Observations and Thoughts Whilst Waiting for the Blue Ribbon Commission Reports - 11247

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ABSTRACT

At the direction of the U.S. President, the Secretary of Energy established a 15-member Blue Ribbon Commission on America's Nuclear Future (BRC) in January 2010 directed to develop policy recommendations for the back end of the nuclear fuel cycle no later than in January 2012. At the end of 2010, USA's only candidate HLW disposal option had been on hold, de-staffed, and de-funded since February 2009, 12 states had banned the construction of new nuclear reactors until a HLW-disposal solution is available, 34 states lacked disposal solutions for Class B and C LLW, and greater then Class C LLW and sealed sources lacked a disposal solution, which adversely affects public confidence in nuclear-waste disposal, Homeland Security, and the Nuclear Renaissance. It also undermines USA's credibility and standings in the international radioactive waste management community. We thus encourage the BRC to address the following perceived root causes for the repeated delays to the establishment of disposition solutions for the long-lived radioactive waste generated during the back end of the fuel cycle:

1) The lack of a fully-integrated national nuclear waste management policy/plan;
2) Inadequate local public and/or political support;
3) A globally unique, very expensive, HLW-disposal concept;
4) Fragmented and inconsistent radioactive waste disposal regulations for HLW and LLW embodying and imposing flagrant societal inequities; and
5) Lack of trust in the messenger,

because, based on our involvement in nuclear waste management and disposal programs in the USA and abroad since 1972, we believe proven solutions are available.

INTRODUCTION

In February 2009 the new Administration in the United States of America (USA or U.S.) announced its intent to: 1) Abort the nation's only candidate used/spent nuclear fuel and other high-level radioactive waste (HLW) disposal solution since 1987 at the Yucca Mountain (YM) site in Nevada (Fig. 1); and 2) Establish a "blue ribbon panel" to review and provide policy recommendations on USA's nuclear energy program.[1] Please note that he term HLW as used herein includes used and spent nuclear fuel.

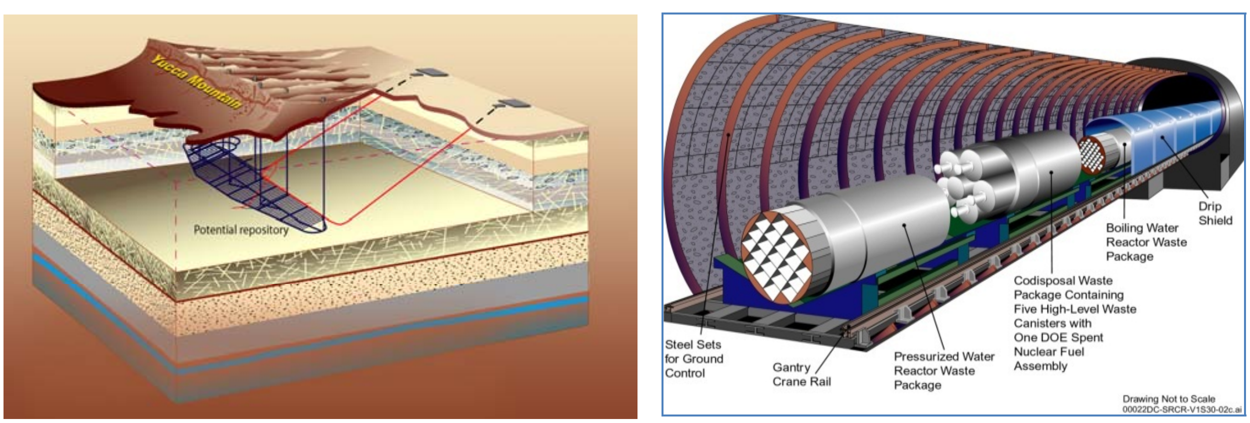

Fig. 1. *To the left* - Schematic illustration of the layout of the proposed HLW repository (in blue color) and the underground research laboratory (in red color) at the YM site. *To the right* – Schematic illustration of a HLW-disposal room at the YM site.

At the direction of the White House, *"The Blue Ribbon Commission on America's Nuclear Future"* (BRC) was established in January 2010 by the Secretary of Energy (the Secretary) (www.brc.gov) to develop policy recommendations for the back end of the nuclear fuel cycle no later than in January 2012. In March 2010, the Secretary approved the establishment of the following three BRC subcommittees: 1) The Reactor and Fuel Cycle Technology Subcommittee; 2) The Transportation and Storage Subcommittee; and 3) The Disposal Subcommittee. The focus herein is on the charter assigned to the Disposal Subcommittee with an emphasis on social acceptance:

"How can the US go about establishing one or more disposal sites for high-level wastes in a manner that is technically, politically and socially acceptable?"

The main reasons for selecting this focus and emphasis are: 1) The main experiences and expertise of the authors are in those areas; 2) Although HLW-disposal solutions have been studied around the world for more than 60 years, the opening of the world's first HLW disposal system (repository) is still at least 10 years away; and 3) Operating storage solutions are abundant both in the USA and abroad. This document identifies a set of perceived root causes to the repeated delays to and resulting long-standing lack of disposal solutions for several radioactive waste categories emanating from the nuclear fuel cycle. It also outlines related potential solutions based on the authors' involvement in and monitoring of nuclear waste management programs in the USA and abroad since 1972. Furthermore, observations, comments, and recommendations provided herein embody and embrace the following two long-standing fundamental ethical and moral obligations defined in the International Atomic Energy Commissions (IAEA's) "Conventions" most countries with overt nuclear capabilities have signed:

- The generation responsible for generating the radioactive waste is responsible for its safe disposition; and
- The disposition solutions chosen by the generating generation should not impose undue burden on future generations or environments.

As follows, one major tenet of this paper is that in order for a waste disposal solution to be socially acceptable, it needs be fully integrated with and evaluated in the perspectives of the related generation and treatment options. Another major tenet is that selective adaptation of applicable lessons-learned by other successful programs enhance the potential for social (and political) acceptance. Select waste disposition (storage, treatment, and disposal) stratagems and the state-of-the-art in the various related repository sciences and technologies in the USA and abroad are thus summarized and commented upon in the subsequent text. Special attention is given to the operating Waste Isolation Pilot Plant (WIPP) repository (Fig. 2) program in the USA (www.wipp.energy.gov), and the mature, fully-integrated, Finnish (www.posiva.fi) and Swedish (www.skb.se) nuclear waste management programs.

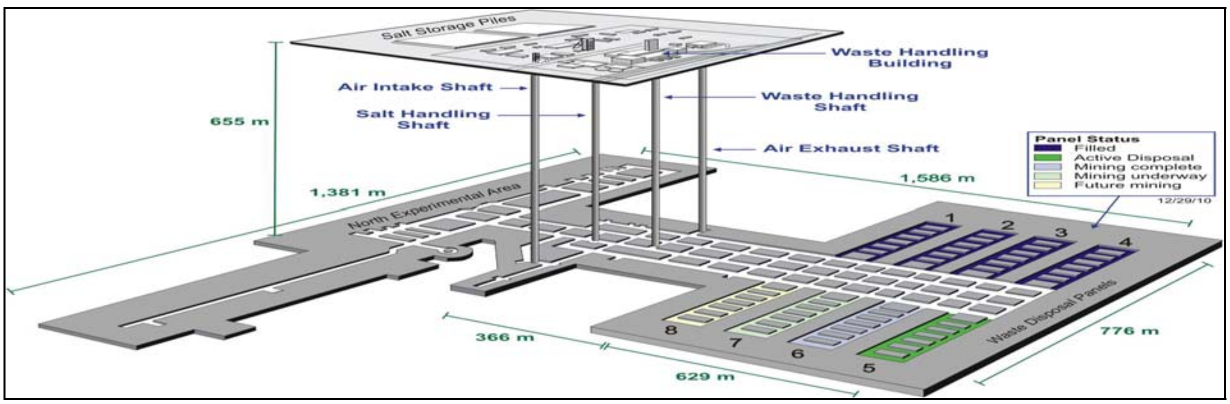

Fig. 2. Schematic illustration of the layout of the WIPP underground research laboratory and repository, including the repository development and operation status at the end of 2010 (Courtesy of DOE).

At the end of 2010, WIPP (Fig. 2):

1. Was the only currently-operating deep geological disposal system for long-lived, solid-state-waste, containing LLRIs in the world.
2. Had safely operated almost 12 years and been re-certified twice.

3. Had also been evaluated for safe disposal of HLW, including a suite of in-situ tests [2-5].
4. Offers a multitude of successful stratagems and lessons-learned that had not been used in the USA or abroad as natural analogues for establishing and sustaining public and political confidence in deep geological disposal of waste containing LLRIs.

The remainder of this paper is organized in the following three main sections:

- A BACKGROUND section providing information on the charters for the BRC and a listing of the rock types pursued by the world's most mature repository programs.
- A DESCRIPTION AND DISCUSSION section beginning with concise descriptions of the legal and regulatory frameworks for radioactive waste disposal and the current radioactive waste classification system in the USA and how they compare with those employed elsewhere. Select historical events, milestones and *perceived* statuses of advanced nuclear-energy and -waste-management programs in the USA and a few select European countries are also highlighted, including *perceived* challenges to technical, social, and political acceptance and *envisioned* potential solutions, and potential paths forward for safe management and timely and cost-effective disposal in the USA of waste containing LLRIs based on the authors experiences dating back to 1972. *The main emphasis is on social acceptance*.
- A SUMMARY OF MAIN OBSERVATIONS AND COMMENTS section reiterating select portions of the information presented in the preceding text.
- A REFERENCE section containing a full listing of the references indicated by Arabic numbers within brackets in the text [1-26].

BACKGROUND

The Blue Ribbon Commission's Charter

The 15-member BRC was directed to: 1) *Conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities*; and 2) Report back no later than in January 2012, including a draft report no later than in July 2011.[1] Specifically, the BRC was to provide advice, evaluate alternatives, and make recommendations for a new plan addressing the following issues:

a. Existing fuel cycle technologies and research and development (R&D) programs. Criteria for evaluation should include cost, safety, resource utilization and sustainability, and the promotion of nuclear nonproliferation and counter-terrorism goals;
b. Options for safe storage of used nuclear fuel while final disposition pathways are selected and deployed;
c. Options for permanent disposal of used fuel and/or high-level nuclear waste, including deep geological disposal;
d. Options to make legal and commercial arrangements for the management of used nuclear fuel and nuclear waste in a manner that takes the current and potential full fuel cycles into account;
e. Options for decision-making processes for management and disposal that are flexible, adaptive, and responsive;
f. Options to ensure that decisions on management of used nuclear fuel and nuclear waste are open and transparent, with broad participation;
g. The possible need for additional legislation or amendments to existing laws, including the Nuclear Waste Policy Act of 1982, as amended; and
h. Any such additional matters as the Secretary determines to be appropriate for consideration.[1]

Status of the BRC and TRUW and HLW Management in the USA and Abroad at the End of 2010

By the end of 2010, the BRC and its three subcommittees had held several public fact-finding meetings at different locations in the USA. Some BRC members and BRC consultants had also visited the Finnish and Swedish nuclear waste management programs. The BRC also had an open invitation to visit with and be visited by Andra (www.andra.fr), the implementer of the French long-lived intermediate-level radioactive waste (ILW-LL) and HLW disposal program.

At the end of 2010, the WIPP repository had operated safely for almost 12 years.[2-5] It had also been recertified twice (www.wipp.energy.gov). As illustrated on Fig. 2, the WIPP repository and its adjacent underground research laboratory (URL) are situated 650 m below the ground surface (in the lower half of a more than 200 million-year-old, approximately 600-m-thick, laterally-extensive, seismically-quiescent, rock salt formation). Disposal space is developed in stages as disposal needs arise. On 6 December 2010, 72,422 cubic meters of long-lived transuranic radioactive waste (TRUW) had been safely received, handled and disposed of at the WIPP site after having been safely transported by trucks more than 17.7 million kilometers (www.wipp.energy.gov).

The YM repository program had been stripped of funding and personnel since February 2009[1] but was still a legally-viable HLW-disposal option at the end of 2010 pending rulings by the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Court of Appeals for the District of Columbia Circuit on the Secretary's motion on February 1, 2009 for the withdrawal of and the stay of the proceedings for the May 2008 construction license application (CLA) for a 70,000 metric tons HLW-repository at the YM site. Whether or not the YM HLW repository survives, it will no longer be the first HLW repository to open in the world; it will likely be opened by Finland in 2020, followed by France, Sweden, and, perhaps, Germany by the end of 2025. If the YM HLW repository timely survives current political challenges and is timely re-staffed and re-financed, it could also possibly open before the end of 2025. In addition to tuff, which has only been studied in the USA so far, the following four geological formations had also been extensively studied for several decades and are thus deemed to embody the most mature and, thus, most promising repository concepts in terms of technical, social and political acceptance:

1. Rock salt (e.g., in Germany and USA/WIPP).
2. Argillite/mudstone/shale (e.g., in France and Switzerland).
3. Crystalline basement rocks (e.g., in Canada, China, Finland, Japan, Sweden, and Switzerland).
4. Over-consolidated clay (e.g., in Belgium and Japan).

Belgium, Finland, France, Japan, Sweden, Switzerland, and the USA still operate domestic URLs in their respective candidate repository host rocks. Several of these URLs host multi-national research activities but only rock-repository programs are considered in this paper, i.e., clay is not addressed herein.

On 23 December 2010, the NRC published [6] the following updates to two of its five Findings in the 1994 Waste Confidence Decision (Code of Federal Regulations, Title 10, Part 51, Subpart 21(a)) in the Federal Register:

Finding 4: "The Commission finds reasonable assurance that, if necessary, spent fuel generated in any reactor can be stored safely without significant environmental impacts for at least 60 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of that reactor in a combination of storage in its spent fuel storage basin and either onsite or offsite independent spent fuel storage installations." (The previous "Finding" limited the storage period to 30 years.)

Finding 2: "The Commission finds reasonable assurance that sufficient mined geologic repository capacity will be available to dispose of the commercial high-level radioactive waste and spent fuel generated in any reactor when necessary." (The previous "Finding" pre-supposed reasonable assurance of a mined HLW-disposal solution by the end of first quarter of 2025.)

However, the modified NRC findings may not mitigate current bans on new nuclear reactors in 12 states due to the already more than 12-year-overdue opening of a domestic HLW-disposal solution.[7] Other states might also employ this stratagem to ensure that the development of at least one HLW-disposal solution is continued.

Notwithstanding the global lack of HLW-disposal solutions for another decade, there is still a consistent global trend that deep geological disposal is the preferred solution among nations, i.e., the IAEA, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) and the European Commission (EC) of the European Union (EU) all recommend disposing of HLW in a solid form in stable geological formations. For example, on 3 November 2010, the EC released its long-awaited proposed Nuclear Waste Directive (the Directive). If approved by the EU's Council of Ministers and the European Parliament, the related legislation would direct all EU member states to develop plans to store radioactive waste in safe repositories. This legislation has been drafted and debated by Brussels officials for years, and covers all kinds of radioactive waste and used nuclear fuel, whether from nuclear power plants or medical and research facilities. It specifically notes that:

"*It is broadly accepted at the technical level that deep geological disposal represents the safest and most sustainable option as the end point of the management of high level waste and spent fuel considered as waste.*"

The Directive also allows two or more EU-member states to share a repository but they would not be allowed to export nuclear waste outside the EU for disposal. *It also insists governments inform and consult the public when drawing up their plans.* Regarding disposal operations, the legislation would make the IAEA's safety standards legally binding across the EU, including the work of independent authorities licensing repositories and inspecting their operations. As follows, *the Directive offers information on policy measures relevant to the BRC charter.*

DESCRIPTIONS AND DISCUSSIONS

The acceptance of nuclear power has experienced a global warming during the past decade in that it has become one of the preferred options for clean energy both in the USA and abroad. It is also the only clean energy option offering sufficient capability and flexibility to serve large communities and, in particular, daily fluctuating energy demands. The term used for this global paradigm is the "*Nuclear Renaissance*".

Although the focus herein is on disposal of HLW, the safe disposal of other U.S. waste categories containing LLRIs that may be generated during the back end of the nuclear fuel cycle are also described and discussed because several of them currently lack a disposal option/solution. The three main U.S. radioactive waste categories addressed herein are: low-level radioactive waste (LLW), TRUW, and HLW. As illustrated on Fig. 3 using France for comparison and as an example of the IAEA waste classification guidelines, the waste classification system used in the USA differs from those used in other countries. One such difference is that USA does not have the ILW category most other countries have. Instead, USA has the TRUW category, which only nations with nuclear-defense programs have but may classify differently, and the greater than Class C (GTCC) LLW category. Also, although the LLW classification is used both in the USA and abroad, both the characteristics and the inherent risks to human health and safety, and to the environment posed by LLW in USA differ from those used in other countries. In simple terms, the U.S. waste classification is largely based on how the waste was generated and what it is not.

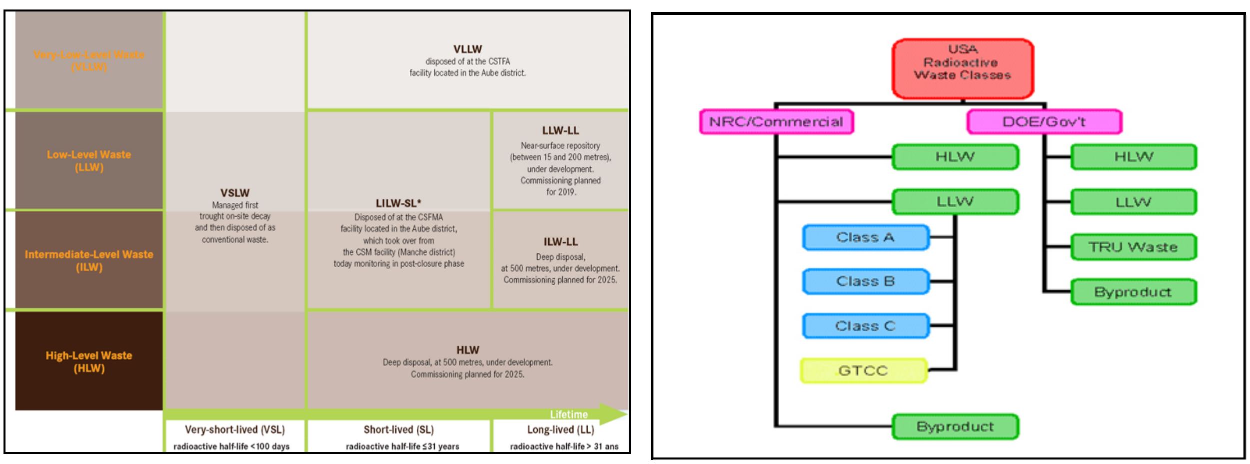

Fig. 3. Schematic illustrations of the radioactive waste classification systems used in France (to the left) and in the USA (to the right), respectively.

As repeatedly demonstrated in the USA and abroad during the past 40 years, social and, ultimately, political acceptances govern both the rate of progress and the cost of the proposed technical solutions.[8,9] As elaborated upon below, in the case of proposed disposal systems for HLW and other waste categories containing LLRIs, ***trust in the messenger***, *including the applicable regulation(s)*, is the only option for the vast majority of the human population to base a decision upon due to:

a) The long temporal and huge spatial scales involved;
b) The advances sciences and technologies involved; and
c) The multitude of potential features, processes and events (FEPs) that are evaluated.

As elaborated upon in the subsequent text, there are two sets of HLW-disposal regulations in the USA. The post-closure safety and assessment (P/SA) period in one set, also referred herein to as the "nation-wide set", is 10,000 years,[10,11] whereas it is 1 million years in the other set, also referred to herein as the site-specific set".[12,13]. Although the portion of the biosphere to be considered typically varies as a function of the amounts and types of waste to be disposed of, for HLW repositories it typically covers a horizontal area in excess of 30 square kilometers and at least the uppermost 500 meters (m) of the geosphere. Using WIPP as the example, the volume evaluated for 10,000 years in the 1996 Compliance Certification Application (www.wipp.energy.gov) was approximately 75 cubic kilometers (km^3), which probably is less than half of that considered for the YM HLW repository. The WIPP P/SAs addressed 1,800 initial parameters and their evolution during 10,000 years under different conditions that resulted in 600 different scenarios randomly combining FEPs with a probability of occurrence greater than 10^{-8}.

In simple terms, all post-closure P/SAs for disposal system designed to safely contain and isolate waste categories containing LLRIs include the following five categories (buckets) of FEPs: 1) FEPs we know we know; 2) FEPs we think we know; 3) FEPs we know we don't know; 4) FEPs we think we don't know; and 5) FEPs we don't know we don't know. Since the P/SAs, typically, are the main yardsticks for post-closure compliance with applicable licensing criteria, they are subject to intense scrutiny and skillfully used by opponents to nuclear energy and the proposed disposal solution to argue the projected risks. The fact the P/SA numbers are merely approximations intended to bound potential risks is often lost in this debate. Furthermore, terms and units used are not readily understood by the general public and many scientists and engineers do not convey information to or communicate with the general public in terms it understands. Most people thus face the following five options:

1. To reject the proposed disposal solution because it is not understood and thus scares them.
2. To reject the proposed disposal solution due to ideological beliefs.
3. To reject the proposed disposal solution because it lacks personal, political, and/or financial benefits.
4. To accept the proposed disposal solutions because it has personal, political, and financial benefits.
5. To accept the proposed disposal solution because the individual trusts that the individual and/or organization proposing the solution has the requisite objectivity, experience, expertise, and credibility, and the applicable regulation(s) provide adequate safety.

Clearly, there are also other reasons why individuals accept and reject a proposed disposal solution for waste containing LLRIs. For example, despite having no relationship to the potential risks imposed by disposed waste containing LLRIs, the scary visual memories of the Hiroshima and Nagasaki events in the early 1940s, and the exaggerated risks and potential consequences of the 1979 Three Mile Island and the 1986 Chernobyl accidents continue to adversely affect people's acceptance and support of proposed disposal solutions for radioactive waste. Another (mental) challenge to address and mitigate is thus captured in the following Mark Twain statement:

"It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so."

In summation, P/SAs conducted in support of HLW- and TRUW-disposal facilities are not exact, include assumptions, hypothetical boundary conditions, and uncertainties, and are beyond the comprehension of most individuals, including the authors'. They are, however, the only means to project the risks imposed over time by a disposal system designed to safely contain and isolate waste containing LLRIs. *An integral component of achieving trust is thus the perceived protection provided by applicable laws and regulations*. However, as elaborated upon below, ***the current legal and regulatory frameworks and the LLW and HLW regulations in the USA embody social inequities that generate concerns and distrust rather than trust***.

Challenges Embodied in the Current Legal and Regulatory Frameworks

The Low-Level Nuclear Waste Policy Act of 1980 (LLWPA) [14], the WIPP Land Withdrawal Act of 1992 (WIPP LWA) [15] and the Nuclear Waste Policy Act of 1982 (NWPA) [7], as amended, are the current legal cornerstones in the USA for safe management and disposal of LLW, TRUW, and HLW, respectively. With the exception of TRUW disposal, the following three conditions are deemed to complicate the timely and cost-effective disposal in the USA of other waste categories containing LLRIs and to also compromise public trust in the related regulation:

1. **Fragmented Regulatory Authority** - Whereas all commercial nuclear waste generators are regulated by the NRC and/or the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE) regulates federal sites with the exception of TRUW and HLW disposal (Fig. 3).
2. **Inconsistent Regulatory Requirements** - Individual states can apply for and be granted authority by the NRC and the EPA to regulate and oversee the safe management and disposal of LLW within its state, provided the state regulation is at least as stringent as the corresponding NRC and/or EPA regulation. States with this authority are called "Agreement states". For example, whereas the NRC regulation limits the period of compliance for Class A-C LLW to 500 years, the Agreement state regulation promulgated by Texas Commission for Environmental Quality require peak dose calculations. Waste Control Solutions LLC thus had to conduct P/SAs for their two proposed near-surface LLW landfills covering more than 125,000 years to establish that the peak period occurred after approximately 36,000 years and that the peak dose was well below the regulatory limit. Considerable time was also expanded on arguing details of the algorithms, codes and models used despite the marginal risk and consequences represented by the peak dose. Furthermore, LLW regulations also vary among Agreement states, which further conveys the following two confusing messages to the general public:
   a) The definition of safety is subjective; and
   b) The safety definitions established by the NRC and the EPA do not provide adequate safety in states promulgating more stringent regulations.
3. **Unsuccessful Disposal Strategies** - Each state is responsible for the safe management and disposal of the LLW generated within its borders but they can join in "Compacts" where one state provides disposal for the LLW generated in the other member states. Notwithstanding the opportunity states have had for several decades to build their own disposal facility or team with one or more other states, only one new LLW Compact has been developed since 1990; the Texas/Vermont Compact. Furthermore, albeit there are multiple options for safe disposal of Class A LLW (Fig. 3) in the USA, at the end of 2010, 34 states lack a disposal solution for their Class B and C LLW (Fig. 3). The only potential solution for these states is an ongoing campaign to allow generators located outside of Texas and Vermont to access the Texas/Vermont Compact LLW-disposal facility.

The WIPP-LWA sets aside a square surface area (land parcel) measuring 6.4 by 6.4 kilometers (km) from public use.[15] The depth of the underlying WIPP disposal system is limited by a separate agreement with the State of New Mexico to 1,863 m. This portion of the geosphere now accommodates the surface facilities and underground openings needed for the WIPP TRUW repository (Fig. 2). The shortest distance between any emplaced TRUW and a compliance point at the WIPP site is 2.4 km. The WIPP TRUW repository was certified by the EPA in May 1998 to meet all applicable regulations.[16] It opened in March 1999 following the dismissal of all legal challenges.

The NWPA directed the then Secretary to site, develop, and open two deep geological repositories for safe disposal of the nation's HLW three years apart; the first repository was to open no later than on 31 January 1998.[7] Following the December 1987 amendment to the NWPA (NWPAA),[17] the second repository program was terminated and the YM site became the nation's only candidate HLW-repository site. However, local opposition and Congressional lack of action have caused several delays to the projected opening date for the YM HLW repository. In December 2008, the then Secretary advised Congress that the YM HLW repository would not open until the very earliest in 2017 but more likely in 2020.[18] He also advised Congress that the legal capacity of the YM HLW repository was smaller than the nation's projected stockpile of HLW in 2010 and suggested the capacity of the YM HLW repository be expanded. If this recommendation was rejected, he suggested the prompt siting and development of a new HLW repository based on the sites abandoned in or before 1987. At the end of 2010, neither of these recommendations had been acted upon by the Congress. Furthermore, it is unlikely Congress will act upon them until after the Secretary has "accepted" the final BRC report. The 2017-2020 opening of the YM HLW repository projected by the then Secretary in December 2008 is thus no longer deemed attainable. With the final BRC report not being due until January 2012, which is a national-election year, it is unlikely that Congress will act upon it until in 2013. As follows, if the YM HLW repository is not re-started before 2013, it will experience an additional delay of five years, pushing its earliest possible opening date to 2022 but more likely to 2025.

Highlighted below are select "historical" events and milestones of USA's and a few select European countries' nuclear-energy and nuclear-waste-management-and disposal programs deemed to be relevant to the BRC's charter and to the social acceptance of its pending reports.

Nuclear Energy

At the end of 2010, USA still had the largest nuclear energy program in the world, hosting 104 of the world's 440 commercial nuclear reactors. However, nuclear reactors only contribute to approximately 20% of the nation's total energy consumption, which is less than half of that provided by nuclear reactors in several European countries, including Finland, Germany, Sweden, Switzerland, and the United Kingdom (UK), and less than one-third of that provided in France. One *perceived* reason for USA's comparatively low percentage of nuclear to the nation's total energy consumption is that no commercial nuclear reactor has been started in the USA since the early 1980s, whereas the nation's total population and energy consumption has increased significantly. Four *perceived* related root causes to the long-standing lack of new reactors are:

- Public and "ideological" opposition;
- The huge economic investments required;
- The long gestation period before the return on investments starts; and
- The inherent financial risks.

Furthermore, despite simplified licensing procedures intended to shorten the gestation time for new reactors and government promises to provide start-up financing for new commercial reactors, also referred to as loan guarantees, the Nuclear Renaissance seemed to stall in the USA during 2010. The Administration's request in 2010 for an interest rate in excess of 11.6% for a loan guarantee for a new commercial reactor was neither economically-acceptable to the applicant nor deemed supportive by the nuclear industry of a domestic Nuclear Renaissance. In contrast, several other countries realizing the need for timely access to energy in order to be able to sustain and improve quality of life and production are aggressively planning and investing in nuclear energy. For the reasons summarized below, we consider Finland the current role model for the Nuclear Renaissance.

At the end of 2010, Finland, with a total population of approximately 5.3 million people, had four operating nuclear reactors, was scheduled to start a fifth reactor in 2013, and had a "decision-in-principle" for the siting of three additional reactors. Interestingly, one planned reactor project (Fennovoima) will be majority-owned (66%) by the Finnish industry (Voimaosakeyhtiö, which counts 69 organizations as its shareholders) rather than by any of the two large Finnish utilities or any foreign utility, although the German utility EOn has a 34% stake in the project.

One stratagem, or rather root cause, deemed to have significantly contributed to the successful development of nuclear reactors in Finland is the direct linkage between the development of nuclear reactors and the timely availability of the disposal options required to minimize the risks to public health and safety and the environment from the types and volumes of radioisotopes generated. This concept is schematically illustrated on Fig. 4 and is henceforth referred to as *a fully integrated national nuclear waste management policy*, ***something the USA currently does not have at the end of 2010***.

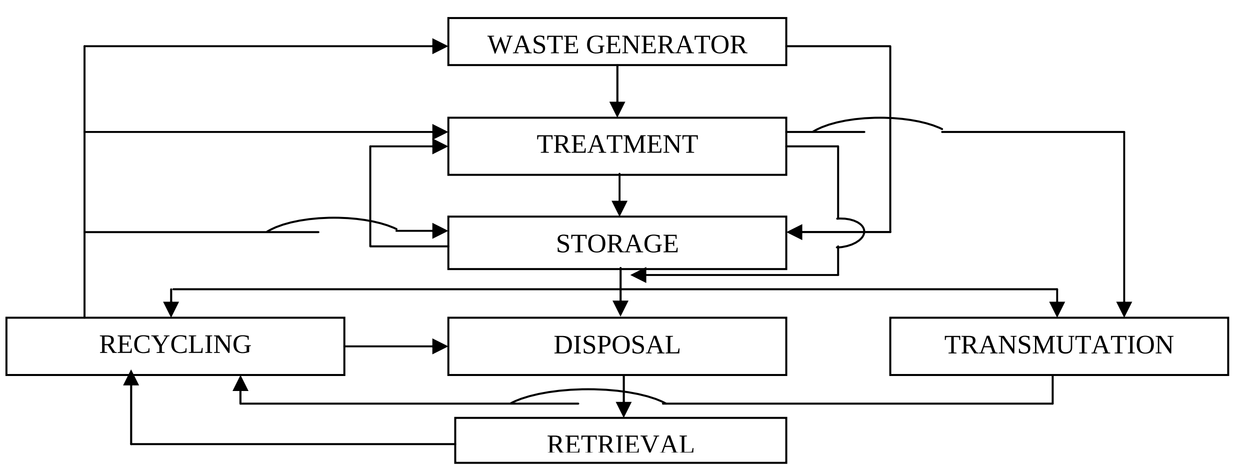

Fig. 4. Schematic illustration of the main components of a fully-integrated (holistic) national radioactive waste management policy.[19]

Nuclear Waste Management and Disposal

Another Finnish pioneering landmark stratagem is that the implementing organization for the HLW disposal program, Posiva OY, decided in the late 1980s to evaluate then mature HLW disposal concepts and programs in other countries and to adopt and tailor stratagems, concepts, and components suited to Finnish conditions and/or expediting the domestic repository-science and -technology bases. Based on this evaluation, Posiva decided to focus on the voluntary siting approach and disposal concept developed and pursued by the Swedish Nuclear Fuel and Waste Management Company (SKB), the KBS-3 concept. Posiva and SKB have successfully collaborated since then and both have successfully advanced their respective radioactive waste disposal program and have benefitted from local acceptances well above 50% at potential and candidate HLW-repository sites during the last two decades.

Both Finland and Sweden have had fully-integrated nuclear waste management policies and programs for more than 30 years. This long-standing national commitment to nuclear energy based on an active fully-integrated national radioactive waste management program (Fig. 4), augmented by international collaborations, has minimized the inherent delays of siting and developing HLW repositories experienced in Finland and Sweden compared to those experienced in some other countries such as e.g., Canada and UK. It has also propelled Finland, *"the little engine that could"*, to the global forefront of both nuclear energy production per capita and the timely development of safe disposal solutions for the resulting waste. In addition to enhancing social acceptance of the disposal concept by teaming with the SKB, Posiva's tailored adaptation of the SKB program probably shortened the gestation period for its HLW-repository at least 5 years.[20]

With regards to the path(s) forward for nuclear waste management and disposal in the USA, the "technical" pre-requisites for disposal are essentially governed by: the types and amounts of "waste" generated; and when and how the generated waste needs to be dispositioned (stored, treated, and disposed). In other words, waste-disposal analyses must be integrated with the generating source. As follows, due to the current uncertainty about: a) Future reactor technologies and waste streams, and b) The future of the YM HLW repository, *the pending BRC reports need to outline disposal solutions for both existing and future waste streams, and both without and with access to the YM HLW repository.* The following five multi-faceted, closely-related, conditions are deemed particularly important for achieving social acceptance of any proposed disposal system for waste categories containing LLRIs:

1. Early and sustained majority acceptance in the county hosting the proposed facility, including veto right through the site selection process up to but not after the selection of the final site (lex Sweden).
2. A robust disposal concept with a high confidence factor, i.e., a disposal concept pursued by other nation.
3. A simple and stable geology with a repository host rock of adequate vertical and lateral extents.
4. Credible and understandable "messengers".
5. Nationally uniform laws and regulations.[20]

With regards to conditions 2 and 3, at the end of 2010 there are four groups/families of rocks that could be tapped for site-specific repository-siting and development information less than 23 years old, i.e., argillite/mudstone/shale, granite, rock salt, and tuff. Although only two of those are domestic projects, i.e., the WIPP and the YM projects, their respective approach and evolution differs dramatically and provide two bounding domestic analogues for what to do and vice versa to achieve and sustain social acceptance. However, the historical record in the USA suggests that regardless of the resources being allocated or the pedigree of the technologies used or proposed, the following three major challenges must be successfully dealt with in order to achieve and sustain social acceptance and progress:

- Wide-spread public fear, fueled by misinformation spread by various interest groups;
- Long-standing political reluctance to address and support HLW-disposition solutions; and
- Long-standing, wide-spread, lack of confidence and trust in the organization responsible for developing the nation's HLW repositories.

In our opinion, the most promising path forward for the development of safe disposal systems for HLW in the USA is as follows:

1. Re-establish one nation-wide set of safety/risk/performance criteria for all types of HLW-disposal systems.

2. Assign the oversight of the siting, design, development, and operation of future HLW repositories to one or more entities with a vested interest in reaching the goal line in a timely and cost-efficient, yet safe, manner.
3. Consider only regions/areas/sites where ***the majority (>50%) of the residents*** support the hosting of a HLW repository. In order to ensure social equity, a clear geographical distinction needs to be made between *"near-field"* and *"far-field"* residents, which could be accomplished by distinguishing between:
   i. Residents and businesses directly exposed to the potential risks imposed by the repository, i.e., living in the immediate vicinity of the proposed disposal facility, say 10 km (= near-field zone 1);
   ii. Residents and businesses exposed to the potential risks imposed by the storing and/or transporting of the waste, say 1 km (= near-field zone 2); and
   iii. Residents and businesses located outside the aforementioned two near-field zones (= far-field zone).
4. Evaluate and adapt tailored applications of stratagems, concepts, and components of other mature repository programs. At the end of 2010, the most advanced European radioactive waste management programs pursue HLW repositories in rock salt (Germany), granite (Finland and Sweden) and argillite/mudstone/shale (France and Switzerland).

As mentioned in the preceding text, WIPP also constitutes a successful domestic analogue on how to establish and maintain local acceptance of a disposal solution for waste containing LLRIs. Among the many successful stratagems employed at WIPP, we believe the 1994 WIPP Disposal Decision Plan (Fig. 5) to be particularly relevant.[21] It contained 47 officially-announced interaction points with regulators and other interested parties, all accessible to the public, during a four-and-a-half-year-long period preceding the submittal of the opening of WIPP. It should be noted that the 47 public-interaction points shown in Fig. 5 were augmented with an even greater number of other meetings with or open to the public.

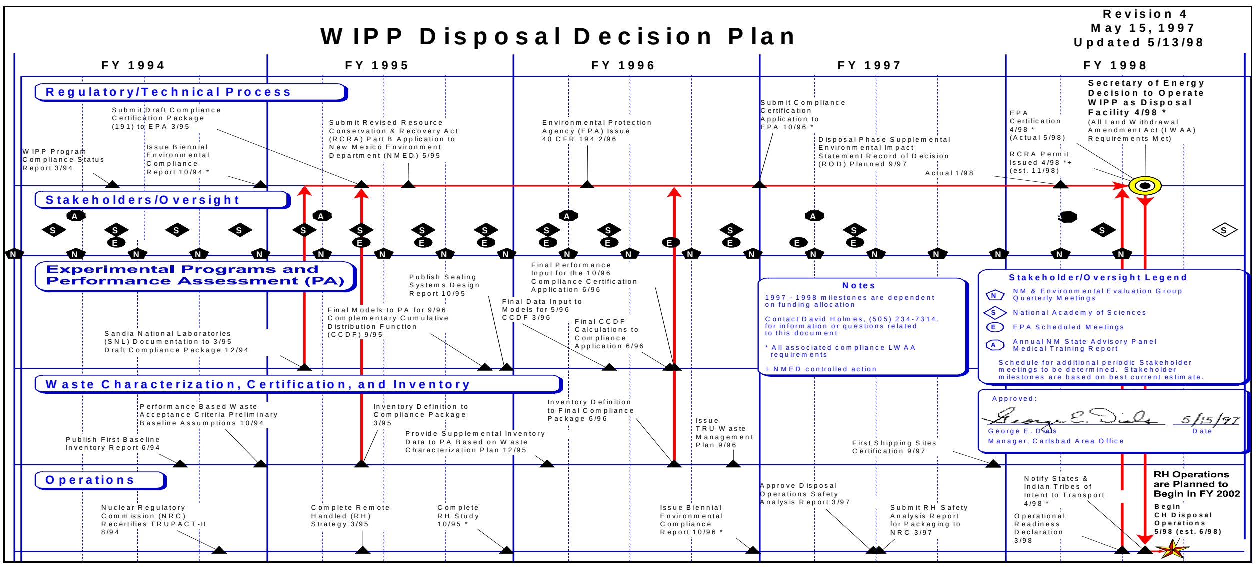

Fig. 5 The 1994 WIPP Disposal Decision Plan.[21]

As follows, *we recommend both the BRC and the rest of the world to look outside the "HLW bucket" and consider WIPP an option for demonstrating the proof of principle for deep geological disposal of waste containing LLRIs as well as other wastes containing LLRIs. We also recommend the stratagems used and the lessons learned during the siting, site-characterization, development, certification/re-certifications, and safe operation of WIPP be studied in detail by competent individuals for components that might increase "near-field" social acceptance, reduce cost, and shorten the timeline for a new repository before a future national policy for waste disposal is enacted.*

We would also like to acknowledge the importance of independent review groups to both public and political acceptance. In addition to the seven domestic independent peer review groups and the international peer review group established in the mid-1990s to review components of the 1996 WIPP Compliance Certification Application (CCA), more than 10 years earlier the state of New Mexico had established a "permanent" Environmental

Evaluation Group (EEG) chartered to monitor WIPP and to conduct independent tests as deemed required to ensure that the research being done at WIPP addressed all applicable areas and was conducted in compliance with all applicable procedures and EPA regulations. To the residents in New Mexico, the EEG served as a "sanity check" and "truth serum" and when it confirmed results and conclusions presented by the DOE and its contractors, primarily Sandia National Laboratories (SNL), they were generally accepted and appeared to make people feel more comfortable about WIPP. *Two perceived major reasons for this implied trust were the relevant subject matter expertise vested in the members of the EEG and their longevity in serving.*

As summarized in the preceding text, the current legal and regulatory frameworks for nuclear waste management and disposal in the USA are geographically inconsistent. With regards to the perceived safety embodied in applicable laws and regulations, we chose to only address current regulatory conditions of concern because they were deemed to also highlight the related legal issues. Following are five current regulatory conditions deemed to embody social inequities that undermine public trust in the U.S. LLW- and HLW-disposal regulations:

1. The current waste classification system is not activity-based and does neither reflect the respective waste category's inherent radiation risks to human health and safety nor to the environment.
2. The regulatory authority is based on two main categories of waste generators. As indicated on Fig. 3, the government, i.e., DOE, is "self-regulating" the safe management of all government-generated radioactive waste [22], and the NRC (and/or the EPA) is regulating the safe management and disposal of all privately-generated radioactive waste plus the safe disposal of government-generated TRUW and HLW.
3. The NRC and the EPA have two sets of regulations pertaining to HLW disposal that vary geographically; one set [12,13] applies to the YM site (site-specific) and the other set [10,11] applies to the rest of the USA (nation-wide), of which only the nation-wide EPA regulation [11] currently applies to WIPP. Two current social inequities between the two sets are: i) The distance between the perimeter of the waste and the regulatory compliance point(s); and ii) the required time for the post-closure P/SAs. The post-closure compliance at the YM site is measured and projected for 1 million years 18 km away from the repository in a specific direction, whereas it is 10,000 years and not to exceed 10 km in any given direction in the national regulations. The fact that they are only 10,000 years and 2.4 km at WIPP does not instill confidence in the safety embodied in the site-specific regulations.
4. Both the NRC and the EPA can authorize individual states to regulate and oversee compliance with applicable state regulations within their respective state, with one proviso being that the state regulation is at least as stringent as the related/replaced federal regulation but has no proviso for an "upper bound". Current Agreement state LLW-management and -disposal regulations thus vary in terms of the pre-requisite safety and performance requirements among states.

Conceivably, the long-standing lack of nationally uniform radiation/risk-based safety standards for the management and disposal of LLW and HLW undermines public trust in both the applicable regulation and the actual messenger(s) because *why should the general public in one state or adjacent to a given site accept assurances of adequate safety when the regulation(s) used to define their safety is(are) less stringent than the corresponding regulation(s) used elsewhere in the USA?* Actually, the problem could be more complex than that because, *why should the general public feel comfortable with the "home-made", essentially waste-generator-based nuclear waste classification system used in the USA when most of the rest of the world are using activity-based waste-classification standards based on the guidance provided by the IAEA (Fig. 3)?*

In our opinion, the root cause for the current lack of consistency among the nation's LLW-disposal regulations is the current charter for the Agreement States. Figuratively speaking, the definitions of safety have typically been raised and changed from a high-jumping contest in the NRC and EPA regulations to a pole-vault competition with different bar heights in the Agreement State regulations. The related question is: *why should the public in one state believe that the "messenger" can be trusted that their state's regulations provide adequate health and environmental radiation protection when another or several other states have much more restrictive/protective regulations?* ***A potential remedy for harmonizing the current inconsistent regulatory framework for LLW-disposal would be to limit the charter of the Agreement States, to oversee compliance with nationally uniform NRC and EPA regulations with the pre-requisite that "overseers had been properly trained and certified by the NRC and/or EPA. A potential remedy to harmonize the current inconsistent regulatory framework for HLW disposal would thus be to vacate the site-specific regulations and re-evaluate and re-promulgate, if necessary, the national regulations.***

In order for USA to open its first HLW repository by the end of 2025, either the YM HLW repository has to *timely* survive the following as well as any new challenges:

1. Its current political challenge.
2. Pending rulings by the NRC and the U.S. Court of Appeals for the District of Columbia Circuit on the Secretary's motion for withdrawal of the CLA for the YM HLW repository.

It is unlikely that the final ruling would occur in time to be of guidance to the BRC. The pending BRC reports must thus address the following three basic HLW-disposal options:

1. The YM HLW repository is available at the current legal capacity.
2. The YM HLW repository is available with increased capacity, which could require two options; a) The YM HLW repository is sized to accommodate all projected HLW for the next 30-60 years, and b) The YM HLW repository is supplemented by another HLW repository.
3. The YM HLW repository is not available.

In case the YM HLW repository does not survive all current challenges, based on the current historical record, the opening of USA's first HLW repository would be delayed at least 30 years.[20] However, it is compelling to suggest based on the historical records of the German and WIPP repository programs that a gestation period of about 20 years could be attainable if successful stratagems and lessons learned from those programs are timely and effectively implemented. The gestation period could even be significantly shorter than 20 years if the mission of WIPP is expanded to also allow disposal of HLW.[23] With regards to this potential option, it might be more readily accomplished if limited to a given quantity of defense-generated HLW (DHLW). Clearly, the WIPP mission could also be expanded to accommodate the safe disposal of GTCC and GTCC-like LLW, and sealed sources. Another apparent advantageous attribute of the WIPP region is that the residents in the host county for WIPP as well as those in the adjacent counties are already familiar with and accepting to hosting nuclear installations.

The history and current perilous status of the YM HLW repository program will likely adversely affect the Nuclear Renaissance in the USA and, perhaps, abroad. Augmented by the long-standing lack of disposal solutions for several other LLRIs, USA's international credibility and standings in the nuclear waste management community will continue to erode until a successful nuclear waste management policy is in effect and is implemented in a timely and cost-effective manner. It is unlikely that Congressional action will be forthcoming prior to the pending final policy recommendation from the BRC; currently due no later than in July 2012. With 2012 being a national/presidential election year, it is also unlikely that the Congress would propose and submit for Presidential enactment a politically and publicly controversial legislation until 2013, at the earliest.

MAIN OBSERVATIONS AND CONCLUSIONS

At the end of 2010, USA had neither started a new commercial reactor during the past 27 years nor managed to develop safe disposal solutions for several waste categories containing LLRIs despite more than 50 years of costly efforts.[24] Following are five *perceived* root causes to the long-standing lack of HLW-disposal solutions:

1. Lack of political will at the highest national level.
2. Successful opposition by various interest groups.
3. Lack of a fully-integrated nuclear waste management policy/program.
4. Inconsistent nuclear waste management and disposal regulations.
5. Lack of trust in the messenger, including regulator(s) and the implementing organization(s) and their respective consultants.

As a result, USA's standings as an international "authority" and a credible spokesperson on radioactive waste management and disposal issues and topics have gradually deteriorated during the past 20 years because it has had virtually nothing positive to offer to the international radioactive waste management community in terms of repository sciences and technologies. One *perceived* reason for USA's lack of contributions to the international radioactive waste management community is that the pursued HLW-disposal concept is globally unique and of little applicability and interest to the rest of the world. Another *perceived* reason it that the successful stratagems and other lessons learned at WIPP, [e.g., 2-5,16,21,23,25,26] including a suite of HLW-disposal-related in-situ tests in the WIPP URL,[2-5] may not have been duly evaluated and promoted either domestically or abroad, which, in our opinion, is not in the best interest of establishing and sustaining either national or global social acceptance of deep geological disposal of waste containing LLRIs. Expanding the WIPP mission to allow for HLW disposal would shorten the gestation period for a HLW repository at least 20 years.[27] Limiting the expansion to a given quantity DHLW would probably be both more socially and politically acceptable. Two reasons we favor this solution are:

1. There is no apparent need for or benefit in re-processing DHLW.
2. Depending upon how long time the commercially-generated HLW (CHLW) has been stored, the thermal output from the DHLW packages is only 10-30% of that emitted by the CHLW packages.

With regards to public *trust in the messenger*, it embodies the following two major fundamental components:

- The perceived safety provided by applicable laws and regulations.
- The trust in the actual messenger(s).

In our opinion, the first step in regaining trust and respect in the international radioactive waste management community would be for the USA to develop a fully-integrated radioactive waste generation, management and disposal policy tailored on successful domestic and foreign stratagems and other applicable lessons learned. The following successful stratagems and lessons-learned in other repository programs are submitted for consideration:

1. Only site HLW repositories in communities where the majority of the residents support them.
2. Allowing the potential/candidate host communities a place at the table, including veto right up to but not beyond the point the final site is selected.
3. Assigning the implementation of the program to an organization with a vested interest in establishing and maintaining public trust in the proposed disposal solution in order to also save time and money.
4. Nationally uniform waste management and disposal regulations perceived by the general public to provide adequate safety.
5. Distance/shield the implementation of the HLW-disposal program from the political community and its continually changing weather vanes.
6. Ensure that the opinions voiced are representative of those actually being potentially physically affected by the proposed disposal solution. Based on foreign approaches, it could be accomplished by a clear distinction and assignment of different importance values to the following three geographically/risk-based vocal/opinion zones:
   i. Those emanating from residents and businesses located in the immediate vicinity of the proposed disposal site (= near-field zone 1);
   ii. Those emanating from residents and businesses in the immediate vicinity of the proposed a) storage site and b) transportation routes leading to the storage and disposal site(s) (= near-field zone 2); and
   iii. Those emanating from residents and businesses located outside of the aforementioned two near-field zone" (= far-field zone).

   A referendum is often used abroad by the host community for a potential facility for waste containing LLRI to establish and verify the majority opinion of its residents. In our opinion, this measure could and should be used in Nevada before the YM HLW repository is aborted for political reasons.

With no U.S. HLW-disposal solution in sight for at least another 10 years,[9] conceivably additional CHLW-storage solutions will be needed for Homeland Security, financial (e.g., the breach of the "Standard Contracts" [9,24]) and space reasons. Although not described in the preceding text, we strongly recommend the BRC and, ultimately, the Congress to carefully evaluate the benefits of the concepts used and lessons learned at the Swedish underground disposal facility for short-lived LLW and ILW (SFR) at Forsmark and the underground long-term (30 years plus) storage facility for HLW (Clab) at Oskarshamn (www.skb.se) (Fig. 6) because both of them embody excellent environmental radiation protection and human-intrusion safeguards and have been safely operated for more than 20 years.[20,24]

In closing, our overriding observation and conclusion is that the siting of disposal facilities for HLW as well as for other waste categories containing LLRIs, cannot be looked upon in isolation if realistic, defensible, and sustainable national nuclear-waste-disposal solutions are to be politically and socially acceptable. We thus urge the BRC to outline *a realistic, long-ranging (> 30 years), fully-integrated, national nuclear-waste management policy, including prioritized solutions*, in the pending reports to avoid the following epitaph:

"They gave birth astride a grave, the light gleams an instant, then it's night again."

(From Waiting for Godot, Act 1, by Samuel Beckett, 1953.)

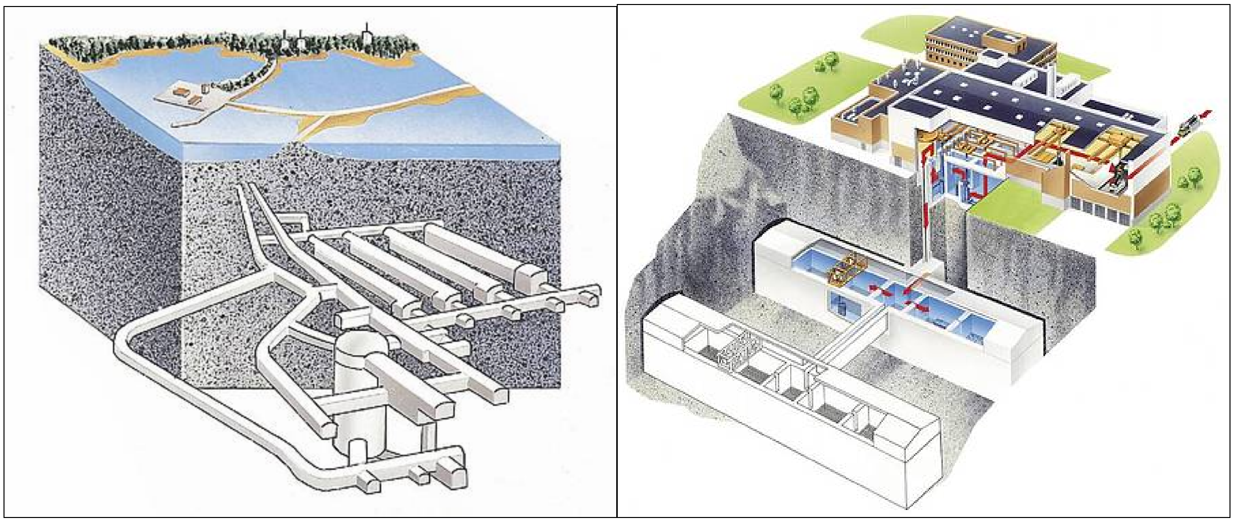

Fig. 6. Schematic illustrations of the operating Swedish underground facilities for disposal of short-lived LLW and ILW (SFR) (to the left) and for long-term storage of HLW (Clab) (to the right). (Courtesy of SKB)

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