Paper #3: What Is Happening in Other Countries?

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Nuclear Waste Management Organization

The Nuclear Waste Management Organization (NWMO) was established in 2002 by Ontario Power Generation Inc., Hydro- Québec and New Brunswick Power Corporation in accordance with the *Nuclear Fuel Waste Act* (*NFWA*) to assume responsibility for the long-term management of Canada's used nuclear fuel.

NWMO's first mandate was to study options for the long-term management of used nuclear fuel. On June 14, 2007, the Government of Canada selected the NWMO's recommendation for Adaptive Phased Management (APM). The NWMO now has the mandate to implement the Government's decision.

Technically, Adaptive Phased Management (APM) has as its end-point the isolation and containment of used nuclear fuel in a deep repository constructed in a suitable rock formation. Collaboration, continuous learning and adaptability will underpin our implementation of the plan which will unfold over many decades, subject to extensive oversight and regulatory approvals.

NWMO Social Research

The objective of the social research program is to assist the NWMO, and interested citizens and organizations, in exploring and understanding the social issues and concerns associated with the implementation of Adaptive Phased Management. The program is also intended to support the adoption of appropriate processes and techniques to engage potentially affected citizens in decision-making.

The social research program is intended to be a support to NWMO's ongoing dialogue and collaboration activities, including work to engage potentially affected citizens in near term visioning of the implementation process going forward, long term visioning and the development of decision-making processes to be used into the future The program includes work to learn from the experience of others through examination of case studies and conversation with those involved in similar processes both in Canada and abroad. NWMO's social research is expected to engage a wide variety of specialists and explore a variety of perspectives on key issues of concern. The nature and conduct of this work is expected to change over time, as best practices evolve and as interested citizens and organizations identify the issues of most interest and concern throughout the implementation of Adaptive Phased Management

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Three Discussion Papers on Community Engagement about Used Nuclear Fuel Storage and Disposal

November 2009

PAPER #3: WHAT IS HAPPENING IN OTHER COUNTRIES?

Important Note to the Reader:

> This paper contains a large number of web-links to Internet sites. Like information from any source, the information content one finds on any specific web site may range from highly reliable to seriously misleading. For example, Wikipedia entries are generally quite reliable, but specific details can be wrong or incomplete. *For any specific points that are important to you as a reader, always check and compare a number of different sources during your Internet search.*
>
> The web-links provided in this paper were active as of mid-November 2009. If you are searching for a specific document, and a web-link appears to be unusable, try a general search using the name of the document.

3A: Introduction.

At last count thirty-one countries around the world, among them Canada, were operating some 435 nuclear power plants to generate electricity, and thus also producing nuclear waste of different types. The first commercial-scale power plants commenced operations in a few countries in the mid-1950s and in 1968 in Canada. So far, no permanent storage or disposal facilities have been completed for wastes from these sources and the radioactive waste has been accumulating in various temporary storage facilities here and elsewhere for over fifty years. In most countries that have announced publicly a commitment to construct some type of permanent facility, the proposed timelines indicate that many more decades will elapse before those structures are ready to receive the wastes.

One important distinction in this area is between what is called "HLW" (high-level waste) and "L&ILW," that is, low- and intermediate-level waste.[*] As its name implies, HLW is highly radioactive when it is first handled, continues to generate heat and thus requires cooling for a number of years, and continues to be radioactive for very long periods of time. Some countries, notably Russia and the United States, also have substantial quantities of HLW originating in nuclear weapons production. In Canada's

[*] This account is based on NEA (1989) and Hystee (2008); see the References section at the end.

CANDU nuclear reactors, which use unenriched uranium as a fuel source, HLW is represented by the fuel bundles that are removed from the reactors at the end of their useful life.

L&ILW, on the other hand, has minimal radioactivity and does not require cooling or special shielding. In Canada L&ILW includes: operational low-level wastes from routine maintenance (mops, rags, etc.); operational intermediate-level wastes (e. g., reactor core elements); refurbishment waste (motors, valves, etc.); and, in the future, decommissioning waste (the entire nuclear reactor itself, when it is at the end of its useful life). L&ILW may also include radioactive wastes from medical, industrial, and research sources.

This paper deals primarily with HLW and summarizes what is currently known about the plans of various countries to deal with their high-level radioactive waste. All of the information is taken from publicly-available Internet sources, most of which are websites maintained either by national agencies that have legal responsibility for the waste within their borders, or international agencies with other types of mandates in this area. A complete list of the URLs for the Internet-based information sources is given in both the "Country Profiles" and the "References" sections later in this paper. Downloading and using the PDF file for this paper onto a computer with Internet access will enable one to click on these URLs and be taken directly to the various websites.

With a single exception (the website of the agency in France, which is in French), all of the chosen websites are in English. An attractive feature of many of these sites is the availability of maps, diagrams, and illustrations, such as drawings of the waste canisters and the engineering of sites. The WIPP facility in the United States (at Carlsbad, New Mexico) has an office located at the site that is open to the public, and one of the websites for the German proposed site at Gorleben features a "virtual tour" of the facility.[†]

3B: Overview.

In all cases where countries have given detailed consideration to the method of disposal, the preferred choice is an engineered repository placed 300-1000 metres underground in a suitable geological medium. "Suitable" refers to an underground formation that resists intrusion from water; granite rock, salt domes, sedimentary rock, and clay formations are all regarded as qualifying for this purpose.

The following nations have made public commitments to using deep geologic disposal for the long-term isolation of highly radioactive wastes: Belgium, Canada, China, Finland, France, Germany, Japan, Russia, Spain, Sweden, Switzerland, the United States, and the United Kingdom. In three of those countries – China, Russia, and

[†] http://www.dbe.de/en/sites/gorleben/1/index.php

Spain – there have only been announcements of future plans, without further details. In two others, Italy and South Korea, decisions have been taken quite recently that will result in the formulation of plans for repositories, but no specific directions have been set. But in Belgium, Canada, Finland, France, Japan, Germany, Sweden, Switzerland, the United Kingdom, and the United States, many years of detailed studies have been carried out in exploratory shafts and underground laboratories.

Of the countries named in the first list above, only Finland has actually chosen a repository site and set a date (2012) for the beginning of construction work. Sweden is perhaps next in line, announcing in June 2009 the choice of a site near the community of Östhammar, which has shown strong community support for hosting a facility. At the other end of the spectrum, in the United States, where the Yucca Mountain location had been originally chosen twenty-two years ago, in 1987, the siting process seems to be grinding to a temporary halt as a result of determined opposition from the state of Nevada and others. As of early 2009, the U. S. Secretary of Energy had decided to strike a special panel to examine an alternative plan for high-level radioactive waste disposal.

The following section contains brief accounts of the current situation for the disposal of HLW in selected individual countries. The phrase "NEA profile" stands for the most current information available on the website of the Nuclear Energy Agency, which is a specialized agency within the OECD (Organisation for Economic Co-operation and Development). Based in Paris, the organization provides its member countries with advice on nuclear safety, radioactive waste, nuclear science and law, and related areas. (Go to: http://www.nea.fr/).

All of the countries listed below are among those which have adhered to the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management," which came into force in 2001 and is managed by the International Atomic Energy Agency (IAEA), a United Nations entity. The Convention specifies the obligations, which the contracting parties have agreed to, with respect to the management of radioactive materials:

- http://www.iaea.org/Publications/Documents/Conventions/jointconv.html
- http://www.iaea.org/Publications/Documents/Infcircs/1997/infcirc546.pdf

Of course, not all countries that are currently operating civilian nuclear reactors have revealed their plans for dealing with HLW on a long-term basis. But, based on publicly-available information, it appears to be accurate to say that all nations which have announced plans for dealing with HLW to date have indicated that they will construct a deep geologic repository for these wastes.

3C: Country Profiles.

1. Belgium.

Belgium has been generating electricity from nuclear power since 1975, but in 2003 the federal parliament approved a measure to begin a gradual phase-out of commercial nuclear power plants beginning in 2015. In 1980 the government created a separate agency, the Belgian Agency for Management of Radioactive Waste and Enriched Fissile Materials, known by the French/Dutch acronym ONDRAF/NIRAS, with responsibility for both HLW and L&ILW.

The agency opened an underground research laboratory, the High Activity Disposal Experimental Site, in the so-called "Boom clay" layer in the Mol-Dessel area of Belgium, where work continues up to the present time. The 2005 NEA profile (the most recent available) states: "The current plan for conditioned high-level and long-live, alpha-bearing waste is disposal in deep geological formations, and an extensive R&D programme, started in 1974, is concerned with assessing the use of a clay formation as host rock for a repository." An interim safety assessment completed in 2002 concluded that the Boom clay would provide a viable host material for long-term disposal of the country's HLW. The ONDRAF website states that the R&D program is ongoing and that final decisions about a timeline for developing the disposal site have not yet been made.

Websites:

- http://www.nirond.be/engels/1_index_eng.html [English-language website]
- http://www.nirond.be/francais/1_index_fr.html [French-language website]
- http://www.nea.fr/html/rwm/profiles/Belgium_profile_web.pdf

2. Canada.

In 2007 the Government of Canada accepted the recommendation, made by NWMO (the Nuclear Waste Management Organization), that used nuclear fuel produced in Canada (HLW) should be permanently stored or disposed of underground in a suitable deep geological repository located somewhere in the nation where a community agrees to serve as a willing host for this material. In May 2009 NWMO issued an "Invitation to review a proposed process for selecting a site" for a deep geologic repository.

The Government of Canada announced in January 2009 that an environmental assessment process was being commenced to review the proposal for a deep geologic repository for low- and intermediate-level radioactive waste (L&ILW) near the community of Tiverton, Ontario and the Bruce nuclear reactor site.

Websites:
HLW:

- www.nwmo.ca
- http://www.nwmo.ca/designingasitingprocess
- http://www.cnp.ca/nww/index.php [Nuclear Waste Watch, "a network of organizations concerned about high level radioactive waste and nuclear power in Canada"]

L&ILW:

- http://www.opg.com/power/nuclear/waste/dgr/index.asp
- http://nuclearsafety.gc.ca/eng/mediacentre/releases/news_release.cfm?news_release_id=331
- http://www.ceaa-acee.gc.ca/050/documents/31039/31039E.pdf

3. China.

China is now operating eleven nuclear power reactors, but the country is in the midst of a tremendous wave of construction for energy plants. In addition to many coal-fired plants, 15 new nuclear reactors are under construction and an additional 18 are in the planning stage, with many more on the drawing boards.

The Chairman of China's Atomic Energy Authority, Chen Quifa, gave a major speech on his country's nuclear policy in April 2009 at a NEA conference, including special mention of China's adherence to the international Joint Convention, which the national legislature had ratified in 2006. In this speech mention was made of a commitment to develop a deep geologic repository for high-level radioactive waste, but no further details or timelines were offered.

Websites:

- http://www.world-nuclear.org/info/inf63.html
- http://www.chinadaily.com.cn/china/2009-07/02/content_8346480.htm
  Newspaper article, "Nuclear power to rise ten-fold by 2020" (2009-07-02)
- http://www.caea.gov.cn/n602670/n621903/n621904/168676.html:
  "Chen Qiufa stressed the six rules on nuclear energy development" (2009-04-20)
- http://english.people.com.cn/200604/29/eng20060429_262209.html
  "China's legislature approves convention on nuclear waste management" (2006)

4. Finland.

Electricity generation from nuclear power began in Finland in 1977, and by 2008 nuclear accounted for about a quarter of total electricity supply. A proposal to establish a deep geologic repository, to be located in an underground granite formation at Onkalo, located a few miles from Olkiluoto, where a nuclear power plant is operating, was made ten years ago. Eurajoki, the host municipality, gave its approval in 2000 and the national government ratified the decision in May 2001. An underground research facility was established at the site in 2004; construction is scheduled to begin in 2012 and the disposal facility is expected to begin operating in 2020.

Websites:

- http://www.nea.fr/html/rwm/profiles/Finland.pdf
- http://www.stuk.fi/ydinturvallisuus/ydinjatteet/loppusijoitus_suomessa/loppusijoituslaitos/en_GB/laitos/
- www.posiva.fi/en/
- http://en.wikipedia.org/wiki/Olkiluoto_Nuclear_Power_Plant

5. France.

France began using nuclear energy to generate electricity in 1959, and of all nations using this energy source, France has by a wide margin the largest percentage of its national total produced in this way – 59 plants generating close to 90% of the nation's total, with additional amounts produced for export. France developed a major waste reprocessing facility for the enriched uranium fuel used in its reactor design; it also provides this service for waste shipped from Japan and the United States. A complex three-stage process, which recovers uranium and plutonium for re-use, is carried out first at the reprocessing unit at La Hague and then in two other uranium conversion facilities. Electricité de France (EdF) expects to generate 20% of its power from recycled uranium and plutonium by 2010. This recycling through reprocessing reduces considerably the volume of HLW that ultimately must be disposed of, but since some very hazardous wastes still remain, construction of a long-term disposal facility is required.

ANDRA (the National Radioactive Waste Management Agency) was established by legislation as the radioactive waste management authority in 1991. The French government passed the Nuclear Materials and Waste Management Program Act in June 2006. It declared that deep geologic disposal is the preferred solution for high-level and long-lived radioactive wastes, setting 2015 as the target date for licensing a repository and 2025 for opening it. An underground research laboratory has been established at Bure, in a clay formation, which lies in or near a small zone that is likely to be selected as the site of a repository. The current schedule indicates that during the years 2009-2013 a site selection process, including public input, will be carried out, with 2013 as the target date for selection of a preferred site. Following site selection, construction of a facility is expected to take ten years.

Websites:

- http://www.andra.fr/ [French]
- http://www.andra.fr/international [English]
- http://www.andra.fr/download/site-principal/document/inventaire/352.pdf [in French]
- http://www.nea.fr/html/rwm/profiles/France_profile_web.pdf
- http://www.world-nuclear.org/info/inf40.html
- http://en.wikipedia.org/wiki/Nuclear_power_in_France

6. Germany.

Commercial use of nuclear power began in Germany in 1961 and by 2002 nuclear plants were producing about a quarter of that country's electricity. However, in 2002 a law was passed instituting a moratorium on all new nuclear plants and requiring existing ones to be phased out between the years 2009 and 2023. The new federal coalition government, elected in September 2009, has promised to reconsider the phase-out of nuclear power.

The Federal Office for Radiation Protection (German acronym: BfS) has official responsibility for regulating high-level radioactive waste. As long ago as 1975 German legislation stipulated that HLW should be disposed of underground in a suitable geologic formation, and for most of that time formations known as salt domes have been preferred. One such site, Gorleben, was identified already thirty years ago as the best of these sites and preliminary exploratory work was carried out for many years until political opposition brought it to a halt in the year 2000. Further characterization of this site has been delayed indefinitely since that time.

Websites:

- http://www.bfs.de/en/bfs
- http://www2.kernenergie.de/r2/en/Gut_zu_wissen/Storage/interim-storage-conditioning-final-disposal.php
- http://www2.kernenergie.de/r2/en/Unsere_Position/Positionspapiere/Position/2008-03-01_Endlagerung.php?navanchor=2210006
- http://www.thebulletin.org/web-edition/reports/nuclear-waste-repository-case-studies/nuclear-waste-repository-case-studies-germ
- http://www.dbe.de/en/sites/gorleben/1/index.php
- http://en.wikipedia.org/wiki/Nuclear_power_in_Germany

7. Italy.

Italy is an unusual case, having begun its nuclear power program in 1963 and then abruptly shutting it down entirely in 1987, at the time when three plants were operating, as a result of the government's interpretation of the results of a national referendum held in the aftermath of the Chernobyl disaster. Plans had been put into place for decommissioning those plants and dealing with the HLW and L&ILW kept in temporary storage at the plant sites. But – despite a continuing flurry of laws, policies, and ministerial decrees – essentially nothing has been done except to "mothball" the sites.

Then, in July 2009, the Italian parliament passed a law authorizing ENEL, the country's electricity producer, to re-enter the nuclear sector. In August 2009 ENEL signed an agreement with Electricité de France, its French counterpart, setting up a joint venture under which at least four new nuclear plants will be built. The

government has promised to issue more ministerial decrees within a short period, dealing both with the sites for the new plants as well as for nuclear waste repositories.

Websites:

- http://www.world-nuclear.org/info/inf101.html
- http://en.wikipedia.org/wiki/Nuclear_power_in_Italy
- http://www.nea.fr/html/rwm/profiles/Italy_report_web.pdf
- http://www.neimagazine.com/story.asp?storyCode=2019592: "Italy's shutdown strategy," 03 December 2003
- http://www.neimagazine.com/story.asp?storyCode=2053568: "ENEL statement 'Return to nuclear, an historic choice' in English" (13 July 2009)
- http://www.neimagazine.com/story.asp?storyCode=2053745: "ENEL and EDF team up in Italy," 03 August 2009

8. Japan.

Japan began using nuclear-generated electricity in 1966 and by 2008 there were 63 nuclear reactors producing about 35% of the nation's power. For many years Japan has shipped used nuclear fuel to both France and the UK for reprocessing; the highly radioactive waste residues were vitrified (turned into a glass form) at the reprocessing sites and shipped back to Japan for interim storage. Japan has now constructed its own reprocessing facility as Rokkasho. NUMO, the Nuclear Waste Management Organization of Japan, has legal responsibility for dealing with radioactive wastes of all types. The Horonobe Underground Research Center carries out research and development programs on geological disposal for high-level radioactive waste.

On December 19, 2002, NUMO officially announced the "Start of Open Solicitation for Volunteers for Preliminary Investigation Areas (PIAs) for a HLW Repository," and all municipalities in Japan were eligible to apply. In January, 2005, Toyo town in Kochi prefecture submitted an application to become a volunteer area. This initiated an internal procedure at NUMO to confirm geologic conditions in Toyo, leading up to a more detailed literature survey of the area. Meanwhile, NUMO continued to call for other municipalities to volunteer. In April 2007, Toyo withdrew their application after the election of a new mayor who opposed the siting of a facility in the municipality.

Currently, Japan's announced timeline for the repository siting process is as follows:

1. 2008-12: selection of areas for detailed observation;
2. 2023-37: selection of a site for repository construction;
3. ~2025: design of a repository, start of construction;
4. 2033-37: start of operation.

Websites:

- http://www.numo.or.jp/en/
- http://en.wikipedia.org/wiki/Nuclear_power_in_Japan
- http://www.japannuclear.com/nuclearpower/program/waste.html*
- http://www.numo.or.jp/en/jigyou/new_eng_tab03.html
- http://www.jaea.go.jp/english/04/horonobe/index.html
- http://www.nea.fr/html/rwm/profiles/Japan_profile_web.pdf

*See the useful summary chart for HLW disposal plans on this site, which includes comparative timelines among Belgium, Finland, France, Germany, Japan, Sweden, and the United States.

9. South Korea.

The Republic of Korea began commercial production of nuclear power in 1978 and currently has twenty operating nuclear plants, which generate about 40% of the country's electricity. Korea is thus one of the nations in the world that is most heavily dependent on nuclear power for electricity generation. Additional nuclear plants are planned. Korea operates two different types of nuclear reactors (including the CANDU type), and HLW is kept in temporary storage at the reactor sites.

In a recent development, the government enacted a "Radioactive Waste Management Act" which came into force on the first day of 2009; among other provisions, it establishes a separate agency, the Korea Radioactive Waste Management Corporation, to manage these wastes. There are as yet no details about the type of HLW repository that will be chosen.

Websites:

- http://en.wikipedia.org/wiki/Nuclear_power_in_South_Korea
- http://www.nea.fr/html/rwm/profiles/Korea_profile_web.pdf
- http://www.nea.fr/html/law/legislation/updates/Korean%20RWMAct.pdf: Republic of Korea, "Radioactive Waste Management Act," 2008
- http://www.khnp.co.kr/tech/english/index.jsp

10. The Netherlands.

There is a single nuclear power plant in the Netherlands (Borssele) that supplies a relatively small percentage of the country's needs; discussion continues about whether to build any new nuclear plants. The Central Organization for Radioactive Waste (COVRA) stores HLW at the Borssele site, including the wastes that are returned from Britain and France after reprocessing. A deep geologic repository is considered to be the only viable option for long-term disposal of HLW, and there are candidate sites in both clay and salt formations. A research program on the feasibility of retrievable

disposal was completed in 2001, but no decisions have been taken on a process for finding a specific site.

Websites:

- http://www.thebulletin.org/web-edition/reports/nuclear-waste-repository-case-studies/nuclear-waste-repository-case-studies-the-
- http://www.nea.fr/html/rwm/profiles/Netherlands_profile_web.pdf

11. Russia.

Russia's commercial nuclear power plants date from 1963 and it currently has 31 operating reactors, with plans to expand that number considerably; Russia also exports nuclear power plants and technology to countries such as China, India, and Iran. Like the U. S., Russia (the former Soviet Union) also has varied, extensive, and extremely hazardous radioactive wastes from weapons and military applications.

Until 2008, when a new law on radioactive waste management was presented, Russia had no legislation dealing with these wastes. Article 30 of the bill proposed the creation of one or more deep geologic repositories for HLW and created the "Enterprise for Radioactive Waste Management RosRAO" as the responsible agency. At present, the State Atomic Energy Corporation "ROSATOM" still retains many responsibilities for nuclear wastes, with RosRAO scheduled to assume those roles in 2010. In terms of candidate sites for deep geologic repositories, mention has been made of sites in the Kola Peninsula, the Chita region, and Krasnoyarsk Region, all of them areas in the far north and east (Siberia) of the country, with the Nizhnekansky Rock Massif (Krasnoyarsk Region) appearing to be the first choice.

Websites:

- http://www.world-nuclear.org/info/inf45.htm
- http://en.wikipedia.org/wiki/Nuclear_power_in_Russia
- http://www.rosatom.ru/en/safety/
- http://rosrao.ru/eng/ [English: site under construction as of 11/09]
- http://www.minatom.ru/en/news/15681_19.06.2009
- http://www.greenworld.org.ru/?q=ang_rao_com:
  "New Russian law on radioactive waste management"

12. Spain.

Spain's nuclear program began in 1968 and its eight nuclear reactors currently supply about 20% of its electricity needs. Radioactive waste management was placed in the hands of ENRESA (Empresa Nacional de Residuos Radiactivos SA) in 1984. A law was passed in 2006 authorizing the construction of a centralized interim storage facility while research efforts to continue on the non-site-specific conceptual designs for a permanent deep geologic repository in a granite, clay, or salt formation.

Websites:

- http://www.world-nuclear.org/info/inf85.html
- http://www.nea.fr/html/rwm/profiles/Spain_profile_web.pdf
- http://www.enresa.es/ [click on English]

13. Sweden.

Sweden has been using nuclear power since 1972 and the ten plants currently in operation account for nearly half of all electricity generation in the country. In 2001 the government approved a process for site selection for the construction of a deep geologic repository.

In early June the Swedish Nuclear Fuel and Waste Management Company (SKB) chose Forsmark, in the municipality of Östhammar, a crystalline bedrock site, as the place for its deep geologic repository, where HLW will be emplaced at a depth of 500 metres. Östhammar is near Sweden's east coast, about 125 km northeast of Stockholm. For SKB this concluded a process lasting about twenty years, during which feasibility studies had been carried out in a total of eight municipalities that had expressed some interest in hosting the facility.

During the last stages of the process, the options had been confined to two candidates from that larger group – Östhammar as well as the Laxemar site in the municipality of Oskarshamn (where one of Sweden's nuclear power plants is located and where an interim storage facility also has been established). SKB explained its final choice of a site as being influenced by the particularly favourable qualities of the rock formation at Forsmark. However, SKB had made a commitment to the two communities that, no matter which one was chosen as the repository site, both would have an important role in the future development of the HLW disposal strategy and that both would benefit from the long-term infrastructure investments made for this purpose.

Websites:

- http://www.skb.se/default____24417.aspx
- http://www.vattenfall.com/www/vf_com/vf_com/365787ourxc/366203opera/555848newpo/557004biofu95352/1231919nucle/index.jsp
- http://www.thelocal.se/19852/20090603/:
  "Östhammar wins bid to store nuclear waste," 03 June 2009
- http://en.wikipedia.org/wiki/Nuclear_power_in_Sweden

14. Switzerland.

Commercial nuclear power operations begin in Switzerland in 1969 and there are now four nuclear power plants generating about 40% of the nation's electricity, and additional plants are planned. Implementation responsibility for waste management

has been devolved to the National Co-operative for the Disposal of Radioactive Waste (NAGRA), a consortium of the reactor operators. The country's Federal Council adopted a "Sectoral Plan for Deep Geological Repositories (Conceptual Part)" in April 2008. The plan sets out a three-stage process for site selection:

1. Identifying suitable sites based on safety and geological criteria;
2. Consultation with citizens in the proposed site areas and their participation in socio-economic studies, leading to a selection by NAGRA of at least two candidate sites for HLW;
3. Further geological characterization of the candidate sites, including drilling of exploratory boreholes, plus discussion of compensation measures with affected communities and specification of long-term monitoring programs.

Websites:

- http://www.nagra.ch/
- http://www.bfe.admin.ch/radioaktiveabfaelle/index.html?lang=en
- http://www.bfe.admin.ch/radioaktiveabfaelle/01277/01306/index.html?lang=en&dossier_id=02151
- http://en.wikipedia.org/wiki/Nuclear_power_in_Switzerland

15. The United Kingdom.

Great Britain, along with the United States, Russia, and France, is among the earliest users, beginning in 1956, of civilian nuclear power. The country is also one of the pioneers in nuclear fuel reprocessing, both for its own reactors and for used fuel shipped from other countries; reprocessing generates highly radioactive liquid wastes that are then vitrified and allowed to cool for long periods in interim storage.

The U. K. government is committed to developing a deep geological repository for HLW and its Nuclear Decommissioning Authority (NDA) currently is responsible for managing the process of site selection. The Department of Energy and Climate Change (DECC) has recently assumed regulatory oversight authority for radioactive waste. In June 2008 the government published a White Paper entitled "Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal" and also launched the voluntary process to site a facility. Since the launch two communities in the region of West Cumbria, located in the vicinity of the Sellafield nuclear chemical facility, which is owned by the NDA, have expressed interest in being considered as a host community for the disposal site.

The NDA also issued consultation documents on public and stakeholder engagement as well as on how environmental assessments of proposed sites are to be carried out. Specific suggestions have been made for engaging stakeholders at early stages in the decision process, including steps such as previewing work programs, participating in joint fact-finding programs, and reviewing the results of various work programs.

In 2003 the Government had appointed an independent group to review these issues – the Committee on Radioactive Waste Management (CoRWM). This group solicited expert advice, and also carried out an elaborate public and stakeholder engagement process, on a variety of disposal options for HLW, before presenting its recommendation for deep geological disposal in July 2006. The committee remains active in this area, issuing two long reports on geological disposal in July and October 2009 (see below). CoRWM maintains a website with current information as well as an elaborate document archive on its activities to date.

Websites:

- http://decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/nuclear/radioactivity/waste/waste/management/management.aspx
- http://www.official-documents.gov.uk/document/cm73/7386/7386.asp:
  "Managing Radioactive Waste Safely," June 2008 [PDF file]
- http://en.wikipedia.org/wiki/Sellafield
- http://news.bbc.co.uk/2/hi/europe/8155601.stm:
  BBC News, "U.K. nuclear waste strategy in jeopardy," 17 July 2009
- http://www.nda.gov.uk/
- http://www.corwm.org.uk/default.aspx
- http://www.corwm.org.uk/Pages/Current%20Publications/2550%20CoRWM%20Report%20on%20Geological%20Disposal%20Final%2031%20July%2009.pdf:
  "Geological Disposal of Higher Activity Radioactive Wastes," July 2009
- http://www.corwm.org.uk/Pages/Current%20Publications/2543%20CoRWM%20Report%20on%20RD%20Final%2030%20October%202009.pdf:
  "Report on national research and development for interim storage and geological disposal of higher activity radioactive wastes, and management of nuclear materials" (October 2009)

16. The United States.

Commercial nuclear power plants started operating in the United States in 1960, and currently 104 units are producing electricity, accounting for about 20% of the nation's power. Used nuclear fuel (referred to there as commercial spent nuclear fuel) is reprocessed and the resulting liquid wastes are vitrified and placed in temporary storage, awaiting long-term disposal in a deep geologic repository, a plan that was first announced in the *Nuclear Waste Policy Act* of 1982.

The U. S. also has, of course, significant quantities of military and defence-related material, which it calls transuranic waste (see the Wikipedia entry listed below). Beginning in 1999, the Department of Energy (DOE) has been sending a large amount of this material to the Waste Isolation Pilot Plant (WIPP), located near Carlsbad, New Mexico, where it is emplaced in caverns half a mile deep in the Permian Salt Formation in the Chihuahuan Desert. Some of these wastes are sent long distances across the country. For many years DOE has carried out elaborate design,

construction, and safety testing strategies for the containers and transportation modes used for shipping hazardous radioactive wastes.

Between 1982 and 1986 DOE screened a number of potential sites for a geologic repository for the commercial spent fuel, first narrowing the list to three; then, following almost 20 years of site characterization work at Yucca Mountain, this site was approved by a joint resolution of the U. S. Congress in 2002. In June 2008 DOE submitted a license application to the Nuclear Regulatory Commission for permission to begin constructing the repository at Yucca Mountain, with a projected start date for repository operations in 2017.

However, in March 2009 the U. S. Secretary of Energy, Steven Chu, announced that "Yucca Mountain as a repository is off the table" and that he would set up a panel of experts to recommend alternative sites and strategies for long-term disposal of commercial spent nuclear fuel. In an interview two months later Chu suggested that possibly a salt formation – which is the type of geological structure already used for WIPP and being studied by a number of other countries, such as Germany – could replace the Yucca Mountain site.

Websites:

- http://www.ocrwm.doe.gov/
- http://www.wipp.energy.gov/
- http://www.ocrwm.doe.gov/uploads/1/06237PD_The_National_Repository_at_Yucca_Mountain.pdf
- http://www.nrc.gov/waste.html
- http://en.wikipedia.org/wiki/Transuranic_waste
- http://www.nwtrb.gov/
- http://en.wikipedia.org/wiki/Yucca_Mountain_nuclear_waste_repository
- News results for **yucca mountain**
- http://www.technologyreview.com/business/22651/ [interview with Steven Chu, May 2009, on nuclear waste policy]

3D: Conclusions.

Military production of nuclear weapons began in 1945 and civilian nuclear power reactors used to generate electricity have been operating for almost sixty years. All of these uses of nuclear energy generate at least some residual wastes that are extremely hazardous due to radioactivity and that must be disposed of safely for very long periods of time. To date the only preferred type of solution for this problem is sequestration of the wastes in a deep underground geologic formation.

However, with the sole exception of the United States (at WIPP in New Mexico), no country has yet completed construction of a suitable facility for this purpose, and most countries utilizing nuclear energy are still some decades away from even starting this project. At the same time, construction of many new nuclear power plants, and active

planning for many additional ones, has accelerated around the world in recent years. Thus a great deal more HLW is very likely to be created and stored in temporary holding facilities over the coming decades.

The following chart summarizes much of what is known at this time about the state of progress in this area.

Table 3-1:
Status of Nuclear Waste Creation and Disposal at Present

	Category	Countries
A.	**Nations with HLW and L&ILW:**	
1.	Deep repository operating	United States (WIPP, New Mexico) [military waste only]
2.	Site for repository approved	Finland, Sweden
3.	Early stage of public engagement under way for eventual site selection	Canada, Japan, United Kingdom
4.	Technical assessment under way, no site selection process begun and/or completed successfully to date	Belgium, France, Germany, Netherlands, Slovak Republic, Spain, Switzerland, USA (commercial waste)
5.	Commitment to deep repository, technical assessment planned	China, Czech Republic, Hungary, Italy, Mexico, South Korea, Russia
6.	No disposal program under way or limited information available:	
	(a) large civilian nuclear operations	India (planned), Ukraine
	(b) smaller operations	Argentina, Armenia, Brazil, Bulgaria, Lithuania, Pakistan, Romania, Slovenia, South Africa, Taiwan
B.	**Nations with L&ILW only (plus a little HLW from research reactors):**	
7.	Disposal planning under way	Australia, Austria, Norway
C.	**Others with nuclear programs:**	
8.	Status unknown	Iran, North Korea
D.	**Nations announcing entry or re-entry into civilian nuclear power in future (proposed or planned):**	Albania & Croatia, Bangladesh, Belarus, Egypt, Israel, Italy, Jordan, Kazakhstan, Morocco, Persian Gulf States, Poland, Thailand, Turkey, Vietnam

Resources available on Internet Websites

(Web-links active as of mid-November 2009)

Individual Country Profiles: See section 3C above.

General:

- http://www.nea.fr/html/general/profiles/welcome.html [nuclear power]
- http://en.wikipedia.org/wiki/Nuclear_power
- http://en.wikipedia.org/wiki/Nuclear_power_by_country
- http://en.wikipedia.org/wiki/Nuclear_energy_policy
- http://en.wikipedia.org/wiki/High-level_radioactive_waste_management
- http://en.wikipedia.org/wiki/Radioactive_waste
- http://en.wikipedia.org/wiki/Deep_geological_repository
- http://www.ocrwm.doe.gov/factsheets/doeymp0405.shtml
- http://www.nea.fr/html/rwm/welcome.html
- http://www.nea.fr/html/rwm/profiles/
- http://www.radwaste.org/disposal.htm
- http://www-ns.iaea.org/tech-areas/waste-safety/disposable.htm

References for Further Reading

A. Papers from CARL [Citizens, Agencies, Researchers, Licensing Bodies in Belgium, Slovenia, Sweden and the UK]:

1. Bergmans, Anne (2006). "Stakeholders in radioactive waste management and their networks":
   http://www.carl-research.org/docs/20080416140742FQSF.pdf

2. Bergmans, Anne and others (2008). "Wanting the Unwanted: Effects of public and stakeholder involvement in the long-term management of radioactive waste and the siting of repository facilities":
   http://www.carl-research.org/docs/20080222112500ZGYI.pdf

3. Elam, Mark and G. Sundqvist (2007). "Six domains of decision for stakeholder involvement in nuclear waste management":
   http://www.carl-research.org/docs/20080416115521VAET.pdf

4. Kos, Drago and M. Polič (2008). "The framing of radioactive waste risk: A comparative analysis":
   http://www.carl-research.org/docs/20080523154926HCLB.pdf

B. Other Papers:

5. Hystee, R. J. (2008). "Proposed deep geologic repository for low and intermediate-level radioactive waste at the Bruce site, Tiverton, Ontario": www.nwmo.ca/publications?media_file_id=588

6. King, F. K [no date]. "OPG's deep geologic repository for low and intermediate level waste": http://www.euronuclear.org/events/topseal/transactions/Paper-Session-IV-King.pdf

7. Lidskog, R. and Anderson, A.-K. (2002). "The Management of Radioactive Waste: A description of ten countries": http://www.edram.info/fileadmin/edram/pdf/The_management.pdf

8. NEA 1989: Nuclear Energy Agency, "The management of low- and intermediate-level radioactive waste": http://www.nea.fr/html/brief/brief-06.html

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