

A “Smörgåsbord” of Lessons Learned During 32 Years of Siting and Developing Deep Geological Disposal Systems for Long-Lived, Highly-Radioactive, Wastes - 10056

Leif G Eriksson, Registered Professional Geologist
Nuclear Waste Disposition Consultant, Winter Park, Florida 32789-3252

ABSTRACT

Despite being generated since the early 1940s, at the end of 2009, the opening of the world’s first deep geological disposal system (repository) for used/spent nuclear fuel (UNF) or other high-level radioactive wastes (HLW) is still at least ten years away. In the meantime, UNF and HLW will continue to amass in temporary facilities around the world. It will also continue to feed a long-standing anti-nuclear urban legend that UNF and HLW cannot be safely disposed of and, therefore, all existing nuclear reactors should be closed and no new nuclear reactors should be built, which would result in energy shortages around the world, causing social unrest and financial collapses.

Based on more than 32 years of active involvement and monitoring of UNF and HLW disposal systems in the USA and abroad, this paper suggests that the Waste Isolation Pilot Plant (WIPP) repository in the USA, which has operated safely since 1999, convincingly dismisses the aforementioned urban legend by clearly demonstrating the proof of principle for safe deep geological disposal of long-lived, highly-radioactive, waste. It also conveys the notion that delays to the initially projected opening of a UNF or a HLW repository are inevitable but can be reduced by detailed knowledge about and timely implementation or avoidance, as appropriate of proven successful and unsuccessful repository-development components. The main related observations and conclusions are as follows:

1. National political agendas govern the time-lines and costs for the siting and development of disposal systems for long-lived radioactive materials (LLRMs).
2. Strong local public (and political) support can overcome national political agendas and “long-distance” anti-nuclear propaganda.
3. A robust, preferably multi-national, disposal concept, a “domestically-consistent” regulatory framework, and trustworthy implementation and oversight organizations are cornerstone prerequisites for strong and sustained local public acceptance and support.
4. International collaborations cost-effectively expedite domestic state-of-the-art know-how and strengthen both the robustness of and public confidence in the proposed disposal concept.
5. Repositories have at least a 12-year longer “gestation period” than a reactor, which seems to have been disregarded hitherto in the planning of new reactors.
6. Concurrent planning of a new reactor and the related waste-disposition systems (treatment, storage, and disposal), including “surplus” storage capacity, would reduce many and eliminate some of the adverse impacts of the inevitable repository development delays.

The above and other personal repository-siting and –development observations and lessons learned that, subject to additional analyses, could be used to advantage are thus described and discussed in this paper. However, the intent is not to suggest that there is a universal cookie-cutter template or a magic recipe that can be indiscriminately applied. The intent is to provide a “smörgåsbord” of successful and unsuccessful repository development components that can be sampled to advantage by individuals and programs concerned about progress and cost.

INTRODUCTION

During the past 50 years, nuclear energy has been an integral component of political and financial stability, and quality of life in many countries. However, in the aftermath of the 1979 Three Mile Island accident in the USA and the 1986 Chernobyl accident in Ukraine, commercial interests in and public and political support of new reactors declined drastically around the world [1] until a few years ago. However, just when the future of nuclear energy looked set to be in terminal decline, the politics of global warming delivered a dramatic return to respectability for nuclear power. In July 2009, the International Atomic Energy Agency (IAEA) (www.iaea.org) reported 60 new reactors were either under construction or being considered among its member nations, including 20 nations considering their first reactor [2]. This sharply reversed reactor trend is commonly referred to as the *Nuclear Renaissance* and it was also fueled by the following two conditions:

1. A stellar global nuclear power plant (NPP) safety record after the aforementioned accidents.
2. A realization in many countries that nuclear power was *the only clean energy* source able to provide the vast amounts of both the base-load and, more so, the peak-load energy needed to satisfy current and, in particular, projected energy needs for the next three decades.

However, the opening of disposal systems for the resulting used/spent nuclear fuel (UNF) and other long-lived (half-life >1,000 years), highly-radioactive, waste (HLW) is neither in lock step with existing nor planned reactors. UNF and HLW thus continue to amass in temporary surface and near-surface storage facilities pending the availability of domestic and/or regional disposal solutions. Deep geological (>300 m below the ground surface) disposal of long-lived radioactive materials (LLRMs) in a specially designed repository is the globally-preferred UNF/HLW-disposal solution. Although the USA's UNF/HLW-repository was projected in 2008 to open at the earliest in 2017 but more likely in 2020, it is on an indefinite hold since February 2009. At the end of 2009, the world's first deep geological UNF repository is thus most likely to open in Finland in 2020 (www.posiva.fi) followed by the opening of UNF-repositories in France (www.andra.fr) and Sweden (www.skb.se) by 2025. Two related inconvenient truths are:

1. Despite more than 50 years of costly efforts and a global fleet of 440 reactors in 31 countries, the opening of the world's first UNF or HLW repository is still at least 10 years away.
2. All national and regional UNF-repository programs have experienced multi-year delays and appreciable cost increases. Indeed, some repository projects have even been aborted.

The long-standing lack of an operating UNF repository is an acutely-missing, global link, in the nuclear-fuel-cycle chain that poses a clear and imminent threat to the global Nuclear Renaissance and to Homeland Security in nations with reactors. Anti-nuclear individuals and interest groups have successfully used this missing link and the frequent delays to the scheduled openings of national and regional UNF-repositories to argue and stoke fears among members of the general public that LLRMs cannot be safely disposed of and, therefore, all existing reactors should be closed and no new nuclear reactor should be built. This is an urban legend that can and urgently needs to be dispelled by the track record of the Waste Isolation Pilot Plant (WIPP) repository for transuranic radioactive waste (TRUW) (Fig.1) in the USA (www.wipp.energy.ws). WIPP opened in March 1996 and its design and post-closure performance/safety have already been recertified once. The second 5-year recertification application, submitted in March 2009, is being reviewed by the U.S. Environmental Protection Agency (EPA) (www.epa.gov). TRUW contains radioisotopes with half lives exceeding 24,000 years and the outside of the TRUW-canisters may reach surface dose rates of up to 10 Sieverts per hour [4], which, in turn, demonstrates beyond any reasonable doubt the viability and feasibility of safely disposing of LLRMs in a carefully sited and designed deep geological repository.

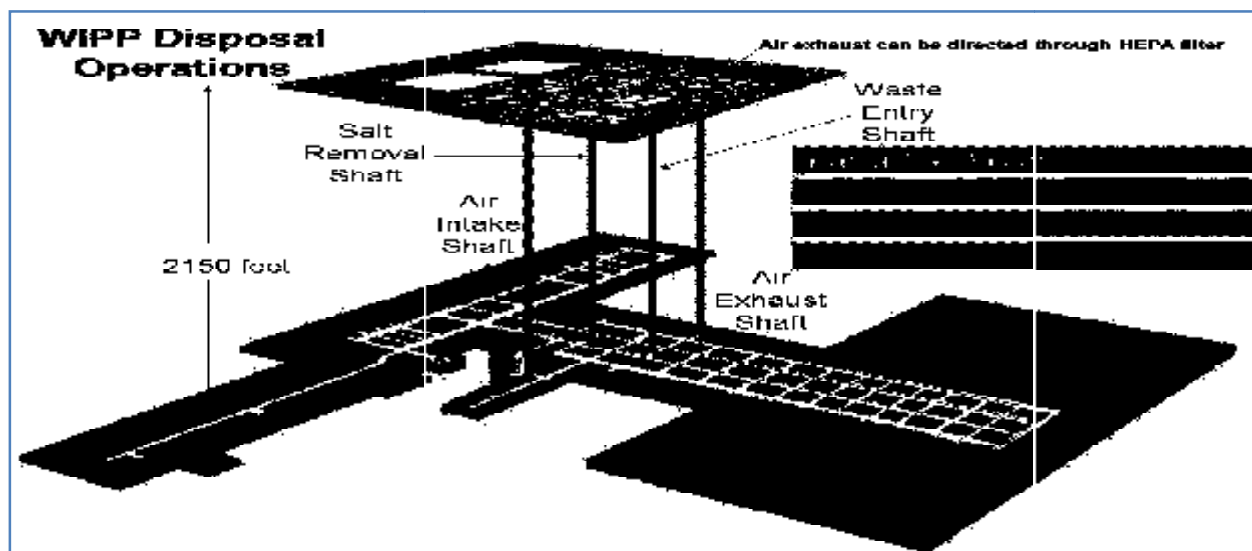


Fig. 1. Schematic illustration of the layout and the current status of the WIPP TRUW repository at the end of 2009 (not to scale). (The tunnels left of the Air Exhaust Shaft have been used since the late 1970s for full-scale TRUW, UNF, and HLW tests [e.g., 4-6].) (2,150 feet = ~650 m.)

In addition, there is an abundance of lessons learned around the world about successful and unsuccessful strategic, policy, and disposal concepts during the past 50 years. If they had been better known and/or more timely adopted and avoided in the past, as appropriate, they could have reduced some past repository delays and cost increases. Summarized below are thus some select personal repository-siting and -development observations made and lessons learned during the past 32 years that might serve as an initial “smörgåsbord” that may be sampled by interested parties at their discretion. Most observations and lessons learned were gleaned from repository programs in the USA and in Europe. Unless denoted by numbers within brackets [1-26], observations, opinions, conclusions, and recommendations presented herein are solely attributable to the author. The numbered references are listed in full in the Reference section, which is preceded by a summary of the main observations and lessons learned. Additional information on the repository programs referred to in this paper is available via their web pages (e.g., www.skb.se).

Lastly, due to the generalizations and simplifications required to address this multi-disciplinary subject matter, the reader is kindly asked to keep the following three concepts attributed to Jean Jacques Rousseau (1712-1778), William Shakespeare (1564–1616), and Samuel Langhorne Clemens, aka Mark Twain, (1835-1910), respectively, in mind while reading this text:

“No generalization is completely true, not even this one.”

“The beauty is in the eye of the beholder.”

“There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.”

BACKGROUND

On June 27, 1954, the Obninsk NPP in the former Union of Soviet Socialist Republics became the world's first NPP to generate electricity for a power grid. In 1956, the Calder Hall NPP at Sellafield in the United Kingdom (U.K.) became the world's first commercial NPP. In December 1957, the Shippingport nuclear reactor in Pennsylvania became the first commercial nuclear-energy generator in the USA; however, the SM-1 NPP at Ft. Belvoir in Virginia was the first reactor to supply electrical energy to a commercial grid (VEPCO) in April 1957 [1]. At the end of 2009, there are 440 licensed reactors in 31 countries but the opening of the world's first UNF and HLW disposal system is still at least 10 years away [3]. Provided below is concise background information on the following repository-related conditions:

1. The perceived statuses of 15 different deep geological repository programs (Table I).
2. The actual and projected gestation periods for the world's four most advanced repository programs and how they relate to a 15-year-long reactor-gestation period due to the fact that the current “euphoric” planning of new reactors, typically, fails to mention the gestation periods for and timing of the resulting waste disposition (treatment, storage and disposal) needs. Whether this is an important consideration in the planning phase of a reactor is a security and financial decision to be made by politicians and the affected utility(ies) but these gestation periods are needed for credible and justifiable political and financial decisions.

As illustrated in Table I, more than 15 nations have considered and at least 10 nations are currently pursuing deep geological disposal systems for long-lived, highly-radioactive, wastes. In addition, it should be acknowledged that although not included in Table I, due to lack of verifiable information, purportedly, Russia has already disposed of HLW in deep boreholes drilled from the surface and is also in the process of evaluating two candidate UNF/HLW repository sites. Due to space constraints and limited knowledge, the subsequent text focuses on the world's four currently deemed most advanced repository programs, i.e., two in the USA, one in Finland, and one in Sweden.

USA has focused on deep geological disposal of UNF and HLW since the late 1950s. In December 1957, an expert group assembled by the U.S. National Academy of Sciences (NAS) concluded that HLW could be safely disposed of in a carefully sited and designed deep geological repository and that rock salt provided the most promising host rock conditions [7]. Following the failed attempt to convert an abandoned salt mine in Kansas to a UNF repository in the 1970s, USA enacted a law in February 1983 [8], the Nuclear Waste Policy Act of 1982 (NWPA), directing the U.S. Secretary of Energy (the Secretary) to *open the nation's first UNF repository no later than 31 January 1998*. This did not happen. In September 2008, the only candidate UNF repository considered since 1987 at the Yucca

Mountain (YM) site in Nevada [9] was projected to open no earlier than in 2017 but more likely in 2020 [10]. However, in February 2009, the YM repository was placed on indefinite hold and a reduced annual budget by the new Administration pending a review by a politically-hand-picked “blue ribbon” panel [11], which, effectively, made an opening of the YM repository even in 2020 (Table 1) virtually unattainable [12]. Furthermore, based on subsequent political statements [e.g., 13], it appears the YM repository might be abandoned prior to the U.S. Nuclear Regulatory Commission’s (NRC’s) pending ruling on the June 2008 YM construction license application (CLA).

Table I. Perceived Statuses of 15 Select National Repository Programs at the End of 2009 [3,14]

COUNTRY	PROJECTED REPOSITORY OPENING	MISCELLANEOUS COMMENTS
Belgium	Around 2040	Focus is on over-consolidated clay in the Mol Dessel area. Hosts related multi-national research since 1984 approximately 220 m below the ground surface in the “Hades” underground research laboratory (URL).
Canada	To be determined	Hosted multi-national research on igneous/crystalline rock in the now abandoned “Pinawa” URL at Lac du Bonnet in the Province of Manitoba. Is in the process of re-starting the repository siting program.
China	Around 2050	Operates a central UNF-storage facility at Lanzhou. Repository sites are being evaluated in the Gobi desert in the Beishan area of the Ganshu province.
Finland	In 2020	Is in the process of developing the “Onkalo” URL in granite located adjacent to the Olkiluoto nuclear power plant (NPP) site and the pending repository site in the voluntary host community of Eurajärvi.
France	In 2025	Focus is on argillites adjacent to the “Bure” URL in the voluntary host districts of Meuse/Haute Marne.
Germany	Moratorium on nuclear energy and waste disposal since 1999	The new Administration will likely lift the current moratorium on new nuclear power plants and nuclear waste disposal in 2010. Has already investigated the “Gorleben” salt dome in great detail as the candidate UNF-repository site. Has also operated the now abandoned “Morsleben” and “Asse mine” repositories for long-lived LLW and ILW, and a URL in the “Asse mine”.
Hungary	Around 2040	Site selection for the UNF repository and adjacent URL expected in 2010, URL tests to be completed by 2025.
Japan	No earlier than 2035	Is pursuing voluntary candidate repository sites with an expressed interest in granite. Operates URLs in clay and granite.
Republic of Korea	To be determined	Repository sites considered on the Guleop and the Dukjeok islands in the late 1990s were abandoned. New siting program is emerging.
Spain	To be determined	Current policy/strategy is based on at least 50 years of UNF storage but participates actively in international repository-related research projects.
Sweden	Opening projected in 2025	Test operations are projected to begin in the “Forsmark” UNF repository in 2023 located adjacent to the Forsmark NP site and an underground disposal facility for long-lived LLW and ILW. Operated the multi-national “Stripa” URL between 1977 and 1992, and is now operating one at “Äspö” since 1995.
Switzerland	No earlier than 2040	Explored granite in the Grimsel URL. Is exploring argillites in the Mont Terri URL. Operates the “ZWILAG” storage facility for UNF, ILW and LLW.
The Netherlands	To be determined	Current UNF-management policy/strategy is based on 100 years of central storage in the “HABOG” surface facility
United Kingdom	To be determined	After failing to obtain permission in 1997 for an URL in granite at the Sellafield site, the repository program was on hold until 2009.
United States of America	No earlier than 2017 but more likely 2020*	*Unattainable due to recent political actions [12,13]. Has operated URLs in basalt, granite, salt, and tuff. Operates a deep geological repository for long-lived, highly-radioactive, waste at the WIPP site in New Mexico since 1999.

If the YM site is abandoned in 2010 [13], or if the NRC does not license the YM repository, there is no other UNF- or UNF/HLW-disposal option pursued in the USA at the end of 2009. Neither is there a central storage facility similar to those in several other countries that could be used to bridge past and future delays to the opening of the

nation's first UNF-repository. Furthermore, in December 2008, the then Secretary announced that the legal capacity of the YM repository would be exceeded by existing UNF and HLW in 2010 [15]. He also suggested that in the event the requested increase in the capacity of the YM repository was declined, the sites abandoned in 1987 and earlier should be used to find another repository site. This "myopic" siting approach would turn the clock back at least 23 years relative to where the YM repository is today [12].

With the exception of the WIPP repository, there is no other actual gestation period for a LLRM repository. Furthermore, there are several possible conception date options, e.g., a) the start of a nation's first reactor; b) the enactment of the legal framework for the current repository-siting program, and c) the start of the site-characterization program at the "selected" site. Option b) was used as the base-line conception date in the subsequent analysis. The other two potential conception dates were also occasionally analyzed below to make the comparisons both more comprehensive and more compatible. The ultimate objective, however, was to try to establish the main reasons for any significant difference in the gestation periods among the four programs.

Based on the 1983 enactment of the NWPA [8] and a projected opening of the YM repository in 2025, the repository-gestation period in the USA would be 42 years. Year 2025 was arbitrarily selected for this analysis because a) 2020 is not deemed attainable [12], and b) it is perceived as the last year a reasonably-plausible UNF-disposal solution must be available under NRC's current nuclear waste management regulations [12]. In light of the potential abandonment of the YM site, an optional repository-opening date of 2048 was also used based on the Secretary's December 2008 "myopic" siting approach. As follows, the repository-gestation period in the USA would be at least 42 years but it could be more than 65 years. It should also be noted that deep geological disposal has been pursued in the USA since 1957 and that the site investigations at the YM site began in 1976. Using these two years as conception dates would result in a 68-year-long and a 49-year-long gestation period, respectively. However, as indicated by the subsequent three case histories, neither of the aforementioned four gestation periods in the USA is considered representative of a currently attainable gestation period in light of the vast data and know-how presently available to emerging reactor and repository programs.

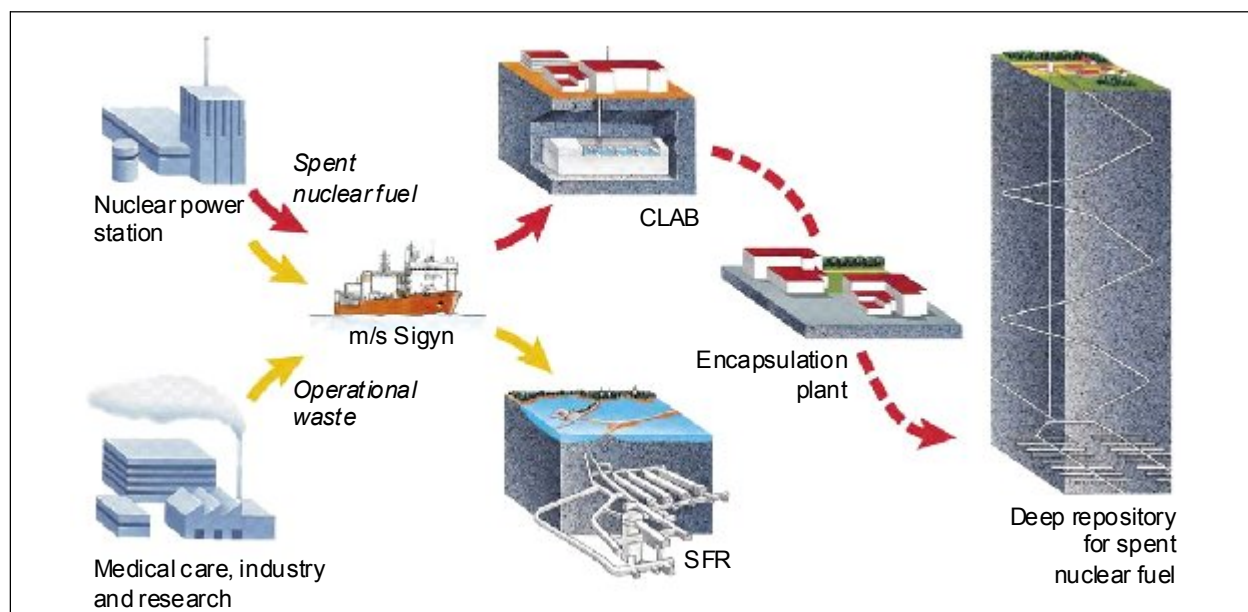
The WIPP repository opened in March 1999 (www.wipp.energy.gov). The project began in the early 1970s when local politicians and residents approached the then responsible federal agency encouraging it to consider the very-thick, laterally-extensive, tectonically-undisturbed, salt beds in New Mexico for safe, deep-geological, disposal of LLRMs [5]. The related legislation was enacted in December 1979 but it was preceded and based upon information obtained through site investigations that had begun in the early 1970s [5]. Using the 1979 enabling legislation as the conception point, the WIPP base-line repository-gestation period would be 20 years. However, this would be a very misleading data point to use in the comparison with the other three repository programs. The WIPP base-line gestation period used for comparative purposes herein is thus 25 years. It is based on the 1974 commencement of the site characterization activities.

As indicated above, the legislation governing the repositories at the WIPP site and the YM site differ, as do their respective regulations and waste categories. It should also be recognized that the two repository projects are managed by two virtually autonomous offices within the U.S. Department of Energy (DOE); the Office of Environmental Management (EM) and the Office of Civilian Radioactive Waste Management (OCRWM) [16].

At the end of 2009, Finland is projected to open the world's first UNF-repository in 2020 (Table I). Although surface investigations at the current candidate repository site adjacent to the Olkiluoto NPP were initiated in the early 1980s, the related legal framework was not established until 1987 (www.posiva.fi). Using the 1987 Energy Law as the conception date, the projected base-line repository gestation period would be 33 years. Using the 1982 start of the site investigations as the conception date would result in a repository gestation period of 38 years.

At the end of 2009, Sweden is projected to open its UNF-repository (Fig 2) in 2023 for full-scale trials and to commence operations in 2025 [17]. The Stipulations Act of 1977 required Swedish reactor owners to produce an account of "absolutely safe" disposal of UNF. At that time, Sweden planned to reprocess its UNF, which is no longer the preferred option. Rather, the preferred Swedish option during the past 32 years has been direct disposal of the UNF, with the central long-term (30-40 years) interim UNF-storage component ("CLAB" in Fig. 2) added in 1983 [17]. Using 1977 as the conception date and 2025 as the birth date, the projected base-line repository-gestation period would be 48 years. However, it should be noted that the preliminary site characterization activities at the Forsmark site, which was selected in June 2009, did not start until in the early 1990s and the detailed site-

investigations did not begin until 2002 [17]. Using year 1992 as the conception date, the gestation period would only be 33 years, which illustrates both the conjectural nature of the base-line conception dates used in this document and that the period between legislation and site selection might be conducive to considerable time savings.



Key: **CLAB** = A central facility for long-term (30-40 years) storage of UNF (opened 1985); **SFR** = A repository for long-lived low- (LLW) and intermediate-level (ILW) radioactive waste, also referred to as operational waste (opened 1988); **Red** arrows depict UNF; **Yellow** arrows depict LLW and ILW; **Solid** arrows lead to operating facilities; and **Dashed** line and arrow lead to planned facilities (both are projected to open for trial operation in 2023 and regular operation in 2025).

Fig. 2. Schematic illustration of core components of the fully-integrated (holistic) Swedish nuclear waste management and disposal program/system (Illustration courtesy of SKB).

As elaborated upon below and in the next section, both the Finnish and Swedish UNF-repository programs have been considerably more stable than the U.S. UNF and HLW disposal program. Notwithstanding the similar site-investigation and -selection periods in Finland and Sweden, one overriding observation is that the Finnish repository program likely saved at least five and perhaps as much as 10 years of research and development (R&D) and also expeditiously built up its domestic state-of-the-art know-how by adopting relevant core components of the Swedish repository program and then continuing to collaborate very closely with the Swedish implementing organization, the Swedish Nuclear Fuel and Waste Management Company (SKB-www.skb.se). As elaborated upon in the next section, the Swedish KBS-3 disposal concept (Fig. 3) was one such beneficial adoption. Among other benefits, it allowed the implementing organization, Posiva OY (Posiva-www.posiva.fi), to make a strong case that the proposed disposal concept was not unique, which in turn made it considerably easier for the affected parties (= local residents and the regulator) to accept. It also very-likely reduced the gestation periods for both the pending underground research laboratory (URL), Onkalo (under construction), and the pending UNF repository. It appears thus reasonable to submit the following observation for consideration:

- The sooner existing applicable knowledge is taken advantage of, the greater is the return in terms of disposal-concept credibility and acceptance, and time- and cost-savings.

In summation, based on the assumptions used for the above scoping calculations, and excluding a potential abandonment of the YM site, the “most-realistic” gestation periods derived at for the four most advanced repository programs in the world at the end of 2009 range between 25 years and 48 years. As follows, in the event a reactor and a UNF repository program are started at the same time, the reactor gestation period is 15 years, and current strategies and policies are re-employed, the waste resulting from the reactor would likely need to be stored for at

least 12 years and perhaps as long as 33 years. Two primary purposes of this document are thus to suggest: a) the planning of new reactors and their respective waste disposition solution(s) at the same time; and b) identify past repository program components that future UNF-repository programs could adopt or avoid, as appropriate, to shorten the aforementioned gestation periods and program costs. For example, a contributing factor to the WIPP repositories' much shorter gestation period than the YM repository was the timely availability and adaptation of the wealth of relevant data on rock salt collected in Germany and at other salt sites in the USA, which, in combination with similar evolutions of the Finnish and Swedish UNF-repository programs supports the following observations:

- Being the “front-runner” is much more time-consuming and costly than being the “collaborator”;
- Domestic and multi-national collaborations can be socio-politically, scientifically, and financially beneficial, domestic political agendas and scientific pride permitting.

These conclusions and another contributing factor in the USA, the different siting approaches, are described and discussed further in the next section.

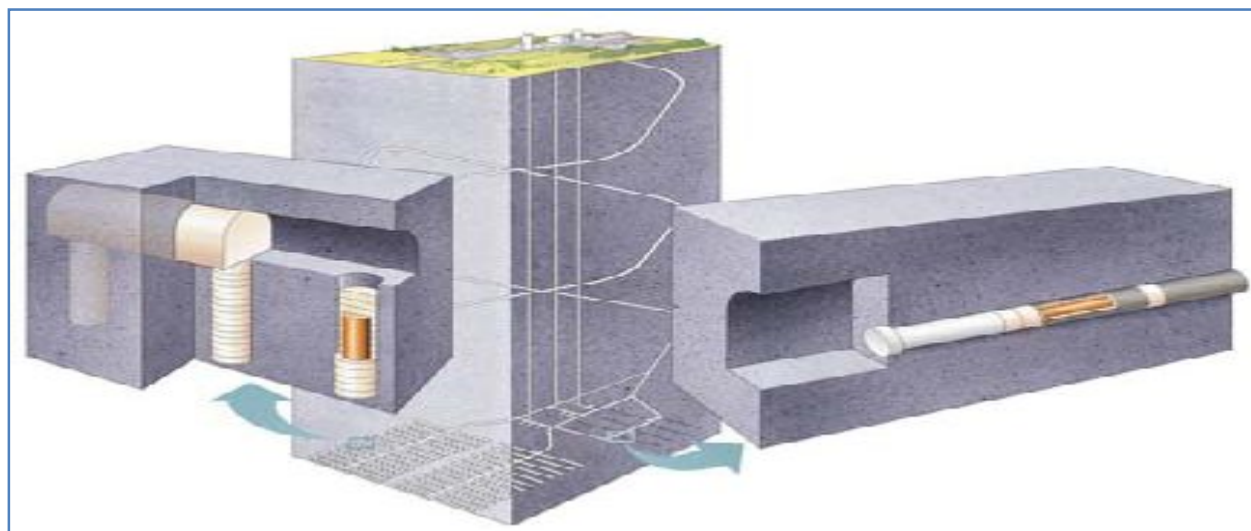


Fig. 3. Schematic illustration of the KBS-3V concept to the left and the KBS-3H concept to the right (Illustration courtesy of SKB).

CONCISE DESCRIPTIONS AND DISCUSSIONS OF SELECT LESSONS LEARNED

The reader is reminded that generalizations were made in this text due to the fact that the subject matter discussed is on spatial and temporal scales, and involves state-of-the-art and beyond-the-state-of-the-art concepts and terms that likely less than 1% of any national population fully comprehend, including this author. The “cherry-picked” observations and lessons learned described and discussed herein are thus simplified and qualitative, rather than absolute and quantitative. This section addresses the following five observations and lessons learned:

1. **National political agendas** govern the time-lines and costs for the siting and development of disposal systems for LLRMs.
2. Strong **local public and political support** can overcome national political agendas and “long-distance” anti-nuclear propaganda.
3. A **robust disposal concept**, a stringent, well-justified, regulatory framework, a strict regulator, and a trustworthy implementation organization are cornerstone prerequisites for strong and sustained local public and political acceptance and support.
4. **International collaborations** cost-effectively strengthen both the robustness and public confidence in the proposed disposal concept/solution.
5. **Disposal of nuclear waste** appears to be an afterthought rather than **an integral planning component of the facilities generating the waste**.

National Political Agendas

One major global challenge at both national and local levels is that *many politicians perceive that supporting anything that could result in their respective home state or district being considered for a UNF repository is a political suicide*. The U.S. Congress' involvement, or rather lack thereof, in the domestic UNF-disposal program is only one example on this wide-spread, "see-no-evil, hear-no-evil, and speak-no-evil" political modus of operandi. The subsequent summary of the lack of action the past 12 years to mitigate the repeated delays since 1985 of the opening of the nation's first UNF repository is a particularly telling and, hopefully, educational real-case story.

Pursuant to applicable law [[8], USA's first repository was supposed to open no later than on 31 January 1998. At the end of 2008, the YM repository was not projected to open before 2017 but more likely in 2020 (Table I), which is not likely to happen either due to recent political "repository-delaying" actions by the new Administration [11,13]. In other words, despite having known for more than 12 years that the legal milestone established in February 1983 for the opening of the nation's first UNF repository would not be met and that the projected opening date was delayed again in 2009, Congress has steadfastly avoided to address and mitigate the aforementioned blatant violation of domestic law by past Secretaries. It will thus be very interesting to learn what the pending "blue-ribbon" panel recommends, and how the Congress reacts to and acts upon the panel's recommendations. In the meantime, following are four author-perceived root causes to the current perilous and comatose status of the YM-repository program that conceivably could be addressed and mitigated in the future [e.g., 12,16,17]:

1. Lack of adequate funding by the Congress.
2. Strong sustained political opposition by the host state.
3. Lack of a contingency for the "inevitable" delays to the opening of a UNF/HLW repository.
4. An implementing organization short on relevant upper-management experience, regularly depleted on institutional memory, and not held accountable for lack of progress.

Clearly, this is only one national example, and political and public attitudes, agendas, and perceptions and their related influences on the decision-making process vary among countries. However, based on the deferral of repository programs and decisions in many other countries, it is compelling to conclude that the same political "I don't want to touch the issue" attitude also exists in other countries. It has been particularly apparent with regards to the regional repository concept where political statements have ranged from "not in my country" to "not on my continent". It is therefore very encouraging to notice how this attitude gradually has changed and that 14 European countries; Austria, Bulgaria, Czech Republic, Denmark, Estonia, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Romania, Slovakia, and Slovenia, resolved in 2008 to set up a European Repository Development Organization (ERDO) to collaborate on nuclear waste disposal [10,18]. The proposal for a "staged, adaptive implementation strategy" for an ERDO results from the European Commission sponsored Strategic Action Plan for Implementation of European Regional Repositories (SAPIERR) Project. The SAPIERR project is in line with proposals from the IAEA, Russia, and the USA (with GNEP) for multilateral cooperation in the fuel cycle in order to enhance global security. Whether one likes it or not, the undeniable and inconvenient facts are:

- A large amount of LLRMs already exists that lacks a reasonably-plausible disposal solution;
- LLRMs continues to be generated at an increasing pace/rate;
- Regardless of how existing and future LLRMs are treated, there will always be a residual volume of LLRMs that need to be safely disposed of;
- It is the responsibility of the LLRM-generating generation to safely dispose of this waste; and
- After more than 50 years of world-wide efforts to develop safe LLRM-disposal solutions, with the exception of the WIPP TRU repository, all other LLRM categories lack disposal solutions at the end of 2009.

During the past 30 years, the site-selection phase has so far shown to be by far the most emotionally-charged, politically-sensitive and -challenging, and time-consuming phase of the UNF-repository-development phases. In simple terms, past (and current) national repository-siting policies/approaches may be divided into the following two main categories:

1. Parental.
2. Voluntary.

The parental policies essentially rely upon a small group of (s)electd individuals for the development of the site-selection criteria and their subsequent implementation, whereas the voluntary policies also account for the opinions of the affected parties during all phases of the project. Indeed, in some nations, e.g., Sweden, the potential host community has veto right throughout the siting process. Another distinct difference between the two policies is that the parental approach typically shortens the time required for the selection of potential sites but requires more time for subsequent the site-characterization and licensing processes. In other words, the parental approach becomes increasingly more challenging with time, whereas the voluntary approach is most challenging in the early stages.

The 1987 selection of the YM site [8] is a particularly telling example on what the results may be when the national political agenda disregards the opinions of the local residents and their elected representatives. It was first recommended by the DOE and the Congress, and then approved by the U.S. President based on multi-attribute analyses of the then three candidate repository sites. The multi-attribute analyses in turn were based on sparse site-specific data augmented with expected outcomes and did not include the opinions expressed in the three candidate host communities and states, including the Governor of Nevada's formal Notice of Disapproval. As history shows, the development of the YM repository has suffered significant delays and cost-increases since 1987, in large part, due to local opposition [e.g., 12,16].

It should also be noted that the best of intentions might fail because between 1992 and 2002, three municipalities in Sweden, i.e., Malå, Storuman, and Tierp, withdrew from consideration. Whereas Malå and Storuman failed to reach majority support among their respective residents, Tierp's decision was based on local politics. Similar examples can be also found in France, Switzerland (Wellenberg), and the U.K. (the Sellafield URL) which illustrates the inherent risk embodied in recognizing and accounting for the opinions vested in local residents but, as illustrated particularly clearly in the USA by the contrasting evolutions of the WIPP and YM projects [e.g., 16], majority local support is imperative to timely progress and, perhaps, ultimate success.

In summation, historical evidence suggests that the probability for success is much higher for the "voluntary" approach than the "parental" approach. However, as mentioned above and discussed further in the next two sections, respectively, even the voluntary approach and a very robust disposal concept may fail.

Local Public and Political Support

As suggested above, majority local public and political support is imperative to long-term progress, i.e., *Necesse Est!* However, due to the virtually incomprehensible spatial and temporal scales and the state-of-the-art and beyond-the-state-of-the-art scientific and technical concepts involved, local residents and their elected representatives essentially face and have to make a choice between the following two main thematic sources of information:

1. Anti-nuclear individuals and interest groups.
2. Pro-nuclear individuals and interest groups.

In other words, most non-ideologically-, non-politically- and non-financially-based opinions are largely formed based on the respective individual's confidence and trust in the "messenger". A related lesson learned is that credibility and trust can only be earned, it does not come with the "territory" [e.g., 18-21]. For example, if an individual believes that inadequate efforts are made to fully and timely inform her/him, which unfortunately has been the case by condescending politicians and scientists in the past, the affected individual will likely reject the proposed project in spite, regardless of its merits. A recurring theme in this document is thus that continuous transparency about what the plans are and how they are being met, including challenges and proposed solutions, timely communications, and a mutually satisfactory resolution of issues, are imperative to earning and sustaining credibility and trust. An integral component is that the presented information is comprehensible to the recipient.

One related, very telling, common lesson learned from the repository programs in Canada, Finland, France, Sweden, Switzerland, U.K. and USA is the crucial importance of *early and sustained majority* acceptance among the residents adjacent to the potential and candidate repository host communities, referred to as affected parties herein. The aforementioned countries experienced local opposition and, with the exception of the USA, they promptly adjusted, modified their siting strategies/approaches, and are now successfully advancing their respective repository program based on the fundamental premise of working very closely, continuously, and openly with the potential host communities to ensure that the majority of their residents are both timely and adequately informed and also

prepared both emotionally and intellectually to host a UNF repository. Indeed, as summarized above the viability and long-term benefits of the “voluntary” approach might be particularly evident in the USA, where the actual gestation period for the WIPP repository is already more than 20 years shorter than that projected for the YM repository at the end of 2008, which have since been delayed. Furthermore, it would be at least 42 years shorter in the event the YM is abandoned or not licensed. However, the siting approach is not deemed to be the sole reason for this difference in repository-gestation periods. As elaborated upon in the next section, the respective disposal concept is another perceived major root cause to the different repository-gestation periods at the WIPP and YM sites.

After being initiated by the local community in the early 1970s, the WIPP project has benefitted from unwavering strong local public and local political support [e.g., 5,6,21]. This support was particularly crucial to the comparatively short duration, approximately three years, and, ultimately, to the successful May 1998 outcome of the WIPP certification process in that it very effectively counterbalanced and mitigated the opposing opinions expressed by a small, very vociferous, group of non-local individuals and interest groups. Another main lesson learned is that the strong local support of WIPP was not self-sustained. It was fueled by an early recognition within both the implementing organization and several Secretaries that cooperation and collaboration with both the host state and the host community was imperative to success [22-24]. The 1994 WIPP Disposal Decision Plan (DDP) shown in Fig. 4 is one of several telling examples on the approach employed by the implementing organization to sustain local support by keeping both affected (regulators and local residents) and interested parties timely abreast of program plans and when additional updates would be forthcoming [23]. As illustrated under the “Stakeholders/ Oversight” caption in Fig. 4, the implementing organization committed to 47 public meetings between 1994 and 1998 at various predetermined stages of the pre-opening phase.

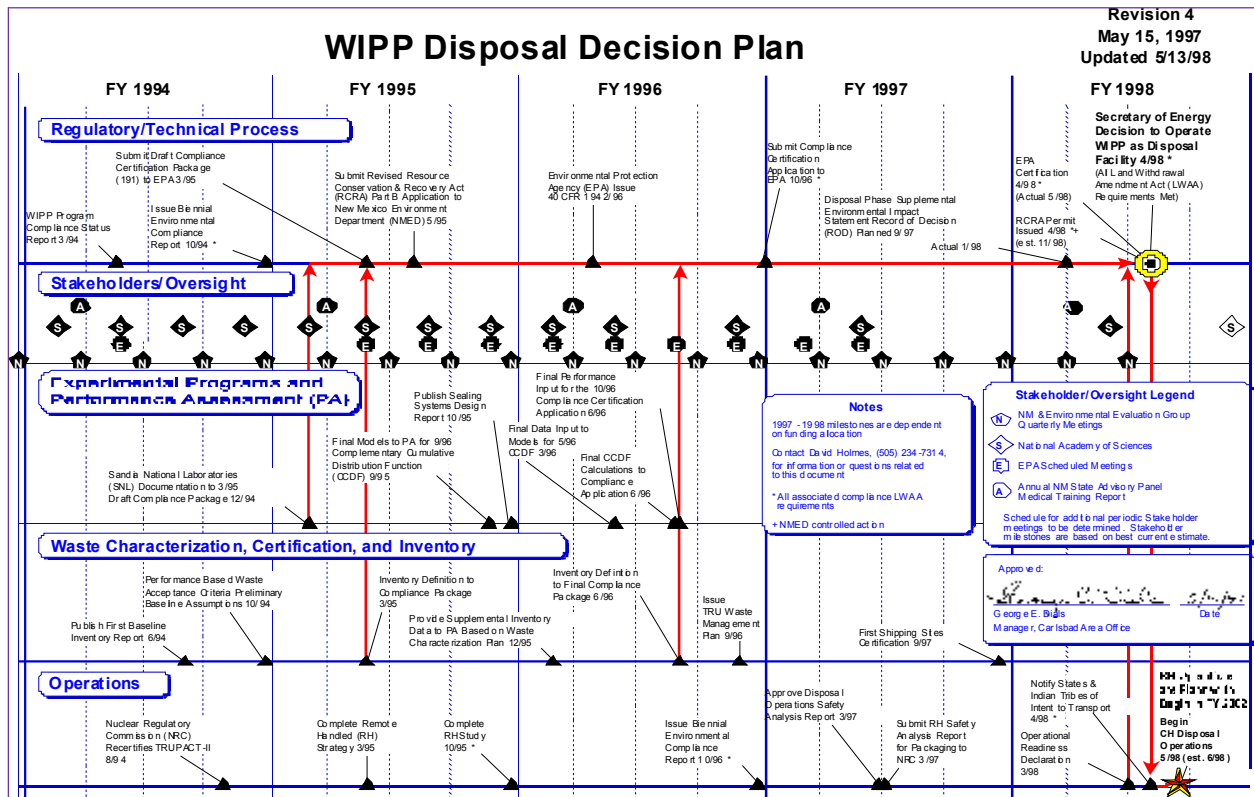


Fig. 4. The WIPP 1994 Disposal Decision Plan [23].

The WIPP implementing organization, the DOE’s Carlsbad Field Office, also periodically published documents before, during, and after this period explaining both the status of the project and the sophisticated concepts involved and terms involved in the state-of-the-art projections of the post-closure performance of the repository in layman terms including solicitation of feedback [5,6,16,24,25]. Unfortunately, none of these valuable lessons learned at

WIPP seems to have made it out of the state of New Mexico. Indeed, despite both the YM and the WIPP projects being managed by the DOE, they were and still are managed by two virtually autonomous DOE offices, where the UNF-disposal office has chosen to not collaborate below the upper management information exchange level (EDRAM) with other repository programs for more than a decade. However, the lessons learned at WIPP [e.g., 4-6,19,23-25] and elsewhere might still be looked upon by the pending “blue-ribbon” panel and others, and adopted to belated domestic and global advantage

History also shows examples of other repository programs having wisely included directly affected parties from the outset or after having faced and realized the critical importance of their sustained support and collaboration. For example, after massive public demonstrations at the potential Almunge site in Sweden in 1992, the Swedish program stepped back and restarted the repository siting process based on voluntary host communities. One of the cornerstones in the new strategy/policy was that the host community would have veto right throughout the siting process. Several communities volunteered to host the repository and, in June 2009, after seven years of detailed site characterization studies at three candidate sites, one in the municipality of Östhammar (Forsmark) and two in the municipality of Oskarshamn (Laxemar and Simpevarp), SKB concluded that the Forsmark site had the most promising geological setting and recommended it for the nation’s first UNF repository (www.skb.se). The annual polls conducted in the two candidate host communities in 2008 showed that 79% of the residents in Östhammar and 86% in Oskarshamn supported the location of a UNF repository in their respective municipality/back yard. Similar to the implementing organization for the WIPP repository, SKB had invested considerable time and resources to ensure that the local residents in the two candidate municipalities and the then two regulators, as well as all interested parties, were fully aware of both the benefits and the risks of the proposed UNF repository. For example, SKB had local offices and also distributed local newsletters (“Lagerbladet”) essentially every third month in the two candidate municipalities and to interested parties designed to keep the residents and other interested parties timely informed about the status and the plans for UNF disposal in Sweden and, occasionally, in other countries.

Mature Disposal Concepts

Although there is no “magical recipe” for the siting and development of a UNF (or HLW) repository because the siting approach needs to comply with domestic socio-political and safety requirements that, typically, vary from country to country. In addition, as site conditions will vary from site to site. Notwithstanding these variables, it is very appealing to suggest based on the historical record that the more commonalities that exist between national repository programs, the more likely is it that the general public in the repository host countries will accept the proposed disposal concept, making the repository program less susceptible to delays and cost-increases. However, as mentioned in the preceding section, even a very robust disposal concept might be successfully opposed and have to be aborted, as were the cases for e.g., the Pangea concept in Australia and the KBS-3V concept at Malå and Storuman in Sweden.

Summarized below are deep geological repository concepts focusing on a) waste-canister-emplacements configurations around a man-made opening located at least 300 m below the ground surface, and b) rock types studied for at least the past 10 years by more than one nation, and that are either still being studied or being successfully implemented. Since neither the deep borehole concept purportedly employed in Russia, the Belgian disposal concept in the Boom clay formation, nor the YM repository concept in vitrified tuff meet all of these criteria, they are not addressed below. The YM disposal concept is, however, used to illustrate one of the five listed waste-canister-emplacements configurations (www.ocrwm.doe.gov). It might also be appropriate to mention that, whereas the Boom Clay in Belgium still is an over-consolidated sediment, the “clays” studied in France and Switzerland are clay sediments that also have been subjected to mild post-depositional metamorphosis that have made them distinctly different than any clay sediment. They are thus referred to as “argillites” in this document and included below.

The following five waste canister emplacement disposal configurations have been investigated extensively to date:

1. Vertical emplacement holes, each containing a single waste canister, e.g., the SKB-3V concept (shown to the left in Fig. 3).
2. Vertical emplacement holes, each containing more than one waste canister.
3. Horizontal emplacement holes, each containing a single waste canister e.g., the WIPP disposal concept for remote-handled TRUW.

4. Horizontal emplacement holes, each containing more than one waste canister, e.g., the Andra C-type concept and the KBS-3H concept (shown to the right in Fig. 3).
5. In-room emplacement of multiple waste canisters, e.g., the Grimsel URL disposal concept and the current YM concept (Fig. 5).

Due to space limitations, only concepts 1 and 4, and concept 5 are schematically illustrated in Figs. 3 and 5, respectively. Furthermore, although concepts 1 and 4 are shown together and can be combined, they are not presently considered in this configuration.

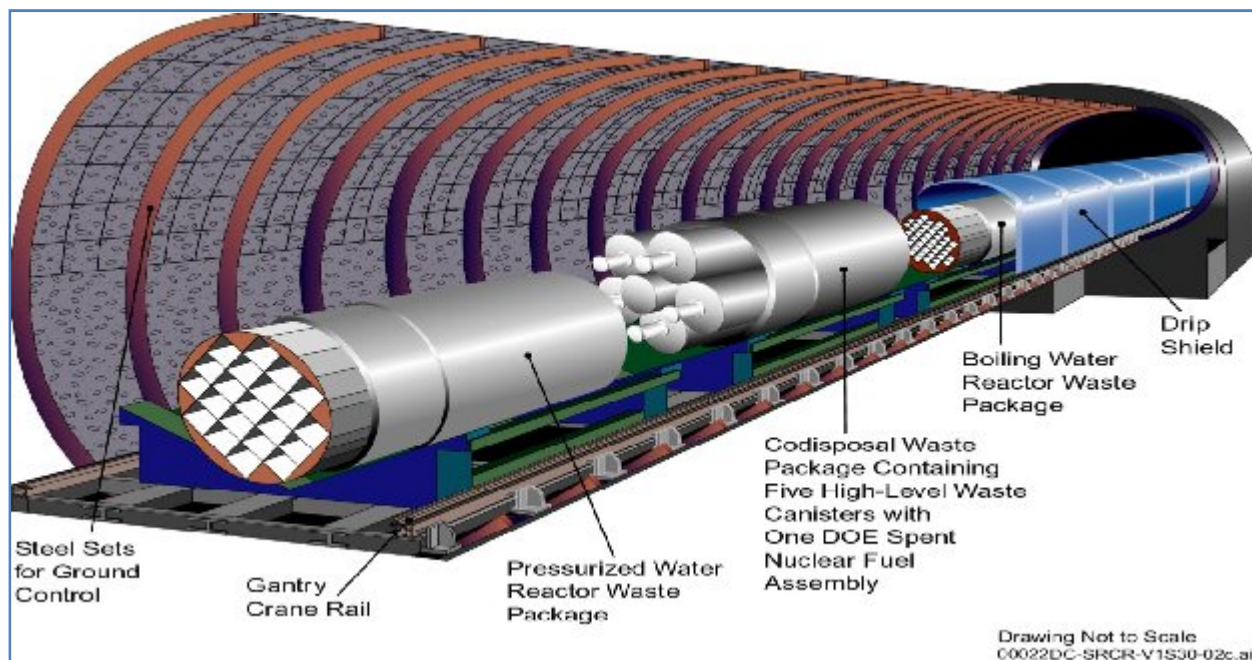


Fig. 5. Schematic illustration of the in-room waste emplacement concept considered at the YM UNF-repository site in the USA.

Concepts for safe deep geological disposal of LLRMs have been pursued for more than 10 years in the following rock types and countries:

- Argillites - e.g., France (www.andra.fr) and Switzerland (www.nagra.ch);
- A broad range of igneous/crystalline rocks - e.g., Canada (www.nwmo.ca), Finland (www.posiva.fi), Sweden (www.skb.se), and Switzerland (www.nagra.ch); and
- Rock salt – e.g., Germany (www.bfs.de and/or www.dbe.de) and USA (www.wipp.energy.gov).

As shown in Table I, other countries have or are also pursuing UNF-disposal solutions in these rock types. An “on-site” URL is an important precursor to establishing the suitability of a given site that also often is used for multi-national R&D activities. Following is a listing of past and current on- and off-site URLs in the aforementioned three rock types:

- Argillites - e.g., Bure in France and Mont Terri in Switzerland;
- Igneous/crystalline rocks - e.g., Pinawa in Canada (www.nwmo.ca), Stripa and Äspö in Sweden (www.skb.se), Grimsel in Switzerland (www.nagra.ch), and Climax in the USA (www.ocrwm.doe.gov); and
- Rock salt – e.g., the Asse mine in Germany (www.bfs.de or www.dbe.de) and WIPP and the Weeks Island mine (no current web address) and WIPP in the USA (www.wipp.energy.gov).

With the exception of the now closed Stripa and the Climax URLs in igneous/crystalline rocks, and the Asse and the Weeks Island URLs in rock salt, conceivably, opportunities still exist for other nations to join and partake in

ongoing R&D in a very cost-effective manner. In no order of implied importance, the main perceived advantages of such co-operations are prompt and cost-effective access to:

1. Mature disposal concepts.
2. Existing databases.
3. Proven site characterization methodologies.
4. Validated numerical codes and models.
5. Relevant expertise and experience, including data acquisition systems and quality control/assurance procedures, and expedited build up of domestic state-of-the-art know-how.

Clearly, there are both spatial and economic advantages associated with emplacing as many waste canisters as possible in each emplacement hole. However, both the orientation of the hole and, more so, the number of waste canisters in each hole increase the challenges associated with the emplacement and retrieval of the canister(s). The thermal pulse induced into the engineered barrier system and the surrounding rock is another non-trivial challenge. However, again, the nuclear fuel cycle needs to be looked upon in a holistic rather than in an individual repository-component perspective to ensure the timely and cost-effective integration and opening of all required facilities [e.g., 26]. In terms of holistic UNF management, Sweden is furthest ahead and its fully integrated nuclear waste management program is schematically illustrated in Fig. 2. It should be noted that Sweden has chosen to ship its UNF by sea to existing and planned storage, treatment, and disposal facilities, which will not be a viable option in many other countries. It should thus also be noted that surficial transportation of UNF and HLW has been safely conducted for more than four decades on five continents. Indeed, at the end of November 2009, 8,079 truck shipments covering 1,542,621 km had been successfully accomplished by the WIPP project during the past 10 years. Similarly, for a variety of reasons, many nation's may not have the benefit of being able to consider the three main rock types a focused upon in this paper. It is thus emphasized that the above described disposal concepts are not limited to the rock types focused upon herein; they could be the starting template/point in most rocks.

International Collaborations

As mentioned above, multi-national collaborations provide timely and cost-effective access to state-of-the-art and beyond-the-state-of-the-art R&D data and knowledge. They also likely enhance public acceptance of a given disposal concept and host rock because an individual's perception of the risks a given repository concept and/or host rock type embody is, conceivably, also influenced by how many other nations are intending to do something similar. However, not all countries benefit from multiple-choices with regards to potential host rocks and may thus have to focus on a given rock type at an early stage in the repository siting process but insight into lessons learned by other programs might still offer significant time and cost-savings.

Planning of Reactors and Repositories

There have been an abundance of articles in both US and foreign press, including statement by representatives of the IAEA, during the past couple of years euphorically referring to the pending or even ongoing Nuclear Renaissance. However, in almost every case, there is no reference to how and when the resulting nuclear waste will be taken care of. As discussed above in the Background section, the world's shortest projected or actual gestation period to date for a LLRM repository is approximately 12 years longer than that for a reactor. Although most NPP sites can accommodate at least 40 years of UNF, as highlighted by the diametrically two opposite political and public actions and reactions to the delayed openings the repositories in Sweden and the USA [17], it is apparent that a holistic nuclear fuel management cycle [26] embodies significant socio-political and financial advantages.

SUMMARY OF OBSERVATIONS AND CONCLUSIONS

The safe disposition of LLRMs has become one of the most challenging socio-political challenges of our time. Whereas the human race has benefitted from nuclear energy for more than 50 years and continues to be increasingly more dependent upon it and thereby also continue to increase the amount waste it generates, it has not yet managed to safely dispose of any UNF or HLW. Three perceived reasons thereto are:

1. The wide-spread residual visual stigma of the mushroom clouds over Hiroshima and Nagasaki in the early 1940s that ended World War II and the related common knowledge about their associated human and structural devastations.
2. The disparity between the exaggerated hypothetical and the actual adverse public health and environmental effects caused by 1979 Three Mile Island and the 1986 Chernobyl accidents.
3. The virtually incomprehensible concepts, and spatial and temporal scales involved in projecting (bracketing) the long term performance/safety of a disposal system for LLRMs.

Notwithstanding these challenges, at least 31 nation's face the challenge today to find one or more safe UNF-disposal solutions. Without any known exception, all these nations are pursuing deep geological disposal. Indeed, some nations have pursued it since the 1950s. In addition, another 20 nations are considering nuclear energy.

Due to the fact that domestic radioactive waste disposal regulations differ among countries, to maintain credibility and trustworthiness, domestic regulators and implementing organizations need to be aware of international guidelines and foreign regulations and programs, and be prepared to explain why the domestic regulation differs from the aforementioned guidelines, if this is the case. Indeed, due to the complexities involved, trust in the messenger is crucial to the acceptance of a repository for LLRMs among the affected parties. History shows that early and regular open/transparent interactions between the implementing organization and the affected parties are crucial for establishing and maintaining local majority support.

Likewise, at least six different disposal concepts for LLRMs are pursued around the world. Each disposal concept is governed by its respective site-specific conditions and, of course, applicable repository performance/safety criteria. As follows, there is no cookie-cutter disposal concept that can be used off the shelf. There are, however, several very mature disposal concepts that will save time and money if used as initial templates and then modified for prevailing domestic site-specific conditions and repository performance and safety criteria. Furthermore, a disposal concept pursued by more than one national or regional program is intuitively more acceptable to laypeople. It also benefits from already having validated databases and performance/safety assessment methodologies and models. The world's currently most advanced "multi-national" deep geological disposal concepts for igneous/crystalline rocks can be found in Finland (www.posiva.fi), Sweden (www.skb.se), and Switzerland (www.nagra.ch), for argillites in France (www.andra.fr), and for rock salt in Germany (www.dbe.ge and/or www.bfs.ge) and in the USA (www.wipp.energy.gov). Clearly, other rock types than those highlighted in this text might also provide adequately safe host conditions for containment and isolation of long-lived, highly-radioactive, waste but they would require more time-consuming and costly studies and also embody the challenge of lacking strength in numbers. They may also be the only option if the site selection is based upon voluntary host communities. However, as illustrated by the YM and the past Basalt Waste Isolation Project (BWIP) repository programs in the USA, pursuing a globally-unique disposal concept embodies time consuming and expensive first-of-its-kind (beyond-the-state-of--the-art) studies.

Inclosing, following are the author's main observations and conclusions:

1. Although sound science is imperative to safety, *politics will rule both the day and the ending*.
2. Neither the best- nor the worst-intended political and ideological agendas will negate the opinion of the local residents in a democratic society.
3. Nationalistic, organizational, and/or scientific prides might impose constraints on the timely and cost-effective adaptation and avoidance of lessons learned elsewhere.
4. Sound science, a robust disposal concept, transparency, and trust in the messenger(s) go a long way towards establishing and sustaining public trust, and thereby minimizing the "inevitable" delays and cost increases.
5. Deep geological disposal in non-salt rocks has gradually transitioned into deep engineered disposal.
6. The global status of repository developments is neither in lock step with the closing of existing nor the planning of new reactors, which could impose serious constraints on the global Nuclear Renaissance.
7. The siting and development of a UNF repository is very time-consuming and costly, and require unique scientific expertise favoring a) multi-national collaborations and b) regional repositories under objective oversight, e.g., IAEA, in host countries that can demonstrate a long-standing political and geological stability.

REFERENCES

1. http://en.wikipedia.org/wiki/Nuclear_power.

2. World Nuclear News, April 27, 2009 (www.world-nuclear-news.org).
3. United States Nuclear Technical Review Board, "Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel". A Report to Congress and the Secretary of Energy, October 30, 2009.
4. G.E. DIALS AND L.G. ERIKSSON, "WIPP – A Safely Operating, Expandable, Proof of Principle for Deep Geological Disposal of Long-Lived Radioactive Materials", proceedings of the 12th International High-Level Radioactive Waste Management (IHLRWM) Conference, Las Vegas, Nevada, USA, September 7-11, 2008, pp. 595-703.
5. U.S. Department of Energy, Carlsbad Area office, "The Waste Isolation Pilot Plant Pioneering Nuclear Waste Disposal", February 2000 (DOE/CAO-00-3124)
6. U.S. Department of Energy, "In Situ Testing at the Waste Isolation Pilot Plant", prepared by R.V. Matalucci, Sandia National Laboratories (SAND87-2382).
7. National Academy of Sciences - National Research Council, Committee on the Waste Disposal of the Earth Sciences, "The Disposal of Radioactive Waste on Land", Publication 519, September 1957.
8. Public Law Public Law 97-425, "The Nuclear Waste Policy Act of 1982".
9. Public Law 100-203, "The Nuclear Waste Policy Amendments Act of 1987".
10. L.G. ERIKSSON and D.L. PENTZ, "The Yucca Mountain Repository – Too Little, Too Late", proceedings from the Waste Management 2009 (WM09) Conference, Phoenix, Arizona, USA, March 1-5, 2009.
11. Office of Management and Budget, "A New Era of Responsibilities: Renewing America's Promise", Government Printing Office, Washington, D.C., February 2009, pp. 63-65, (www.whitehouse.gov/omb/assets/fy2010_new_era/Department_of_Energy.pdf).
12. L.G. ERIKSSON, "Quo Vadis, Herr NucleUS??", proceedings from the Waste Management 2010 (WM2010) Conference, Phoenix, Arizona, USA, March 7-11, 2010.
13. Congress of the United States, House of Representatives, Committee on Energy and Commerce, "Letter to the Honorable Steven Chu, Secretary, Department of Energy", November 18, 2009.
14. GRAM, Inc., "Year 2000 Annual report on 17 Select National Radioactive Waste Management Programs", Prepared for the U.S. Department of Energy, Carlsbad Area Office, Carlsbad, New Mexico, 15 May 2000.
15. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, "Report to the President and the Congress by the Secretary of Energy on the Need for a Second Repository", (DOE/RW-0595), Dec. 2008.
16. L.G. ERIKSSON, "Member Report on the Status and Challenges Facing the Safe and Timely Disposition of Long-lived Radioactive Materials in the United States of America at the End of July 2004", prepared for International Association of Engineering Geologists (IAEG) Commission No. 14, 1 July 2004 (Revision 1). (A Synopsis is also available from the author.)
17. L.G. ERIKSSON, "A Comparison of the Swedish and U.S. Repository Programs", Radwaste Solutions, January/February 2010, pp. 22-30.
18. Association for Regional and International Underground Storage (ARIUS/www.arius-world.org).
19. M.H. MCFADDEN and L.G. ERIKSSON, "The Successful 1998 Certification of the Waste Isolation Pilot Plant Transuranic Waste Repository - Ten Important Lessons Learned", proceedings from the Waste Management 1999 (WM99) Conference, Tucson, Arizona, February 28-March 4, 1999.
20. H.F. MCFARLANE, "The Paradox of Nuclear Waste, Understanding Nuclear Waste in the Coming Nuclear Expansion", Radwaste Solutions, September/October 2006, pp. 32-36.
21. D.P. ALDRICH, 2008, Site Fights: Divisive Facilities and Civil Society in Japan and the West, Cornell University Press, Hardcover, 2008, 254 pages, (978-0-8014-4619-1).
22. L.G. ERIKSSON, "The Waste Isolation Pilot Plant: A Glance in the Rearview Mirrors on Successful and Unsuccessful Strategies", proceedings from the European Nuclear Society's International Topical Meeting (Topseal99), Antwerp, Belgium, October 10-14, 1999, Volume II, pp. 30-36.
23. L.G. ERIKSSON, "The WIPP Disposal Decision Plan: The Successful Road Map for Transparent and Credible Decision-Making", proceedings from VALDOR2001, Stockholm, Sweden, June 10-14, 2001, pp. 326-333.
24. U.S. Department of Energy, Carlsbad Area Office, "Prospectus on Waste Management and Repository Development Collaborations with the U.S. Department of Energy Carlsbad Area Office", (DOE/CAO-00-1000) June 2001 (Revision 1).
25. U.S. Department of Energy, Carlsbad Area Office, "Citizens' Guide to the Waste Isolation Pilot Plant Compliance Certification Application to the EPA", (DOE/CAO-96-1207).
26. L.G. ERIKSSON, G.E. DIALS, and F.L. PARKER, "A Holistic Approach for Disposition of Long-Lived Radioactive Material", proceedings from the Waste Management 2003 (WM03) Conference, Tucson, Arizona, USA, February 23-27, 2003.