Waste fund in that the Added Value Program has a wider scope, such as constructing ferry terminals, funding various educational efforts, etc.[51].

In the early 1990's, SKI initiated the Dialogue Project in which SKI adopted a more communicative approach, and simulated a licensing process. One of the recommendations to come out of this project was that non-governmental organizations should be given financial support if they are to have an effective voice in discussions. Other results of the project were that the regulator can participate in the early stages of a siting process without losing credibility as an independent reviewer of a license application, and that organizations with conflicting interests and views can reach agreement on the basis for decisions [51].

In May 2011, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development held a workshop and community visit in Sweden to provide an overview of the Swedish nuclear waste management program from the perspective of SKB, SSM, the municipality of Oskarshamn, the municipality of Östhammar, and non-governmental organizations. Some of the conclusions of this workshop were [51]:

- Technical soundness is a part of a well-meaning process but it is not enough; procedural fairness is important.
- Stakeholders need access to understandable information. Some tools and methods may be site-specific, but in other cases, what works for one country might work for others and have universal value.
- Stakeholder confidence is never established once and for all. It needs continuous work and upkeep.
- Providing access to all information and documents and allowing enough time for deliberations are important factors for success.
- The veto authority given to municipalities was critical to successful siting.
- Working groups must have access to independent experts not related to the implementer.
- Being informed and being included are different matters; real public involvement should be pursued.
- The citizen competence organizations should be adjustable depending on how the process evolves and the phase of the program.
- Involvement processes should not make a distinction between social and technical issues.

- Consensus is not the goal in the working groups, but real influence and participation. In this way transparency allows trust to be gained.

- Giving non-governmental organizations financial support was one of the core issues in stimulating dialogue between industry and local authorities.

- Local stakeholders trust the regulator, SSM, who will be involving the stakeholders during its review of the license application.

3.3.4 REQUIRED INFORMATION AND EXPERTISE

The information and expertise needed to produce an Environmental Impact Assessment was required. This would require expertise in several technical areas, such as geology, biology, materials science, etc. The necessary information needed to be available to multiple organizations, as well as understandable to people and organizations that didn't necessarily have technical backgrounds.

4. SUMMARY AND INSIGHT

The above sections summarized the status of siting radioactive waste disposal, treatment, and storage facilities for several countries, and provided a more in-depth discussion of the siting process for three countries (Finland, France, and Sweden) that are further along in the siting process. Some of the factors that seem relevant to the siting process for these three countries are summarized in Table 1 below.

In examining Table 1, it can be seen that there were a few factors that all three siting processes had. First, all three had a defined method for public participation. Two (Finland and Sweden) were through the mandated Environmental Impact Assessment process, while France's process involved mandatory public debate and the mandatory formation of local information committees. Second, all three have an underground research laboratory that has been functioning for several years and producing information that can be used to evaluate the safety of the disposal system. Third, all three have a requirement that disposal be reversible or that the waste be retrievable. This requirement is sometimes created as a result of public input; the public seems more willing to accept a repository if decisions and activities to be taken in the future can be reversed, or if future generations can retrieve the waste and make it no longer hazardous by using technologies that have not yet been invented. Fourth, the siting process can take decades. Finland began its current siting process in 1987, so it has taken 27 years to get this far. It should also be pointed out that, although Table 1 indicates that Sweden began its *current* siting process in 1991, Sweden actually began thinking about disposal of radioactive waste much earlier and developed the idea of direct disposal of spent fuel at a depth of 500 m in crystalline bedrock, buffered by bentonite clay, in 1977, 37 years ago.

It is also worthwhile to note that in Finland and Sweden, countries in which the affected municipality has a right to veto the siting of the repository, the sites that consented to the repository were already familiar with nuclear energy. Olkiluoto has two nuclear reactors, while Forsmark has three nuclear reactors. It would seem that familiarity with the nuclear fuel cycle is helpful in obtaining consent from a community to locate a nuclear waste facility in that community.

Table 1. Factors in Siting Processes for Finland, France, and Sweden.

	Finland	France	Sweden
Is consent required from the affected municipality(ies) prior to submission of license application?	Yes (Eurajoki Municipal Council)	No	Yes (Östhammar council)
Is monetary compensation given to sites that agree to host the disposal facility?	No	No	Yes (75% went to site not selected, 25% to site selected)
Type of agency tasked with designing, licensing, and operating repository.	Business (Posiva Oy)	Government (ANDRA)	Business (SKB)
Is funding available for community groups?	No	Yes	Yes
Is a mechanism for public participation established as part of the siting process?	Yes (Environmental Impact Assessment process)	Yes (Local Committee of Information and Monitoring (CLIS) and public debate)	Yes (Environmental Impact Assessment process)
Does an Underground Research Facility exist?	Yes (Onkalo)	Yes (Meuse/Haute-Marne)	Yes (Äspö Hard Rock Laboratory)
Is the proposed repository near existing nuclear facilities?	Yes (Olkiluoto 1 and 2)	No[1]	Yes (Forsmark 1, 2, and 3)
Organization(s) with which affected municipalities have regular communication.	Posiva Oy STUK	ANDRA	SSM SKB
Is there a requirement that disposal be reversible or that the waste be retrievable?	Yes	Yes	Yes[2]
Population density in region of proposed repository	13 persons/km^2 (in 2009)	5 persons/km^2 (in 2007)	6 persons/km^2 (in 2010)
Type of waste disposed of	SNF	HLW	SNF
Year in which current siting process began	1987	1991	1991

Note 1: The surface disposal facilities for very LLW, short-lived LLW, and ILW are located about 60 miles west of Bure in the Aube district.
Note 2: Implied by the requirement that that handling of the waste from today's energy generation shall not impose undue burdens on future generations [54].

APPENDIX A: ADDITIONS MADE TO THE SITING EXPERIENCE DATABASE

The following documents were added to the Siting Experience Database:

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