Disposal Subcommittee
Report to the Full Commission

DRAFT

Blue Ribbon Commission on America's Nuclear Future (BRC)

Washington, DC
June1, 2011

PREAMBLE

The charter of the Blue Ribbon Commission on America's Nuclear Future directs the Commission to "provide advice, evaluate alternatives, and make recommendations" for "a new plan" to manage the back end of the nuclear fuel cycle in the United States. The charter identifies several specific issues to be addressed as part of the Commission's work, including five that the Disposal Subcommittee addresses in this report:

- Options for permanent disposal of used fuel and/or high-level nuclear waste, including deep geological disposal;
- 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;
- Options for decision-making processes for management and disposal that are flexible, adaptive, and responsive;
- Options to ensure that decisions on management of used nuclear fuel and nuclear waste are open and transparent, with broad participation; and
- The possible need for additional legislation or amendments to existing laws, including the Nuclear Waste Policy Act of 1982, as amended.

The Disposal Subcommittee began its inquiry into these issues by posing a somewhat simpler question: "How can the United States go about establishing one or more facilities for permanently disposing of high-level nuclear wastes in a manner and within a timeframe that is technically, socially, economically, and politically acceptable?

This report documents the Subcommittee's findings over the course of 11 months of investigation and deliberation aimed at answering this question and addressing the specific issues raised in our charter. Most importantly, it advances a set of consensus recommendations for consideration by the full Commission. We believe these recommendations, together with the recommendations being developed by the Transportation and Storage Subcommittee and the Reactor and Fuel Cycle Technology Subcommittee, provide a comprehensive framework for putting the U.S. nuclear waste management program back on track.

We want to be clear on one point at the outset: Consistent with our charter and with the direction provided by the Secretary of Energy to guide our work—we have *not* sought to develop recommendations concerning specific locations (or potential locations) for any component or facility of the U.S. nuclear waste management system. Rather we have sought to learn from past efforts—successful and unsuccessful—to site nuclear waste disposal facilities and to develop specific guidance concerning an overarching strategy that we believe can dramatically improve the chances for nuclear waste program success regardless of where specific facilities in the nuclear waste management system are ultimately located.

Throughout, our inquiry and our deliberations have been informed by an underlying conviction that this generation has an ethical responsibility to begin implementing a durable, integrated management strategy and solutions that will enable disposal of spent nuclear fuel and high-level radioactive wastes. If we do not—if more years and decades elapse and we do nothing—we will have made a decision of another kind: a decision to accept the continued accumulation of spent fuel at many dozens of sites around the nation. After recent events in Japan, that prospect can no longer be viewed in the same light. It is still too early to draw definitive conclusions from Fukushima, but if there is one thing that crisis clearly underscores it is that delay and inaction, as much as action, produces its own set of risks and consequences. We realize that siting, licensing and constructing of one or more permanent disposal facilities will take time, so it is

important to ensure that safe and secure interim storage for spent fuel and high-level wastes are part of the integrated approach.

In sum, Americans have benefitted from the energy and deterrent capacity provided by nuclear technology for more than 50 years. We cannot and must not continue to defer responsibility for dealing with the resulting wastes and spent fuel.

The Subcommittee welcomes comment on this draft report from all interested parties. Comments can be submitted electronically at www.brc.gov or by mail at:

Blue Ribbon Commission on America's Nuclear Future
c/o U.S. Department of Energy
1000 Independence Avenue SW, Washington, DC 20585.

A draft of the full Commission's main report will be released by July 29, 2011 in accordance with the schedule set out in our charter. To be considered as the Commission develops the first public draft of its main report, comments on this Subcommittee report must be received by July 1, 2011. All comments will be made publicly available on the Commission website. Any comments received after July 1st will be considered as the Commission prepares its final report, which is due to the Secretary of Energy by January 29, 2012.

EXECUTIVE SUMMARY

The Disposal Subcommittee of the Blue Ribbon Commission on America's Nuclear Future has commenced to address a set of issues, all of which bear directly on the central question: "How can the United States go about establishing one or more disposal sites for high-level nuclear wastes in a manner and within a timeframe that is technically, socially, economically, and politically acceptable?"

To answer this question and to develop specific recommendations and options for consideration by the full Commission, the Subcommittee and individual Commissioners held multiple meetings and deliberative sessions; visited Finland, France, Japan, Russia and Sweden to learn first-hand about their disposal programs; and heard testimony from numerous experts and stakeholders. The Subcommittee also benefited from commissioned papers on several related topics; these papers may be found on the Commission web site at www.brc.gov. All of these inputs have helped to inform the conclusions and recommendations that are summarized below and detailed at greater length in the Subcommittee's full report.

Recommendation #1: ***The United States should proceed expeditiously to develop one or more permanent deep geological facilities for the safe disposal of high-level nuclear waste.***

The Subcommittee concludes that permanent disposal is needed under all reasonably foreseeable scenarios for nuclear materials with a low probability of re-use. This includes defense and commercial reprocessing wastes and many forms of used fuel currently in government hands. The Subcommittee believes it is also highly likely that permanent disposal will be needed to safely manage at least some portion of the existing commercial spent nuclear fuel inventory. The need for a disposal solution is, in our view, inescapable. It is also independent of policy debates concerning past or future applications of nuclear technology.

The Subcommittee further concludes that geologic disposal in a mined repository is the most promising and technically accepted option available for safely isolating high-level nuclear wastes for very long periods of time. This view is supported by decades of expert judgment and by a broad international consensus. All other countries with spent fuel and high-level waste disposal programs are pursuing geologic disposal. The United States has many technically suitable geologic media for a repository. Other concepts for geologic disposal have been proposed; these options may hold promise but will require further investigation.

Nuclear materials that require long-term isolation exist and we have benefited from the activities that produced them. There is no ethical basis for abrogating responsibility for their safe, long-term disposition to future generations. Thus, while subcommittee members hold different views about the potential for future re-use of spent fuel, we all agree that it is time to begin developing and implementing integrated, workable solutions that include interim storage and disposal of spent nuclear fuel and high level radioactive wastes.[1]

After Fukushima, it is clear that past assessments of the safety and adequacy of current interim storage arrangements for spent nuclear fuel will need to be revisited. We anticipate that this process will be undertaken by the relevant regulatory authorities in the months and years ahead and we do not presume to prejudge the conclusions that will be reached. Whatever those conclusions are, however, they can only

[1] See the Transportation and Storage Subcommittee's draft report for details regarding interim storages and transportation.

underscore the Subcommittee's central conclusion that it is imperative to move forward with implementing an integrated approach which would enable safe permanent disposal solution for the inventories of high-level waste and spent nuclear fuel that already exist in the United States within a reasonable time frame. After decades of broken promises and unmet deadlines in the nation's nuclear waste management program, tangible progress is needed—both to build confidence in our technical and institutional ability to responsibly manage the nuclear fuel cycle and because of the long lead-times needed to site and license nuclear waste facilities of all kinds.

Recommendation #2: ***A new, single-purpose organization is needed to develop and implement a focused, integrated program for the transportation, storage, and disposal[2] of nuclear waste in the United States.***

The U.S. Department of Energy (DOE) and its predecessor agencies, subject to annual appropriations and policy direction by Congress, have had primary responsibility for implementing U.S. nuclear waste policy for the last 60 years. Having examined this experience, the Subcommittee concludes that new institutional leadership for the nation's nuclear waste program is needed. A new organization offers the best opportunity to establish—from the outset—the track record of consultation, transparency, accountability, and scientific and technical credibility needed to re-establish trust with the public and key stakeholders.

We conclude that a federal corporation chartered by Congress offers the most promising model, although the Subcommittee believes that other organizational models might also be effective. Less important than the specific model chosen is that the new organization fosters a culture that consistently demonstrates the attributes noted above (i.e., transparency, accountability, etc.). In addition, the Subcommittee believes it will be crucial for a new waste management organization to have (1) a focused and well-defined mission, (2) the financial and institutional means to deliver on its commitments, and (3) sufficient independent authority—subject to appropriate financial, technical, and regulatory oversight—to provide institutional and programmatic stability over time.

However, the Subcommittee recognizes that it could take several years for this new entity to be authorized, funded, staffed and ready to proceed. DOE should continue making progress on this issue i.e. research on different geologic media and engineered barrier systems as well as other non-site-specific tasks can and should be conducted in the interim, while the new organization is being set up. Likewise, the NRC and the EPA should work on developing new site-independent geologic disposal safety standards.

Recommendation #3: ***Assured access to the balance in the Nuclear Waste Fund (NWF) and to the revenues generated by annual Nuclear Waste Fee payments from ratepayers and utilities is absolutely essential and must be provided to the new nuclear waste management organization.***

The current NWF and fee mechanism is not working as intended. No new policy or organization will succeed unless this changes. Specifically, revenues from the fee and the balance in the NWF must be made available to implement the nation's waste management program, as needed, independent of other budgetary pressures. This will require (1) extricating the NWF from the web of budget rules that have created an unintended and dysfunctional competition between expenditures from the Fund and spending on other federal programs and (2) removing funding decisions from the annual federal budgeting and appropriations process. Of course, greater budget independence must come with effective oversight mechanisms to ensure that resources—in this case the NWF fees—are being spent wisely to advance the objectives for which they are intended.

[2] Later in the report we use the term "management" to refer to these three activities (i.e., transportation, storage and disposal).

Recommendation #4: ***A new approach is needed to site and develop nuclear waste management and disposal facilities in the United States in the future. We believe siting processes for all such facilities are most likely to succeed if they are:***

(1) Consent-based—in the sense that affected communities have an opportunity to decide whether to accept facility siting decisions and retain significant local control.

(2) Transparent—in the sense that all stakeholders have an opportunity to understand key decisions and engage the process in a meaningful way.

(3) Phased—in the sense that key decisions are revisited and modified as necessary along the way rather than being pre-determined in advance.

(4) Adaptive—in the sense that process itself is flexible and produces decisions that are responsive to new information and new technical, social, or political developments.

(5) Standards- and science-based—in the sense that the public can have confidence that all facilities meet rigorous, objective, and consistently-applied standards of safety and environmental protection.

This Subcommittee recommendation flows directly from an examination of the history of waste-management efforts in the United States and other countries. In the case of the United States, several lessons can be drawn from the decades-long effort to site a repository at Yucca Mountain in Nevada and from the ultimately successful completion of the Waste Isolation Pilot Plant (WIPP) facility in New Mexico. One lesson is that support for a facility (or at least acceptance)—both in directly affected communities and on the part of the host state—is a critical element of success. A second is that transparency and accountability, along with the flexibility to adapt to new information and to the concerns of key constituencies, are essential to sustain public trust in decision-making processes and institutions.

The approach to repository development laid out under the Nuclear Waste Policy Act Amendments of 1987 was highly prescriptive, subject to inflexible deadlines, and—as actually implemented—widely viewed as being driven too heavily by political considerations (as compared to independent technical and scientific judgments). By contrast, other countries—notably Canada, Finland, and Sweden—have adopted a phased, adaptive, and consent-based approach to facility siting and development. Finland and Sweden, in particular, have each successfully sited a deep geologic repository with the support of the host community.

Although there are notable political, cultural, and other differences between the United States and Finland and Sweden, their experience suggests that several process characteristics can greatly improve the odds of success: (1) a clear and understandable legal framework for moving forward with facility development; (2) financing for state, tribal, and local governments and citizen organizations that wish to be engaged in the process; (3) concerted efforts to promote public knowledge and awareness, both of nuclear waste issues generally and of plans for individual facilities specifically; and (4) openness and transparency in interactions among and within the implementing organization, the national government, states, tribes, local governments, and the public.

Implementing a phased, adaptive siting process with these characteristics will take time. However, attention to process must not come at the expense of progress. Without tying the waste management program to inflexible deadlines, it will nevertheless be important to articulate reasonable performance goals and milestones so that the new organization can be held accountable and so that stakeholders and the public can have confidence that the program is moving forward.

Recommendation #5: ***The current division of regulatory responsibilities between the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) is appropriate and should continue. In addition, we urge that new, site-independent safety standards be developed by the two agencies in a formally coordinated joint process that actively engages and solicits input from all the relevant constituencies.***

Many witnesses have recommended that the EPA and NRC regulatory systems be made consistent with each other. Some have also pointed out that it would be far better if such a rationalization or harmonization happened before any future disposal sites were identified, even for screening purposes, to avoid or at least minimize the perception that standards are being set to ensure that one or more (pre-selected) sites will meet them. This seems particularly important for individual protection requirements, which have been a clear point of contention in the past; however, it is likely to be relevant for many other issues as well. Greater harmonization could be pursued in a number of ways—for instance, through a regulatory negotiation or with the help of an independent expert panel.

The Commission also received and considered recommendations for a more fundamental redrawing of regulatory roles and responsibilities at the federal level (i.e., transferring all regulatory authority to the NRC or EPA). We concluded that while there are opportunities for improvement in the EPA/NRC regulatory process and in the working relationship between these agencies, the general division of roles and responsibilities that currently exists between EPA and NRC is appropriate and should be preserved.

Recommendation #6: ***The roles, responsibilities, and authorities of local, state, and tribal governments (with respect to facility siting and other aspects of nuclear waste disposal) must be an element of the negotiation between the federal government[3] and the other affected units of government in establishing a disposal facility. All affected levels of government (local, state, tribal, etc.) must have, at a minimum, a meaningful consultative role in important decisions; additionally, states and tribes should retain—or where appropriate, be delegated—direct authority over aspects of regulation, permitting, and operations where oversight below the federal level can be exercised effectively and in a way that is helpful in protecting the interests and gaining the confidence of affected communities and citizens.***

Federal–tribe and federal–state relations have been central to resolving the nation's nuclear waste management challenges from the outset. Indeed, much of the difficulty of finding workable disposal solutions for spent fuel and high-level radioactive waste can be traced to the inherent tensions that exist in these relationships, especially when the legitimate interests and rights of different groups, represented at different levels of government, come into conflict.

The nature of these issues and the structure of our federal system mean that no single formula or approach offers a certain path to avoiding these conflicts in the future, or for successfully navigating them when they arise. A facility for the isolation of spent nuclear fuel and high-level waste will only be constructed as a result of very complex negotiations between the federal government and state, tribal, and local governments. Therefore, the Subcommittee believes it would be unwise to attempt to suggest a specific strategy for engaging with state, tribal, and local government authorities at the outset. Experience suggests that the process characteristics discussed under Recommendation #4 can help promote collaboration rather than confrontation and thus improve prospects for successfully establishing one or more disposal facilities. However, our nation's long history of federal–tribe and federal–state conflicts also underscores the difficulty of building trust and confidence in a relationship where the distribution of prerogatives and power is perceived to be largely one-sided.

[3] We are recommending the creation of a federally-chartered corporation which would act as the federal government's implementing arm for waste management in these negotiations

Given that the Atomic Energy Act of 1954 grants the federal government exclusive authority to regulate the possession and use of all radioactive materials, including wastes, the challenge is to affirm a role for states, tribes, and local governments that is at once positive, proactive, and substantively meaningful without increasing the potential for further conflict, confusion, and delay. In discussions about how one might strike this balance, the concept of "meaningful consultation" has emerged as an important term of art—one that can and has allowed for a more or less expansive view of state and tribal roles and responsibilities under different circumstances. In the case of WIPP, for example, the fact that the State of New Mexico gained permitting authority over the facility under the Resource Conservation and Recovery Act (RCRA) is often cited as a turning point in gaining state and local support for the project.

The Subcommittee believes that to engage in meaningful consultation on matters related to nuclear waste storage, transport, and disposal, and to exercise their proper regulatory roles and responsibilities in this context, local, state, and tribal governments need access to sound, independent scientific and technical expertise. Here again, the WIPP example is instructive. In that project, an Environmental Evaluation Group, formed of scientific and technical experts who were not associated with DOE or its contractors, was established for the express purpose of providing independent, outside advice to state and local officials concerning matters related to the WIPP facility. By all accounts, this group was instrumental in assuring New Mexico citizens and their representatives—not only in the immediate vicinity of WIPP but across the state—that their health and welfare interests were being protected and that their concerns were being heard and adequately addressed.

Recommendation #7: ***The Nuclear Waste Technical Review Board should be retained as a valuable source of independent technical advice and review.***

Decision makers at all levels of government require access to sound, independent technical advice and expertise. Since it was established under the Nuclear Waste Policy Act Amendments of 1987, the Nuclear Waste Technical Review Board (NWTRB) has performed this role with distinction; it should therefore be retained as a valuable part of our larger institutional infrastructure for ensuring the responsible management of nuclear wastes.

Members should represent a carefully considered mix of scientists and engineers with the relevant mix of expertise. As now, members should serve rotating terms and new members should be selected by the President from a candidate list prepared by the National Academy of Science. The NWTRB should report at least twice per year to the Board of Directors of the new organization and the Congress.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
AMFM	Alternate Means of Financing and Managing
BEA	Budget Enforcement Act of 1990
BRC	Blue Ribbon Commission on America's Nuclear Future
C&C	consultation and cooperation
CEO	chief executive officer
CFR	Code of Federal Regulations
CRA	Congressional Review Act
DHS	U.S. Department of Homeland Security
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DRR	Domestic Research Reactor
EDRAM	Environmentally Safe Disposal of Radioactive Materials
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESF	Exploratory Studies Facility
EU	European Union
FERC	Federal Energy Regulatory Commission
FRR	Foreign Research Reactor
FY	fiscal year
GAO	Government Accountability Office
GRH	Gramm-Rudman-Hollings
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
MRS	Monitored Retrievable Storage

MTHM	metric tons heavy metal
NARUC	National Association of Regulatory Utility Commissions
NAS	National Academy of Sciences
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute
NGO	non-governmental organization
NRC	Nuclear Regulatory Commission
NWF	Nuclear Waste Fund
NWMO	Nuclear Waste Management Organization
NWPA	Nuclear Waste Policy Act
NWPAA	Nuclear Waste Policy Amendments Act
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management (DOE)
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PAYGO	pay-as-you-go
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RD&D	research, development, and demonstration
SNF	spent nuclear fuel
STGWG	State Tribal Government Working Group
TRU	transuranic
TVA	Tennessee Valley Authority
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION AND STRUCTURE OF REPORT

The Disposal Subcommittee of the Blue Ribbon Commission on America's Nuclear Future (BRC) was charged with developing recommendations for how the United States can go about establishing one or more disposal sites for high-level nuclear wastes[4] in a manner that is technically, politically, and socially acceptable. The Subcommittee began its investigation by asking a series of related questions:

1. Are one or more disposal facilities needed under all reasonably foreseeable scenarios?

2. If a permanent disposal system is needed, what are the alternative approaches for disposal?

3. What process(es) should be used to select new disposal sites, and what are the relative roles of federal, state, county, local, and tribal entities?

4. What are the essential elements of technically credible, workable, and publicly acceptable standards and regulations for disposal?

5. What are the essential elements for a technically credible, workable, and publicly acceptable institutional system and process for regulating the safety of disposal?

This report describes the Subcommittee's findings in each of these areas and provides background and context for the recommendations advanced in the Executive Summary. We begin by describing the current inventory of spent[5] nuclear fuel and high-level waste in the United States. In Section 3, we review the history of past efforts to implement a permanent disposal solution for these materials. Sections 4 through 8 then address the above questions.

[4] The term "high-level waste" does not have a fixed definition; however, for purposes of this report, it should be understood to encompass both vitrified high-level radioactive waste, mostly from past defense operations, and "used" or "spent" fuel from DOE and civilian nuclear power reactors.

[5] Throughout this document, we employ the term "spent" nuclear fuel. "Used fuel" is the term that appears in the Commission's charter, but "spent fuel" (sometimes abbreviated "SNF") is the term used in much of the literature on this topic and in many U.S. regulations and statutes concerning the back end of the nuclear fuel cycle.

2. THE NATURE AND SCOPE OF THE NUCLEAR WASTE AND SPENT FUEL MANAGEMENT CHALLENGE IN THE UNITED STATES

More than five decades of civilian nuclear power production[6], and an even longer history of nuclear weapons development, have produced substantial inventories of spent nuclear fuel (SNF) and high-level radioactive waste for which no long-term disposition path has yet been established. These inventories exist and must be safely managed, regardless of the commercial nuclear industry's prospects going forward. At present, no facility for the permanent disposal of high-level radioactive waste is operating in the United States or anywhere else in the world, although Finland and Sweden have each successfully sited and are in the process of seeking licenses for deep geologic repositories for this purpose. In addition, the United States has an operating deep geologic repository for the sole purpose of disposing of defense transuranic (TRU) waste—this facility, called the Waste Isolation Pilot Plant (WIPP), is located in Carlsbad, New Mexico.

This section reviews the main categories of nuclear materials produced by the back end of the nuclear fuel cycle, the quantities of these materials that currently exist and that are projected to be generated over the next several decades, and the nature and duration of the radiological hazards posed by these materials.

2.1 Commercial Spent Nuclear Fuel

Irradiated nuclear fuel, commonly referred to as used or spent nuclear fuel, is a byproduct of the fission reactions that occur in nuclear reactors (in the case of commercial nuclear power plants, the energy from these reactions is used to produce steam for driving turbines that can generate electricity).

The current inventory of SNF from commercial reactor operations in the United States totals approximately 65,000 metric tons[7] (the standard quantity metric used is "metric tons heavy metal" or MTHM). This inventory is growing at a rate of roughly 2,000 to 2,400 MTHM each year as a result of ongoing commercial reactor operations. Estimates of future inventories depend heavily on assumptions about the rate of growth (or decline) in nuclear power production over the next several decades. In a briefing to the full Commission on March 25, 2010, a representative of the Department of Energy (DOE) Office of Nuclear Energy provided a range of projections for the growth in spent commercial fuel volumes up to the year 2050. At the high end, DOE projects that a significant expansion in domestic nuclear power production could result in a total inventory of 210,000 metric tons of spent fuel by 2050. On the low end, even if all nuclear power stations were shut down tomorrow, we would still be faced with an inventory of upwards of 70,000 MTHM of spent fuel (equaling the current inventory of roughly 65,000 MTHM plus all of the fuel in the cores of the 104 commercial nuclear power reactors operating today).

With a few small exceptions[8] , SNF from the nation's commercial power industry exists in the form of uranium oxide pellets stacked in long, zirconium-alloy tubes (known as the "fuel cladding). The tubes are generally mounted in square metal frames to form a fuel assembly (Figure 1); the reactor core of a typical nuclear power plant will hold anywhere from 100 to 1,000 such assemblies. Every 4 to 6 years, the fuel assemblies must be removed and replaced; at this point, they are considered "used" or "spent."

[6] The first commercial nuclear power plant in the United States, the 60-megawatt Shippingport plant in Pennsylvania, began operating in 1957.

[7] Adopted from "*U.S. Radioactive Waste Inventory and Characteristics Related to Potential Future Nuclear Energy Systems*," prepared by Joe T. Carter, SRS, Robert h. Jones Jr., SRS, Alan J, Luptak, INL for the US DOE Used Fuel Disposition, May 211, FCRD0USED-2011-000068, Rev 1.

[8] For example graphite fuel at Ft. St. Vrain 330 MW(e) high-temperature gas-cooled reactor.

Figure 1. Pressurized Water Reactor Fuel Assembly *(Source: World Nuclear Association)*.

The assumption in the early days of the U.S. commercial nuclear power industry was that spent fuel would be reprocessed in a matter of years—not decades—after an initial period of cooling.[9] Reprocessing to recover uranium and plutonium that could be re-used as reactor fuel would result in liquid waste streams suitable for vitrification, similar to the high-level waste streams generated by the nation's defense program. The decision to forego commercial reprocessing—a decision that was initially motivated by weapons proliferation concerns but that later came to reflect cost considerations also—combined with the federal government's subsequent failure to develop a deep geologic repository in the timeframe mandated by the Nuclear Waste Policy Act (NWPA) of 1982, have left nuclear power plant operators with a growing inventory of spent fuel to manage on site. This means that all but a very small fraction of the nation's existing commercial spent fuel inventory is currently being stored—either in water-filled pools or in dry casks—at some 65 reactor sites where 104 currently operating reactors are located and at nine decommissioned reactor sites around the country.

2.2 DOE-Owned Spent Nuclear Fuel

In addition to the SNF currently being stored at commercial nuclear power plant sites, DOE manages SNF at a number of government-owned, mostly defense-related facilities. The current inventory of DOE-managed SNF, however, represents only a small fraction of the nation's total spent-fuel inventory: approximately 2,500 metric tons. In general, DOE has not taken commercial used fuel for storage at its facilities except in special cases. For example, the fuel in the damaged Unit 2 reactor core from the 1979 Three Mile Island accident was moved to the Idaho National Laboratory (INL) for study; in addition,

[9] Current practice is to immerse the used/spent fuel as soon as it is removed from the reactor core in water-filled pools on site; several years later, the fuel may be transferred to dry cask storage. Issues related to the interim storage of used/spent fuel are being addressed by the BRC's Subcommittee on Transportation and Storage; a detailed discussion of these issues may be found in that Subcommittee's report.

DOE has responsibility to store the spent fuel from the unique, gas-cooled Fort Saint Vrain reactor in Colorado (some of that used fuel has been shipped to the INL for storage, while the rest is currently being stored on site). The federal inventory also includes a small quantity of spent fuel—approximately 27 metric tons—from naval reactors. Naval reactor fuel is shipped to the INL for examination and storage. Inventories of government-generated used fuel are growing slowly—a few metric tons per year—due to the operation of naval nuclear reactors as well as government- and university-operated research and test reactors.

Figure 2 shows the quantity and location of spent nuclear fuel at DOE sites. Both wet and dry methods of storage are in use at these sites, although at the Hanford site in Washington State—where by far the largest portion of DOE's current spent nuclear fuel inventory is being stored—all of the fuel has been moved to dry cask storage.

In addition, DOE accepts quantities of SNF from other sources under the Foreign Research Reactor (FRR) and Domestic Research Reactor (DRR) programs. The quantities involved are very small relative to the inventories from other domestic sources of spent fuel. The FRR program was established to support U.S. non-proliferation and nuclear security goals; it accepts used fuel from research reactors in other countries. So far, more than 9,000 used fuel assemblies have been accepted from 29 countries under this program (see Figure 3), which is currently slated to run until 2019. The DRR program accepts used fuel from U.S. universities and other government research reactors.

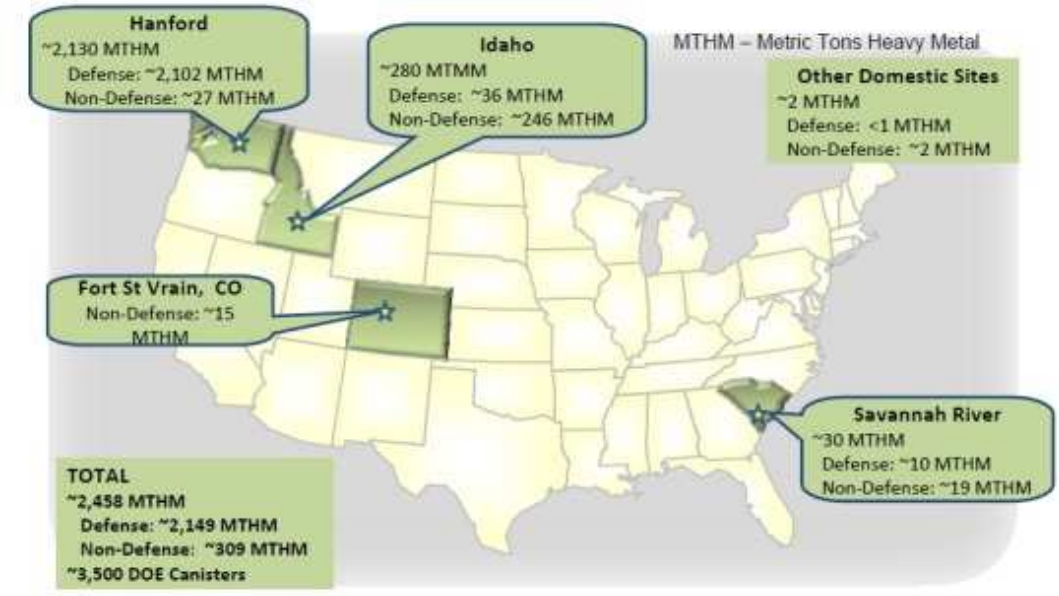

Figure 2. Inventory of DOE-Owned Spent Nuclear Fuel in the United States in 2010[10].

[10] Adopted from "Overview of DOE's Spent Nuclear Fuel & High-Level Waste" -- presentation by Mr. Frank Marcinowski, DOE, to the BRC meeting, March 25, 2010, Washington D.C.
http://www.brc.gov/sites/default/files/meetings/presentations/environmental_management_brc_03252010.pdf

Figure 3. Maps of Countries where Spent Fuel has been shipped from (*Source: National Nuclear Security Administration, Savannah River Site Office*).

2.3 DOE-Owned High-Level Radioactive Waste

Along with spent nuclear fuel, DOE is responsible for managing and ultimately disposing of some 90 million gallons of liquid high-level waste from past fuel reprocessing operations to recover materials (primarily plutonium at Hanford and Savannah River and highly enriched uranium at Idaho) needed for the nation's nuclear weapons program. Most of this waste is being stored at DOE's Hanford, INL, and Savannah River sites—typically in large underground tanks made of stainless or carbon steel. In addition, INL is storing some high-level waste that has been converted to a solid, granular form via a high heat treatment known as calcining. Similarly, DOE has begun converting its inventory of liquid high-level waste into glass, ceramic, or other solid forms suitable for on-site storage in canisters. (The process used to immobilize liquid waste in glass is known as vitrification.) In addition, DOE manages a small quantity of high-level waste from the short-lived operation of a commercial reprocessing facility at West Valley, New York in the late 1960s and early 1970s. This waste is slated for eventual dry cask storage.

High-level radioactive waste from past defense program activities is not considered to be potentially re-usable even if the United States were to commence reprocessing; hence, the assumption has always been that this waste would be immobilized and sent to permanent disposal with no further processing. In fact, the NWPA presumed that defense high-level waste[11] would be disposed of in a "civilian" repository developed under the Act, unless the President determined (following an evaluation that took into account issues of cost efficiency, health and safety, regulation, transportation, public acceptability, and national security) that a separate repository for the defense high-level waste was needed. The Act did not *preclude* a defense-waste-only repository; however, it did not provide for a process to site one. It also made clear that such a repository would be subject to full Nuclear Regulatory Commission (NRC) licensing and to all the state/local/tribal participation provisions that would apply to a commercial repository.

[11] These provisions do not explicitly apply to spent fuel from national defense activities; probably because at the time the Act was passed, there was an assumption that all such spent fuel would be reprocessed.

After the NWPA was adopted, DOE (acting for the President) evaluated the use of a civilian repository for defense waste disposal and concluded that this option would save on the order of $1.5 billion compared to developing separate repositories for civilian and defense waste. Besides this cost difference, DOE found no other factors which distinguished significantly between the options it considered.[12] President Reagan accepted DOE's conclusions in 1985 and since then, DOE's plans have provided for the disposal of defense wastes with commercial spent fuel and high level waste in repositories developed under the NWPA.

Meanwhile, a permanent disposition path has been successfully established for defense waste that is not considered high-level but that has sufficiently high concentrations of TRU elements that cannot be disposed of as low-level waste: defense TRU waste is being shipped to the WIPP deep geologic disposal facility in New Mexico.

Given the circumstances involving Yucca Mountain and the current lack of a "civilian" repository, and uncertainty regarding the economic value of reprocessing commercial spent fuel, some witnesses have suggested that it may now be more efficient to expedite permanent disposal of defense high-level waste in a defense-only geologic repository. Other witnesses believe waste disposal should be driven by the characteristics of the waste and not by the source. As directed by the Commission Co-Chairmen, the subcommittee will investigate this issue over the coming months and will provide its views to the full Commission in late 2011.

Tables 1 and 2 summarize current inventories of DOE high-level waste and commercial SNF.

Table 1. Commercial Spent Nuclear Fuel Estimated Discharge Through 2010[13]

Total Numbers of Assemblies [b]			**Total Initial Uranium (MTU)**[a]			**Average Enrichment**		**Average Burnup (MWd/MTU)**[c]		**Average Age (Yr)**		**Total Radioactivity (Ci)**	
PWR	BWR	Totals	PWR	BWR	Totals	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR
97,400	128,600	226,000	42,300	23,000	65,200	3.74	3.12	39,600	33,300	14.9	15.4	16 billion	7 billion

[a] the estimated fuel discharged has been rounded to the nearest 100 MTU, totals may not appear to sum correctly

[b] the number of assemblies has been rounded to the nearest 200, totals may not appear to sum correctly

[c] the burn-up has been rounded to the next 100 m Wd/MT

[12] *An Evaluation of Commercial Repository Capacity for the Disposal of Defense High-Level Waste*. DOE/DP/0020/1. Washington DC: U.S. Department of Energy, 1985.

[13] Adopted from *U.S. radioactive Waste Inventory and Characteristics Related to Potential Future Nuclear Energy Systems*," FCRD0USED-2011-000068, Rev 1., prepared by Joe T. Carter, SRS, Robert h. Jones Jr., SRS, Alan J, Luptak, INL for the US DOE Used Fuel Disposition, May 2011 http://www.brc.gov/index.php?q=library/documents/commissioned-papers

Table. 2 Projected total Number of High Level Waste Canisters[14]

	HLW Canisters [1] ***Best Estimate***	***Potential HLW Canister Range***
West Valley (commercial)	275	NA [2]
Hanford	10,713	9,746-12,100
INL (Calcine)	3,328	1,190-11,200
INL (Electro chemical processing)	102	82-135
SRS -	7,560	7,560-9,450
Total	***21,980***	***18,900-33,200*** [3]

1. With the exception of Hanford all HLW canisters are 2 feet *10 feet. Hanford HLW canisters are 2 feet * 14,76 feet

2. All the West Valley HLW canisters currently exist

3.Rounded to nearest 100 canisters

2.4 The Nature and Duration of Risks Associated with Spent Nuclear Fuel and High-Level Radioactive Waste

SNF and high-level wastes are hazardous. The primary hazard from spent fuel arises from radiation emitted by radioactive decay. Spent fuel emits high levels of radiation and thus requires shielding to be handled safely. In wet storage, shielding is generally provided by a large volume of water—this is the mode of storage used to cool irradiated fuel assemblies when they are first removed from a reactor core. In dry storage configurations, shielding is generally provided by thick layers of steel and concrete.

The other major hazard from spent fuel arises if radioactive material in the fuel is mobilized into air or water. This won't occur as long as spent fuel remains intact. The fuel exists in the form of solid ceramic pellets that are encased in metal tubes; the tubes in turn are configured in bundles that are designed to withstand 4 to 6 years of exposure to very high temperatures and high levels of radiation in a reactor core. However, for the first few years after fuel is removed from a reactor core, the rapid decay of short-lived radioactive material generates sufficient heat so that overheating has the potential to damage the fuel and release radioactive material if sufficient cooling is not provided. Likewise, over the very long time periods associated with geologic disposal, gradual corrosion processes may breach the fuel container and allow radioactive material to be mobilized in groundwater.

High-level wastes arise from the chemical reprocessing of spent fuel, a process that also generates additional volumes of low-level wastes (including some having radionuclide concentrations greater than those defining the upper boundary of Class C waste given in 10 CFR 61). Modern reprocessing facilities convert all high-level waste streams into solid glass, ceramic, or metal waste forms that are typically contained in stainless steel canisters. High-level waste can emit high levels of radiation and thus requires shielding and handling methods similar to spent fuel. Likewise, over very long time periods, corrosion processes may mobilize radioactive material into groundwater.

[14] Ibid.

Spent fuel and high-level wastes are also chemically hazardous because of the toxicity of some of their constituent elements (i.e., lead and also plutonium and uranium). These chemical hazards, however, are generally small compared to the radiation hazards associated with these materials.

Exposure to radioactive materials—whether natural or man-made—can be damaging because many forms of radiation have the ability to change the structure of molecules, including the structure of molecules found in the tissues of living organisms. Humans are routinely exposed to low levels of radiation in everyday life. These low-level exposures can come from natural sources (e.g., cosmic rays, certain minerals, some foods) and from man-made sources (e.g., building materials, medical procedures such as x-rays, CAT scans, certain cancer treatments, etc.). The materials associated with the back end of the nuclear fuel cycle (including both spent fuel and high-level waste), however, emit very high levels of radiation. This creates the risk of exposure to levels of radiation that would cause irreparable damage to living organisms. The consequences of such damage could be very serious – the exposed individual could develop cancer, for example, or suffer genetic effects (i.e., mutations in the reproductive cells that could be damaging to offspring). Exposure to very high doses of radiation can cause burns or even rapidly developing radiation poisoning, which can lead to death in a relatively short period of time (days to weeks).

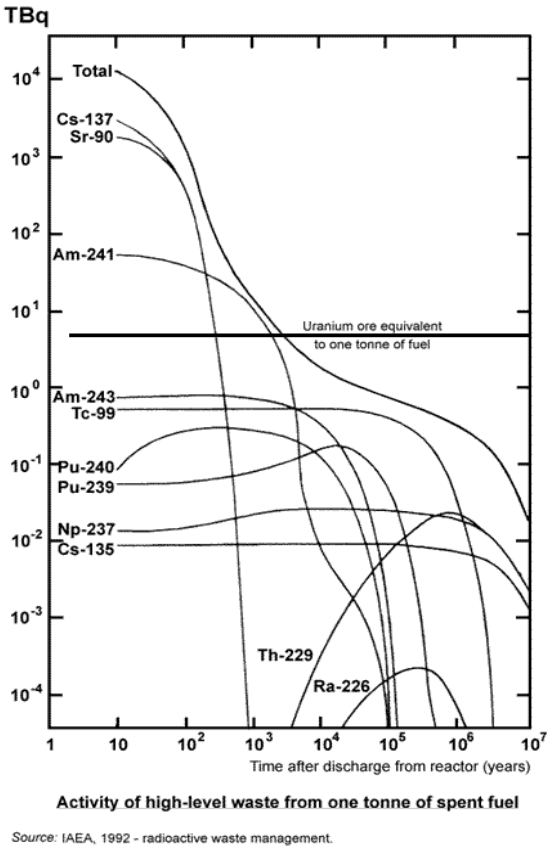

Figure 4. Radiation Decay of Spent Nuclear Fuel after Discharge from Reactor *(Source: World Nuclear Association).*

Some categories of nuclear waste (generally including all high-level waste and virtually all current SNF) remain radioactive for thousands of years because of the long half-lives[15] of some of the radioisotopes they contain. For instance, plutonium-242 has a half-life of 360,000 years, while the half-lives of neptunium-237 and thorium-232 are more than 2 million and 1.4 billion years, respectively. (The half-life of uranium-238 is nearly 4.5 billion years.) The radioactive decay of a typical spent fuel assembly over time is shown on Figure 4. It is worth mentioning, however, that very long-lived isotopes also tend to pose a less acute radiation hazard; by comparison, the more hazardous isotopes tend to be those that decay more quickly (the more rapid the decay, the greater the quantity of the resulting radiation). Risks posed by the radioactive materials depends largely on combination of several factors, including the amount of material, the half-lives of the radioactive isotopes, the type and energy of the radiation emitted, the pathways to the biosphere, and the behavior of the particular isotopes when they enter a living organism.

2.5 Key Findings

- The United States has a substantial existing inventory of high-level radioactive wastes and SNF. These materials exist in different forms and quantities.

- From a quantity standpoint, spent fuel from commercial nuclear power reactors constitutes the largest part of this inventory, totaling approximately 65,000 metric tons. This inventory continues to grow at an annual rate on the order of approximately 2,000 to 2,400 metric tons per year as a result of the ongoing operation of the nation's commercial nuclear power plants.

- DOE owns a smaller quantity of spent fuel, approximately 2,500 metric tons. In addition, DOE is responsible for managing and ultimately disposing of some 90 million gallons of liquid high-level waste, mostly from past defense operations. DOE has begun the process of vitrifying this waste, much of which is currently being stored in underground tanks. Vitrification converts the waste to a solid, glass form so that it can be packaged in canisters in preparation for final disposal.

- SNF and high-level wastes are hazardous primarily because of the radiation they emit as their radioactive constituents decay. Exposure to radiation—whether natural or man-made—can damage molecular structures and can cause genetic defects and cancer.

- Spent fuel and high-level waste present a management and disposal challenge because they contain some heavy elements and fission products that require very long-term isolation from the accessible environment. The half-lives of some of the radioisotopes in these materials are on the order of tens of thousands to millions (and in a few cases, even billions) of years.

[15] Half-life is the time required for half of the initial atoms of a given amount of a radionuclide to decay. Theoretically, these materials remain radioactive forever; however, at some point, they have decayed sufficiently that the remaining radioactivity is deemed insignificant. One rule of thumb for when that threshold of insignificance has been reached is after 10 half-lives: at that point, .05 percent of the original radioactivity remains.

3. THE HISTORY OF U.S. EFFORTS TO MANAGE THE BACK END OF THE NUCLEAR FUEL CYCLE

If there is one point of universal agreement in the many-sided debate about nuclear waste policy in the United States, it is that future efforts to manage the back end of the fuel cycle must reflect the hard-learned lessons of the past. The fact is that the federal government's more than half-century-long record of policy-setting and program implementation in this area has been marked by more failures than successes. This section reviews some of the highlights of this history in an effort to provide essential context for the Subcommittee's recommendations; of necessity, it omits numerous details and nuances. Readers interested in a more detailed treatment should consult some of the many sources available on the Commission's website (www.brc.gov).

3.1 Early U.S. Policy on Nuclear Waste Management (1940s–1982)

In the 1940s, during the early days of nuclear weapons development in the United States, national security considerations took precedence over concerns about the safe disposal of nuclear waste. With the emphasis on rapid production of plutonium for use in weapons, storage in large, underground steel tanks was deemed adequate as an interim means of isolating the highly radioactive liquid waste that remained after acid was used to dissolve irradiated nuclear fuel as part of the plutonium separation process. Even at the time, however, the underground tanks were not considered a long-term solution. In a 1949 report, the Atomic Energy Commission (AEC)[16] emphasized that "better means of isolating, concentrating, immobilizing, and controlling wastes will ultimately be required."

The need for better long-term waste disposal options emerged as an important technical and policy question in the early planning for a commercial nuclear power industry during the 1950s. In 1954, when Congress passed the Atomic Energy Act and established the framework for today's civilian nuclear energy industry, the expectation was that commercial spent fuel would be reprocessed like defense spent fuel for use in breeder reactors. This would result in liquid waste streams, similar to the liquid waste that was already being produced by the government's defense-related reprocessing operations. It was understood, however, that the development of a commercial power industry would greatly increase the amount of radioactivity in high-level liquid waste in need of eventual storage and disposal.

In 1957, the National Academy of Sciences (NAS) issued a report (titled "The Disposal of Radioactive Waste on Land") that looked specifically at the question of long-term nuclear waste disposal. That report reached several important conclusions, among them that "radioactive waste can be disposed of safely in a variety of ways and at a large number of sites in the United States" and that geologic disposal in salt deposits represents "the most promising method of disposal." The NAS further concluded that solidification of liquid waste for transport and disposal would be "advantageous" and that transportation issues would need to be considered in the location of waste disposal facilities.

Prompted by these recommendations, the AEC began investigating mined geologic disposal and potential salt bed repository sites in the late 1950s. Its early efforts included experiments with solids and liquids in salt mines and exploratory work on methods for solidifying liquid wastes. In June 1970, the AEC announced plans to investigate an abandoned salt mine in Lyons, Kansas as a potential demonstration site for the disposal of high-level and low-level waste. At the time, the AEC anticipated that the Lyons site could begin accepting low-level plutonium (TRU) waste as early as 1974 and high-level waste by 1975. By 1971, however, state opposition to the project was growing and in 1974, after a number of technical problems had emerged that called into question the geological integrity of the site, the AEC announced that Lyons was no longer being considered as a potential radioactive waste disposal site.

[16] The AEC was the nation's first overarching nuclear regulatory authority. It was established by the Atomic Energy Act of 1946.

During the same time period (i.e., the early 1970s), the AEC—at the invitation of the local community—began exploring an area of deep salt beds near Carlsbad, New Mexico as a potential repository site for high-level radioactive waste. Disposal at the site—which became known as the Waste Isolation Pilot Plant (WIPP)—was subsequently limited to defense-related TRU waste. Congress authorized WIPP to begin receiving waste as early as 1979; however, it took until 1999 (20 years later) before the first shipments began arriving at the facility. Though ultimately successful, DOE's efforts to open the WIPP facility (Figure 5) were delayed by years of controversy. Despite consistent local support for the project, many state officials were opposed and expressed concern that SNF and high-level waste would eventually be disposed of at the site, along with less hazardous TRU waste. Ultimately, DOE's slow progress on WIPP prompted Congressional action in 1992 and again in 1996 to detail the regulations and procedures DOE would need to follow to open the facility, to address land disposal restrictions, and to provide funding for the construction of bypass roads to be used in transporting waste to the site. The WIPP operational history since first waste shipments in 1999 has been excellent, and still maintains local and state support for its continued existence.

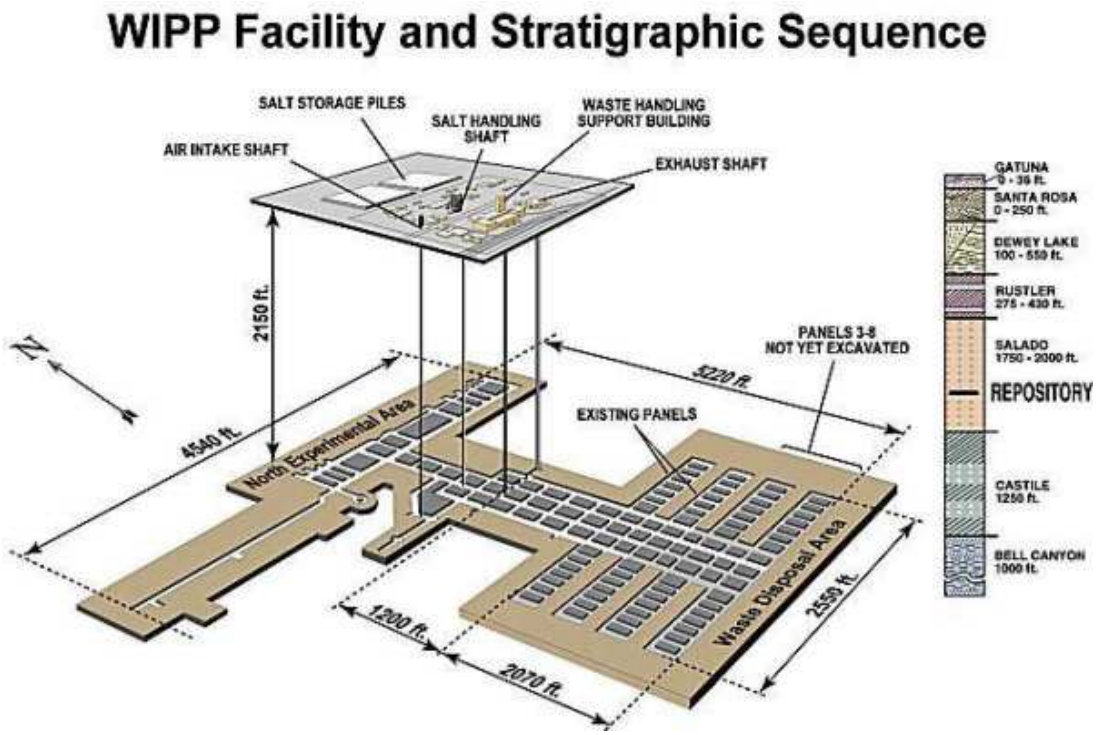

Figure 5. Layout of the Waste Isolation Pilot Plant[17].

The search for a suitable site for long-term geologic disposal of high-level waste continued throughout the 1970s, first under the AEC and later under its successor agency, the Energy Research and Development Administration (ERDA).[18] Among the geologic media considered during this period[19] were bedded salt

[17] http://infranetlab.org/blog/2008/07/the-advantages-of-being-salty/

[18] ERDA, along with the newly formed NRC, took the place of the AEC in 1975. Soon after, in 1977, the functions and responsibilities of ERDA were assumed by the newly formed DOE.

[19] T. F. Lomenick, The Siting Record: An Account of the Programs of Federal Agencies and Events That Have Led to the Selection of a Potential Site for a Geologic Repository for High-Level Radioactive Waste, Oak Ridge National Laboratory, ORNL/TM-12940, March 1996

formations in Michigan, Texas, and Utah; salt domes in Louisiana and Mississippi; basalt formations at Hanford; and a variety of rock types (argillite, granite and volcanic tuff) at the Nevada test site (see Figure 6). Meanwhile, the outlook for future waste management efforts had begun to shift as a result of policy changes prompted by weapons proliferation concerns. In particular, India's test of a nuclear device in 1974 heightened fears that plutonium could be diverted from the civilian nuclear fuel cycle to weapons production.

Figure 6. Sites Considered for a First Repository in early 1980s[20].

Responding to these concerns, President Ford in 1976 issued a presidential directive deferring the commercial reprocessing and recycling of plutonium in the United States. In 1977, President Carter extended this deferral indefinitely and directed the relevant federal agencies to focus on alternative fuel cycles and re-assess future spent fuel storage needs. (The Carter policy was later reversed by President Reagan; however, for a variety of reasons, commercial reprocessing was never resumed.)

Recognizing that the commitment to an open fuel cycle with no spent fuel reprocessing would have an impact on the quantity and type of waste produced by the commercial nuclear power industry going forward, a DOE-led Interagency Review Group in 1979 recommended that a number of potential repository sites for high-level waste be identified in different geologic environments and in different parts of the country.

3.2 U.S. Policy Under the Nuclear Waste Policy Act (1982–Present)

Passage of the Nuclear Waste Policy Act (NWPA) in 1982 marked the beginning of a new chapter in U.S. efforts to deal with the nuclear waste issue. The legislation itself was the product of 4 years of Congressional debate marked, on the one hand, by growing concern about an imminent shortage of spent-

[20] Adopted from: "Nuclear Waste Policy: How we Got Here," Presentation by Mark Holt to the BRC, March 25, 2010. http://www.brc.gov/sites/default/files/meetings/presentations/crs_blueribboncommissionwastepolicyhistory.pdf

fuel storage capacity at operating reactors and, on the other hand, by an equally urgent concern on the part of individual states that they not be selected to host a repository site.

Believing that DOE would need a Congressional mandate if it was ever to succeed in overcoming opposition to the selection of a particular repository site, Congress sought through the NWPA to establish a fair and technically sound process for selecting among potential locations. In fact, to avoid the perception that any one state or locale would be asked to bear the entire burden of the nation's waste management obligations, the Act provided for the selection of two repository sites (though not stipulated in the legislation itself, it was widely assumed that one of these sites would be located in the West, the other in the East). And to further ensure that the end result would not be a single, national repository, Congress included provisions explicitly limiting the capacity of the first repository to 70,000 metric tons until a second repository was opened. As noted earlier, today the combined quantity of civilian spent fuel and defense wastes has already nearly reached this statutory cap. Pursuant to a requirement of the 1987 NWPAA, DOE reported to Congress in 2008 that a second repository would be needed unless the cap was removed.[21]

The NWPA established separate processes for identifying these first two repository sites. The Act directed DOE to nominate at least five sites, with different geologic media to the extent practicable, of which three were to be recommended to the President for detailed study or "characterization" by January 1985. (This tight schedule implied that first repository would be selected from candidate sites that DOE and its predecessor agencies had already been evaluating, including salt domes along the Gulf Coast, bedded salt in the Great Plains and Midwest, volcanic tuff in the West, and basalt in the Pacific Northwest.) Based on the results of this characterization, DOE would make a final recommendation and the President would submit his choice for a first repository site to Congress by March 31, 1987.

The second repository was to be chosen from a list of five sites that included at least three locations that had not been considered previously (this was to ensure that the second site would be located in a geographically different region from the first site). A separate siting program was thus established for the second repository. It focused on crystalline (essentially granitic) sites in the eastern half of the country, the presumption being that the first repository would likely be sited in the west. DOE was required to nominate candidate sites for the second repository (Figure 7) by July 1989, and the President was to recommend a final choice to Congress by March 31, 1990. As with the first repository, the Act established a schedule for DOE to submit a license application for the second repository and for NRC to review it. Unlike the first repository, however, authorization to begin construction of the second repository would require subsequent action by Congress.

Beyond establishing a process for the selection of two permanent geologic high-level waste repositories, the NWPA included a number of other noteworthy provisions:

1. Establish a new Office of Civilian Radioactive Waste Management (OCRWM) within DOE, with a director appointed by the President and confirmed by the Senate.

2. Authorize DOE to enter into contracts with utilities for federal removal of spent fuel from reactor sites beginning by 1998 in return for a fee on utilities' sales of nuclear-generated electricity.

3. Direct DOE to propose a site and design for "monitored retrievable storage" of nuclear waste prior to it being shipped to a permanent disposal site.

[21] *The Report to the President and the Congress by the Secretary of Energy on the Need for the Second Repository*, DOE/RW-0598, U.S. DOE, Office of Civilian Radioactive Waste Management, Washington DC, December 2008. http://www.brc.gov/sites/default/files/documents/second_repository_rpt_120908.pdf

4. Provide for federal storage of civilian high-level waste on an interim basis in emergency situations.

5. Grant states certain rights with respect to oversight over waste storage or disposal sites within their borders and the ability to veto DOE siting decisions, subject to override by both houses of Congress.

6. Give the NRC responsibility for licensing waste facilities, subject to public health and environmental standards established by the U.S. Environmental Protection Agency (EPA).

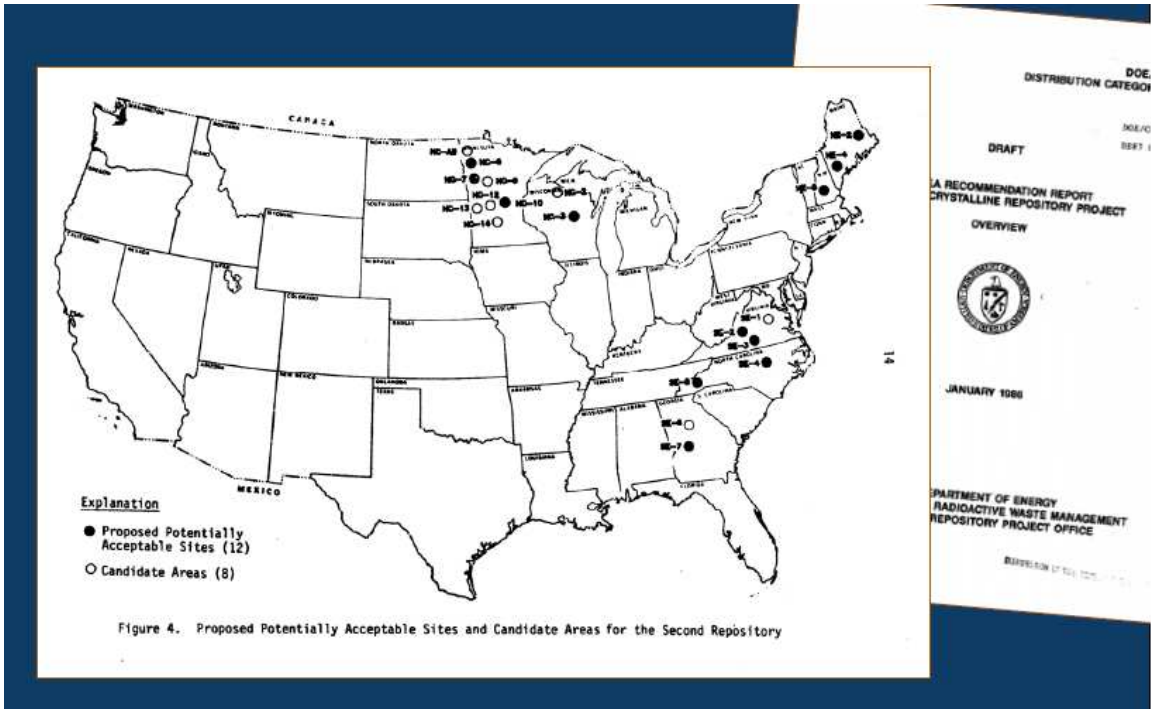

Figure 7. Sites Considered for a Second Repository in the 1980s[22].

In May 1986, Energy Secretary John Herrington recommended the Hanford site in Washington State, Deaf Smith County in Texas, and Nevada's Yucca Mountain for further site characterization as leading candidates for the nation's first permanent high-level geologic waste repository. By that time, however, DOE's efforts to identify promising sites—not only for the two permanent repositories but also for a monitored retrievable storage (MRS) facility—were drawing strong opposition from all potentially affected states. Earlier in 1986, DOE had released a list of 12 areas in seven different states with potentially suitable granite or other crystalline rock formations for a second geologic repository. These sites were all located in the upper Midwest, New England, and along the Atlantic Coast and had been identified through a systematic screening methodology developed by DOE. Nevertheless, citizens, state officials, and Congressional delegations from these states objected strongly to DOE's findings, as did the state of Tennessee, which had been identified as the potential site for a MRS facility that would serve as a central receiving point for waste shipments from nuclear plants east of the Rocky Mountains. Citing rising costs and lower projections for nuclear waste production in the future, Secretary Herrington announced that DOE was suspending efforts to identify and develop a second permanent geologic

[22] Adopted from: "Nuclear Waste Policy: How we Got Here," presentation by Mark Holt to the BRC, March 25, 2010. http://www.brc.gov/sites/default/files/meetings/presentations/crs_blueribboncommissionwastepolicyhistory.pdf

repository. This announcement also came in May 1986—not surprisingly, it served to intensify the opposition of the three states that had been selected as potential hosts for the first repository.

Faced with a deteriorating political situation[23] and growing recognition that the NWPA's original timelines and cost assumptions were unrealistic, Congress revisited the issue of nuclear waste management in 1987. The resulting Nuclear Waste Policy Amendments Act (NWPAA) of 1987 precluded any further research in crystalline rock (the type under consideration for the second repository) of the type found in the East; cancelled the second repository program and directed DOE to report to Congress (between January1, 2007 and January 1, 2010) on the need for a second repository,[24]; nullified the selection of Oak Ridge, Tennessee as a potential MRS site; and designated Yucca Mountain as the sole site to be considered for a permanent geologic repository. The decision was widely viewed as political and it provoked strong opposition in Nevada, where the 1987 legislation came to be known as the "Screw Nevada" bill.

To address concerns about the technical integrity of DOE's assessments, the NWPAA of 1987 established a new federal agency—the U.S. Nuclear Waste Technical Review Board (NWTRB)—for the sole purpose of providing independent scientific and technical oversight of DOE's waste management and disposal program. Congress also tried a new approach to overcoming state and local opposition; under the 1987 amendments, states could receive up to $20 million per year for hosting a repository and up to $10 million per year for hosting an MRS site. The amendments also provided for a presidentially appointed "nuclear waste negotiator" who was authorized to reach agreements with states or Indian tribes to host nuclear waste facilities under any "reasonable and appropriate terms."

So far, however, none of the policy changes introduced in 1987 have succeeded in expediting the development of either a permanent geologic repository or a centralized, interim MRS facility.

3.3 Experience with the Yucca Mountain Repository Program

Following the dictates of the 1987 NWPAA, DOE continued detailed site characterization studies at Yucca Mountain through the 1990s and issued a formal finding of suitability for the site in 2002. This prompted the state of Nevada, which had remained staunchly opposed to the project throughout, to file an official "Notice of Disapproval." A Congressional resolution to override the state's veto, however, was passed and signed by the President, clearing the way for DOE to apply to the NRC for a license to commence construction. The latter step was supposed to follow fairly quickly (within 90 days), but due to litigation over the repository safety standards and for other reasons it took another 6 years.

In the end, DOE's application for a construction license was not submitted until June 2008—a full decade past the 1998 deadline by which the federal government was obliged to begin accepting commercial nuclear waste under the NWPA. Less than a year later, the new Administration declared its intent to suspend further work on Yucca Mountain and later moved to withdraw the application for a construction license to the NRC. At this point, with key decisions by the courts and the NRC still pending, the future of the Yucca Mountain project remains uncertain.

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[23] A statement by Representative Morris Udall of Arizona, on the floor of the House of Representatives in 1987 during debates leading up to the adoption of the Nuclear Waste Policy Amendments Act, summed up the general mood of dismay. Referring to the site selection process in the original NWPA, Representative Udall said, "We created a principled process for finding the safest, most sensible place to bury these dangerous wastes. Today, just five years later, this great program is in ruins. Potential host states no longer trust the technical integrity of the Department of Energy's siting decisions."

[24] The report was delivered in December 2008. (*The report to the President and the Congress by the Secretary of Energy on the Need for the Second Repository*, DOE/RW-0598, U.S. DOE, Office of Civilian Radioactive Waste Management, Washington DC, December 2008) http://www.brc.gov/sites/default/files/documents/second_repository_rpt_120908.pd

Several attributes of the nation's approach to nuclear waste management generally, and to the selection and characterization of the Yucca Mountain site in particular, are widely viewed as having contributed to the significant difficulties encountered in implementing the NWPAA. First, DOE's termination of the second repository siting process, combined with Congress's subsequent action to short-circuit the technical site selection process established under the original NWPA and single out Yucca Mountain as the sole site for consideration, created a widespread perception that the repository location was being determined on the basis of primarily political, rather than technical or scientific, considerations[25].

Second, neither the original site selection process established by the Act nor the subsequent legislative designation of Yucca Mountain as the sole site for consideration was consent-based. Though the project had some support from local constituencies, its designation as the sole site for investigation in 1987 was bitterly opposed by the State of Nevada and the majority of its citizens.

A third issue, and one that pre-dated the decision to focus only on Yucca Mountain, was the practice of setting unrealistic and rigid deadlines. As DOE failed time and again to meet various deadlines, confidence in the federal government's competence to manage either the Yucca Mountain project or its broader obligations concerning the management of civilian and defense nuclear waste eroded among all parties involved. Key stakeholders, including not only citizens of the communities where these materials were being stored but also nuclear utilities and their customers, who continued to pay into the Nuclear Waste Fund (NWF) even as the repository program fell further and further behind, became increasingly frustrated. The fact that the delays were in some part attributable to funding shortfalls compounded this frustration, since these funding problems stemmed not from an underlying shortage of resources but from the waste program's lack of full access to the Nuclear Waste Fund (NWF), as discussed extensively in Section 6. All the while, the federal government was also opening itself (and ultimately U.S. taxpayers) to legal claims and financial damages arising from its failure to comply with its obligations under the Act and with DOE's contractual commitments to utilities in a timely manner.

In fact, the repository development process established under the 1982 Act and its subsequent amendments suffered more generally from a lack of flexibility. Its prescriptiveness made it difficult to adapt or respond to new developments, whether in the form of new scientific information, technological advances, or (just as important) the expressed concerns of potentially affected publics and their representatives. The 1987 NWPAA made no provision for an alternative path forward if Yucca Mountain proved unsuitable on either technical or social and political grounds, or both. In fact, the 1987 Amendments explicitly ruled out consideration of other sites. This lack of adaptability further undermined confidence in the analysis and planning conducted by DOE and other federal agencies, making it easy to view these efforts as mere paper exercises, rigged to justify a fore-ordained conclusion. Similarly, by directing EPA to develop safety standards specific to the Yucca Mountain site in the Energy Policy Act of 1992, Congress undermined confidence that those standards represented an independent scientific judgment about what was necessary to protect human health and the environment.

These attributes of the Yucca Mountain siting process led to a serious erosion of trust, especially among the people of the state of Nevada. The recent decision by the Administration to withdraw the Yucca Mountain license application has further diminished confidence in the government's ability to provide a safe and timely solution for the disposal of used fuel and high-level wastes. This is not a comment on the merits of the decision to withdraw the license application; the Subcommittee was not asked to examine that issue and offers no opinion. However, it is clear to the Subcommittee that waste cleanup commitments were made to states and communities across the United States, and to the nuclear utility industry and its ratepayers and shareholders, that have not been upheld. The decision to suspend work on the repository has left all of these parties wondering, again, if the federal government will deliver on its promises.

[25] Yucca Mountain had been the highest ranked site based upon the scientific and technical siting guidelines.

3.4 Key Findings

- The more than half-century-long history of the U.S. nuclear waste management program is a long, complicated, and often difficult one. Though there have been successes—notably the successful opening and operation of WIPP in New Mexico—the overall picture is one of continual delays, major cost overruns, extreme political controversy, and repeated failures to make good on federal commitments. We can improve on this record only by learning from the hard lessons of the past.

- Much of the difficulty encountered in past efforts to site centralized nuclear waste storage and disposal facilities stems from a fundamental federal/state/tribal rights dilemma. Even where local communities or tribal governments have supported a proposed facility, states have more often been opposed.

- The effort to site a repository at Yucca Mountain has suffered from several flaws—among them inflexible and unrealistic deadlines and overly prescriptive requirements. In addition, the process used to select this site was not consent-based; throughout, the state of Nevada and the majority of its citizens were bitterly opposed. It did not help that the decision to focus solely on this one site was widely seen as being driven by primarily political rather than technical considerations.

- Overall, the performance of the U.S. waste management program to date, and the experience with Yucca Mountain in particular, has led to a serious erosion of trust and confidence among states; key stakeholders, including the utility industry; and the American people in the federal government's commitment and competence to meet its obligations with respect to nuclear waste. The notable exception is the Waste Isolation Pilot Plant and its 12 years of successful operations while maintaining local and state support for its continued existence.

4. THE NEED FOR A PERMANENT DISPOSAL SOLUTION

This section takes up the first two of the organizing questions noted in the Introduction:

1. Are one or more disposal facilities needed under all reasonably foreseeable scenarios?

2. If a permanent disposal system is needed, what are the alternative approaches for disposal?

With respect to the first question, the Subcommittee concludes that: **Yes, one or more permanent disposal facilities will be needed under all reasonably foreseeable scenarios.**

With respect to the second question, the Subcommittee concludes that: **Deep geologic disposal is the best understood and technically accepted option for safely isolating high-level nuclear wastes over the very long time periods required to provide adequate human health and environmental protection**. Deep mined geological disposal is almost universally supported disposal option among scientists and policy-makers. All other countries with spent fuel and high-level waste disposal programs are pursuing mined geologic disposal.

The remainder of this section provides more detail on different disposal options and provides a rationale for the above conclusions.

4.1 The Rationale for Disposal

Because they are highly radioactive and often also contain hazardous/toxic chemicals, SNF and other high-level radioactive wastes must be handled and stored with care. The radiation hazard these materials present diminishes over time, but only very gradually, through decay processes that for some constituents of high-level waste may take hundreds of thousands of years or more. As a result, these wastes must be stored and finally disposed of in a way that provides adequate protection of the public and the environment over very long periods of time.

Broadly speaking, the only alternative to very long-term disposal for the most hazardous and long-lived radioactive elements in SNF would be to separate these elements and transmute them to short-lived fission products or stable isotopes, if that were proved to be feasible.[26] How this might be done through advanced reactor and fuel cycle technologies—and what challenges and opportunities such options might present—are subjects being studied by a different subcommittee of the full Commission. The salient point for purposes of this discussion is that even advanced fuel cycles still generate waste streams that contain large enough amounts of some long-lived radioactive elements[27] that the need for long-term disposal solutions might be reduced but cannot be eliminated.

In concluding that one or more permanent disposal facilities will be needed, the Subcommittee is echoing the consensus view, not only of numerous former expert panels that have looked at the situation in the United States but also of all countries with significant nuclear waste inventories (including those that are

[26] In the past, a number of concepts have been advanced periodically in hopes of eliminating the need for long-term nuclear waste disposal options (including permanent repositories). One program at Los Alamos National Laboratory, for example, focused on accelerator-driven systems for transmuting waste; it eventually evolved into a more comprehensive effort known as the Advanced Fuel Cycle Initiative. This and other initiatives are being reviewed by the BRC's Reactor and Fuel Cycle Technology Subcommittee.

[27] The mass and radioactivity of the fission products produced per unit of thermal energy from a nuclear reactor is essentially the same no matter what type of nuclear fuel cycle is used.

currently conducting recycle or reprocessing fuel cycles) and of major international organizations such as the International Atomic Energy Agency (IAEA).

4.2 The Obligation to Provide for Disposal

Recent events in Japan have re-focused public attention on our decades-long failure to move decisively toward implementing a permanent disposal solution for SNF and high-level waste. Even leaving aside the safety concerns that the Fukushima disaster have brought to the fore, it would seem self-evident, from an ethical standpoint, that the generations who created these wastes and benefited from the activities that produced them have an obligation to ensure they do not unduly burden future generations.[28] That means mustering the financial, programmatic, institutional, and political wherewithal to proceed with the development of an integrated waste management system that would combine interim storage and permanent disposal capabilities.

Even as the ethical and pragmatic case for moving forward has become more urgent, it has become apparent that we must choose an approach that can accommodate large uncertainties and adapt to unanticipated developments. The tragedy that unfolded in Japan in March 2011 offers a stark reminder that things do not always go according to plan and that major surprises and disruptions—not only in terms of natural events and disasters but in terms of scientific and technological developments, societal values and priorities, and economic conditions (to name just a few)—must be expected (even if they cannot be predicted) over the many years that nuclear programs will unfold. Not all of these changes will be negative. On the contrary, future developments—whether they involve game-changing technological advances (fusion would be an example) or new institutional arrangements (i.e., the development of international fuel cycle facilities)—have at least as much potential to simplify our nuclear waste management challenges as they have to complicate them.

In later sections of this report, we argue that the inherently complex and long-term nature of the nuclear waste disposal challenges warrant a fundamentally different, less prescriptive and more adaptive, approach than has characterized the U.S. waste management program to date. At this point, it suffices to highlight the importance of moving forward even in the face of uncertainty about the details of a solution. Uncertainty is not unique to the nuclear waste disposal issue; on the contrary, the most consequential public policy questions tend to share this feature. Nor is uncertainty necessarily an undesirable thing, provided the approach taken to develop solutions is designed to accommodate and even take advantage of new information and other changes over time. What uncertainty does mean is that any rush to impose outcomes—particularly if those outcomes are highly prescriptive and tend to foreclose rather than expand available options—is very prone to fail.

Meanwhile, the central point is that there is little to be gained—and potentially a very high price to be paid—for continued deferral and delay. This is particularly true for certain waste forms such as defense HLW and SNF for which there is no anticipated future economic value and for which the debate about recycling is moot. ***The fact that a problem is difficult and will take time to solve ought to argue for getting started sooner rather than later, though of course the opposite tendency too often prevails.*** After Fukushima, the American public will not overlook, much less forgive, an indefinite prolongation of the status quo. Moreover, only by moving forward can some of the key questions and uncertainties about a future disposition path for high-level nuclear waste and spent fuel be identified and resolved. Fortunately,

[28] The inter-temporal, inter-generational dimensions of this ethical obligation have long been recognized in the U.S. context and internationally. The 1996 IAEA Joint Convention on the safety of spent fuel and radioactive waste management, for example, speaks of the need to avoid "compromising the ability of future generations to meet their needs and aspirations." Put another way, plans for geologic disposal must not impose reasonably predictable impacts on future generations that are greater than those permitted for the current generation.

a well-constructed, well-managed, and well-financed disposal program can do both; achieve tangible progress toward meeting our ethical and moral obligations to current and future generations, while also preserving choices that will allow our descendents to make decisions in their own best interests.

4.3 Options for Permanent Disposal

While several options for disposing of high-level nuclear waste have been considered in the United States and elsewhere, the only option that has been judged technically promising and has been actively pursued to date is deep geologic disposal. At present, ***deep geological disposal remains—in the Subcommittee's view—clearly the most promising and technically accepted option for safely isolating high-level radioactive wastes from the environment for very long periods of time.***

In a recent statement of principles that the European Union (EU) has since recommended should be adopted by all EU member states, the IAEA articulated the aims of deep geologic disposal as follows:

> "Disposal of radioactive wastes in a deep, stable geological environment is intended to provide sufficient isolation, both from human activity and from dynamic natural processes, that eventual releases of radionuclides will be in such low concentrations that they do not pose a hazard to human health and the natural environment."
>
> –IAEA, S*cientific and Technical Basis for Geological Disposal of Radioactive Wastes*, 2003

This section provides additional detail on deep geologic disposal in a mined repository and on a second geologic disposal concept, deep boreholes. Deep boreholes are a geologic disposal option that is less well understood at this point but that warrants further research, development and demonstration (RD&D). Other disposal concepts that have been advanced, mostly on a theoretical basis, are summarized in the text box later in this section.

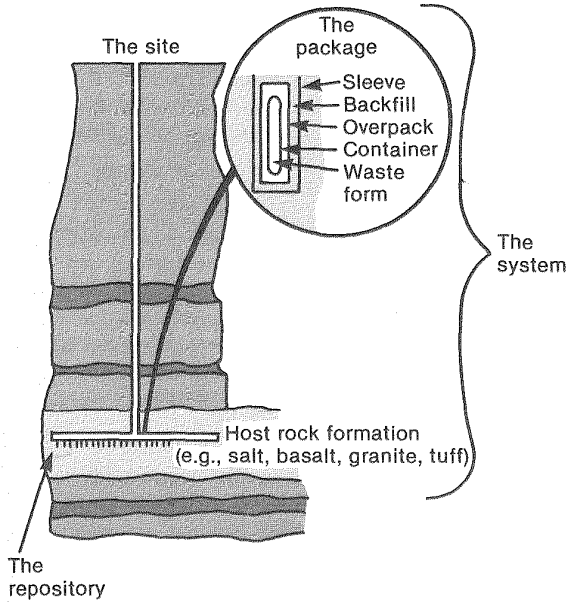
Disposal in a mined geological formation has been the front-running permanent disposal technology in the United States for more than 50 years.[29] Geologic disposal in a mined repository is also the approach being taken in other countries with spent fuel or high-level waste disposal programs.

In a mined geologic repository, high-level radioactive wastes and other wastes would be placed in engineered arrays in conventionally mined rooms in geologic media far beneath the earth's surface. The waste itself would be contained in canisters, drums, boxes, or other packages, as appropriate to its particular form, chemical content, and radiation intensity. As developed and studied around the world, proposals for geologic disposal also employ the concept of multiple barriers.[30] These include both engineered and geologic barriers that improve confidence that radioactive wastes will not return to the biosphere in biologically significant concentrations. Engineered barriers include the waste form itself, canisters, fillers, overpacking, sleeves, shaft and tunnel seals, and backfill materials. Each of these components may be designed to reduce the likelihood that radioactive material would be released and would be selected on the basis of site- and waste-specific considerations. Geologic barriers include the repository host rock and adjacent and overlying rock formations. While engineered barriers are tailored to

[29] In 1957, the NAS Published *The Disposal Of Radioactive Waste On Land.* This report recommended geological disposal and specifically recommended disposal in cavities mined in salt beds or domes. It also noted that "Disposal Could Be Greatly Simplified if Waste Could be Gotten into Solid Form of Relatively Insoluble Character."

[30] The description in this paragraph is adapted from DOE, *Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste*, October 1980, DOE/EIS-0046F Volume 1 of 3 UC-70.

a specific containment need, geologic barriers are chosen for their in-situ properties for both waste containment and isolation. An artist's rendering of the geologic disposal concept is shown in Figure 8.



Mined geologic disposal will use a system comprised of engineered barriers (the waste package and the mined repository) and naturally occurring barriers (the host rock formation and the chemical and physical properties of the repository site itself) to provide long-term isolation of waste from the biosphere.

Department of Energy.

Figure 8. Deep Geological Concept.

According to an international survey of waste management programs conducted by the NWTRB[31], countries are considering a wide variety rock types as potential settings for a deep geologic repository. The range of geologic media that have been considered or investigated as potential disposal sites at different times around the world includes bedded and domed rock salts, crystalline rocks (i.e., granite and gneiss), clay, shale, volcanic tuff, basalt, and various sedimentary rocks other than the foregoing. Each of these rock types and their geological environments have advantages and disadvantages from a strictly technical perspective, and different geologic settings and emplacement methods may be better for particular types of waste; however, many or all of them may ultimately be found to demonstrate acceptable performance for a wide range of wastes. The geologic environment into which waste would be emplaced is a related and perhaps more important consideration than the type of rock by itself.

The Blue Ribbon Commission has benefitted from technical visits to several facilities, including underground research laboratories. This experience contributes to our collective observation that deep geologic disposal constitutes a vital element of all international waste management programs. The USA stands apart from many other countries, because within its borders are many favorable geologic environments that could host such a permanent repository.

[31] *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel,* A Report to Congress and the Secretary of Energy, October 2009, available from the NWTRB website at http://www.nwtrb.gov/reports/reports.html.

Other Disposal Concepts

Besides deep geologic disposal, a number of alternative disposal concepts have been advanced over the years. These options have generally not received as much attention; however, some of them are summarized here to illustrate the range of alternatives that have been considered.

Disposal on or beneath unoccupied islands has been considered by the IAEA as one option for siting an international repository or monitored retrievable storage facility.[32] This concept has also been advanced in public comments received by the Commission. Island sites may offer very low hydraulic gradients and the opportunity to place waste in media with no potable water. In addition, local and regional opposition may be lower in comparison to sites with many neighbors. One obvious drawback of island disposal is that wastes would have to be shipped across the open ocean, potentially giving rise to additional transportation risks—particularly relative to land shipments by rail. On the other hand, Sweden and Japan have had extensive experience with the marine transport of nuclear materials.[33]

Disposal by *in situ* melting, perhaps in underground nuclear test cavities is another method that has been suggested[34] for disposing of liquid wastes from reprocessing. The idea is that the wastes would have sufficient heat to melt the rock surface and produce a glassy lining that would prevent migration. A rationale for this approach is that the cavities already contain radioactive material, so their use for this purpose would not contaminate an otherwise pristine setting. In addition to uncertainties concerning how such a system would perform, however, and whether leakage could be detected, existing regulations reflect a strong preference for shipping and disposing of wastes in solid rather than liquid form. Recognizing that large-scale shipment of liquid wastes could be problematic, it has been suggested that future reprocessing plants could be located at previous underground nuclear test sites.

Sub-seabed disposal (in stable clay sediments) is an option that was investigated by the U.S. Sub-Seabed program and the international community in the 1970s and 1980s. U.S. participation in international activities ended in 1986. The proposed approach was to emplace waste canisters in thick layers of mud on the ocean floor by dropping them in pointed packages (penetrometers) designed to penetrate many feet into the mud. An alternative that was also considered was to emplace the wastes by drilling holes into the mud, as is done in offshore oil production. The idea was that the mud would close behind and around the penetrometer, allowing for very little migration of deep pore water back into the ocean. While many people in the technical community thought that the approach was workable and had some potential advantages over land-based disposal, the concept was very unpopular with most environmental groups, especially those active on ocean issues. Moreover, international treaties on the use of the sea and seabed would likely preclude this disposal concept.

Space disposal—that is, shooting nuclear wastes into solar orbit or even into the sun—has been proposed, although cost considerations and the risk of an accident during launch have generally kept this option from being taken seriously. The current cost of putting objects in near-earth orbit is around $10,000 per pound; given that the U.S. inventory of spent fuel and high-level waste is on the order of 100,000 metric tons, the costs involved would be prohibitive. If one wanted to dispose of only very long-lived waste isotopes (i.e., technetium-99, cesium-135, iodine-129, and the long-lived actinides), then the amounts are much more manageable (on the order of a few million pounds for the current U.S. inventory). Even then, space disposal would be extremely expensive, particularly when one includes the costs of separating out these waste constituents. There have been proposals to launch separated wastes into space using earth-based lifting devices[35] (e.g., lasers, microwaves, and high speed rail guns); however, the capability of these technologies has not been demonstrated.

[32] IAEA, *Technical, Institutional and Economic Factors Important for Developing a Multinational Radioactive Waste Repository*, IAEA-TECDOC-1021, Vienna (1998) and *Developing Multinational Radioactive Waste Repositories: Infrastructural framework and scenarios of cooperation*, IAEA-TECDOC-1413, October 2004. These documents address multinational facilities and are not limited to island disposal. However, proposals involving the Marshall Islands and Wake Island are described.

[33] The BRC staff/consultant team is not aware of any quantitative comparison of the risks of shipments via ship versus rail. However, the IAEA has concluded that transportation risks are not a significant consideration. This comment may not refer to island disposal.

[34] Disposal of Nuclear Waste by *In Situ* Incorporation in Deep Molten Silicate Rock, J. J. Cohen, A. E. Lewis, R. L. Bra, *American Association of Petroleum Geologists Bulletin*, Volume 55 (1971), at http://search.datapages.com/data/doi/10.1306/819A3DEA-16C5-11D7-8645000102C1865D.

[36] For a description of different borehole disposal concepts, see Fergus Gibb, "Deep borehole disposal (DBD) methods," *Nuclear Engineering International*, March 25, 2010, at http://www.neimagazine.com/story.asp?storyCode=2055862.

The subcommittee concurs with conclusions contained in several submissions made to the BRC (e.g. Hansen, et. al, Geologic Disposal Options in the USA, SAND2010-7975C); in the contiguous forty-eight states there are many geologic formations that are likely to be technically suitable for deep geologic disposal of nuclear waste. Given appropriate repository designs, there is substantial confidence that compliance with regulatory standards for waste isolation can be demonstrated for several geologic settings, disposal concepts, and rock types, including salt, shale, volcanic rock, granite, and deep boreholes.

The Subcommittee sees no reason to change the current focus of the U.S. program on developing mined geologic repositories. Whether and how soon additional repositories would be needed after a first repository has been developed is uncertain and would depend on a number of factors. These factors include any physical or statutory limits on the capacity of the first repository, future rates of waste generation, decisions about reprocessing commercial spent fuel, and whether plans to commingle defense and commercial waste in the same repositories remain unchanged (discussed further in Section 6).

Disposal in deep boreholes (rather than in a mined repository) is another form of deep geologic disposal that may offer benefits, particularly for the disposal of certain forms of waste but that requires further exploration[36] The Commission has received a number of public comments about deep boreholes.

Basically, a deep borehole is a cased hole on the order of 45 centimeters in diameter drilled into crystalline basement rock to a depth of 4 to 5 kilometers. In most designs, the bottom 1 to 2 kilometers would be filled with either vitrified high-level waste or spent fuel and some backfill or sealant would be added to fill in the gaps between the wastes and the well casing. Figure 9 illustrates the deep boreholes disposal concept. A recent preliminary evaluation of deep boreholes[37] concluded they have "the potential for excellent long-term safety performance at costs competitive with mined repositories." It further estimated that approximately 600 boreholes would be needed to accommodate 70,000 metric tons of waste (this quantity is comparable to the current U.S. high-level waste and spent fuel inventory).

Deep boreholes could potentially have a number of advantages compared to mined geologic repositories, including: (1) reduced mobility of radionuclides, which would help limit their transport into groundwater and thus the broader environment; (2) greater tolerance for waste heat generation; (3) greater isolation of waste; (4) modularity and flexibility in the sense that disposal capacity can be expanded relatively readily by simply drilling additional boreholes once one or more suitable location(s) have been identified; (5) the possibility of locating several borehole disposal sites across the country, which would reduce risks associated with the transportation of waste to a centralized location; and (6) widespread applicability, which in turn suggests the possibility that this technique could be readily transferred to other countries with high-level waste disposal needs.

On the other hand, deep boreholes also have a number of potential disadvantages, including (1) the difficulty and cost of retrieving waste (if retrievability is desired) after a borehole is sealed; (2) relatively high costs per volume of waste accepted, which may limit its usefulness to small quantities of long-lived radionuclides that pose particular challenges for long-term isolation; and (3) constraints on the diameter of a borehole that could make it difficult—depending on how the waste is packaged—to accommodate some waste streams. Furthermore, the regulatory requirements that would be applied to deep borehole

[36] For a description of different borehole disposal concepts, see Fergus Gibb, "Deep borehole disposal (DBD) methods," *Nuclear Engineering International*, March 25, 2010, at http://www.neimagazine.com/story.asp?storyCode=2055862.
[37] Patrick V. Brady, Bill W. Arnold, Geoff A. Freeze, Peter N. Swift, Stephen J. Bauer, Joseph L. Kanney, Robert P. Rechard, Joshua S. Stein, *Deep Borehole Disposal of High-Level Radioactive Waste*, SAND2009-4401, August 2009, at http://www.mkg.se/uploads/Bil_2_Deep_Borehole_Disposal_High-Level_Radioactive_Waste_-_Sandia_Report_2009-4401_August_2009.pdf.

disposal do not yet exist, since the current regulatory structure for disposing of high-level waste and spent fuel was developed for mined repositories.

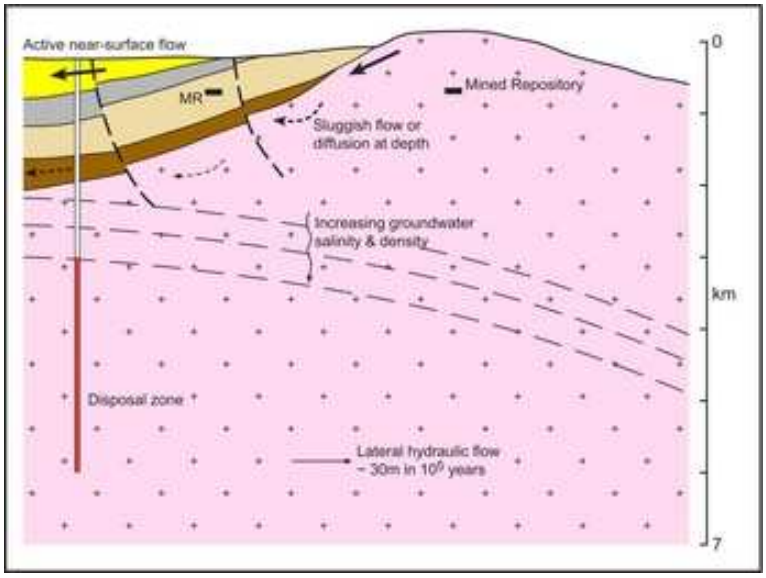


Figure 9. Deep Boreholes Disposal Concept[38].

More generally, the Subcommittee believes that further and more extensive research, development, and demonstration (RD&D) is warranted to help resolve some of the current uncertainties about deep borehole disposal and to allow for a more comprehensive (and conclusive) evaluation of the potential practicality of licensing and deploying this approach, particularly as a potential disposal alternative for certain forms of nuclear waste (i.e., defense high-level wastes and certain types of DOE spent fuel) that have essentially no potential for re-use.[39] Such work would be consistent with Section 222 of the NWPA, which requires DOE to "continue and accelerate a program of research, development, and investigation of alternative means and technologies for the permanent disposal of high-level radioactive waste from civilian nuclear activities and federal research and development activities."[40] Likewise, the EPA and NRC should initiate an effort to develop a regulatory framework for borehole disposal, in parallel with their development of a site-independent safety standard for mined geologic repositories, to support the RD&D effort leading to licensed demonstration of the borehole concept.

4.4 Retrievability and Reversibility

The concepts of retrievability and reversibility have been part of the discussion from the earliest days of considering geologic disposal. However, they have assumed increasing visibility with time, particularly over the last 20 years. This has been largely, though not exclusively, due to (1) a reaction to societal desire in many cases to be able to see and monitor the waste and preserve options to remove it, along with

[38] Bill W. Arnold, Peter N. Swift, et al, "Into the Deep," *Nuclear Engineering International*, March 25, 2010. http://www.neimagazine.com/story.asp?storyCode=2055856.

[39] We note that DOE's 1981 decision to develop geologic repositories also provided for continuing work on backup technologies specifically, including very deep boreholes. "Program of Research and Development for Management and Disposal of Commercially Generated Radioactive Wastes," dated April 16, 1981. Federal Register 40:26677 (May 1981).

[40] This requirement comes with the proviso that funding for research and development on alternative disposal methods must be provided through direct appropriations for that purpose; the Nuclear Waste Fund can only be used for "non-generic" research and developmental purposes.

(2) a more programmatic consideration that in countries currently using a once-through fuel cycle, a time may come in the near future when a decision to reprocess and recycle fuel that has been emplaced in a repository may call for its retrieval. Questions regarding the definitions of the terms; the length and terms of maintaining the capabilities to reverse or retrieve; and the safety, security, economic, and societal implications now receive more attention.

While no standardized definitions for "retrievability" and "reversibility" exist, in general their implications are clear. Reversibility means the more generic ability to reconsider and reverse course at any time during the development and implementation of a geologic disposal program. It would include, for example, the ability of potential host communities to decide at a later time that they wish to remove themselves from consideration. Or it could mean that an initial decision to emplace spent fuel in a repository is reversed to instead make the spent fuel available for reprocessing and recycling. Reversibility is largely a reflection of the approach and policies taken in program development. Retrievability is more specifically the technical capability to remove waste that has already been emplaced underground in a geologic disposal facility. [41]

The Subcommittee has considered retrievability and reversibility as closely related but distinct issues. The Subcommittee is of the view that the United States should pursue the development of one or more geologic disposal facilities. For mined geologic repositories, the existing requirements concerning retrievability in existing regulations (40 Code of Federal Regulations [CFR] 191 and 10 CFR 60.111 (b)) are appropriate and should be retained. Retrievability, as embodied in these regulations, is intended to allow for the removal of the emplaced waste if the repository is not behaving as anticipated, and its performance is called into question for any reason prior to permanent closure of the repository, and not as a way to retain easy access to emplaced materials for possible later recovery and reuse. Past evaluations of potential mined geologic repository sites in various geological media, including granite, salt and volcanic tuff, have indicated that a wide range of candidate mined repository sites could meet the existing retrievability requirement.

U.S. requirements for the retrievability of high-level waste were established in the NWPA of 1982 and are codified at 10 CFR 60 111 (b):

(b) *Retrievability of waste.* (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after the waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For the purposes of this paragraph, a reasonable schedule is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

[41] It is important to recognize that retrievability is not an absolute or binary characteristic—rather it is a relative one. The question is how easy (or difficult) would it be to retrieve materials from a geologic disposal facility and over what time frame. Wastes that were disposed of geologically could always, if absolutely necessary, be recovered somehow—although different methods of disposal could make it more or less expensive to do so.

Potentially promising nuclear waste management system concepts that incorporate other disposal approaches—including boreholes—may be considered in the future. In such systems, a multi-decade post-closure retrieval requirement may be neither practical nor necessary. In developing the recommended borehole geologic disposal safety standard then, as allowed by the current regulation, the retrievability time period can and should be reassessed as part of a larger evaluation of disposal system performance objectives.

On the subject of reversibility, the Subcommittee views this attribute as an important part of what we believe should be a staged, adaptive approach to waste management and disposal in the United States (the details of this approach are discussed in later sections). In other words, for a program to be adaptive, there needs to be some capacity to reverse course, at least for a period of time. The point of an adaptive approach is to develop a technical method of disposal in combination with a management system[42] where both work together to meet safety and environmental requirements in a societally responsible and responsive manner. Flexibility is needed because implementation of the program will take at least several generations, over which time technology and values are sure to evolve but in unpredictable ways. While there is general consensus that we cannot rely on active management over the many millennia of safety and environmental concern, an adaptive, staged approach plans for a program that is highly adaptive in the near term, when it is reasonable to believe in strong institutional oversight and management capacity.

International Approaches to Retrievability and Reversibility

Not surprisingly, other countries have also grappled with the issues of retrievability and reversibility in the context of their nuclear waste management programs. For example, retrievability was included as a policy requirement in Finland's decision to move forward with a geologic repository at Olkiluoto; however, it is not something that the implementing entity will need to address from a regulatory standpoint. This is because Finland does not view retrievability as a safety requirement. Sweden's regulations take a different approach: They require that protective capability be the central driver of repository design, but they also state that if any measures are adopted to make access to the waste easier (or to make intrusion more difficult), the effects of such measures on the overall protective capability of the repository must be reported. In effect, the Swedish approach seems to implicitly discourage any serious consideration of retrievability, either for safety or energy resource reasons.

In contrast, the Subcommittee has heard that the Canadian public has insisted on retrievability as an element of repository design. This view is apparently rooted in the belief that we cannot know today what technological solutions may eventually become available that would change our preferred approach to nuclear waste disposal. In sum, although there is no international consensus on retrievability, the majority view seems to be that safety, environmental, and public health considerations should be given more weight in addressing this issue than concerns about preserving ready access to previously disposed-of spent fuel as a potential energy resource for the future.

[42] Descriptions of an adaptive, staged approach can be found in the National Academy of Sciences "*One Step at a Time*" report and in the Canadian NWMO "*Choosing a Way Forward*" recommendation document.

4.5 Key Findings

- One or more permanent disposal facilities for high-level nuclear waste will be needed in the United States under all reasonably foreseeable scenarios. This conclusion holds even if "full recycle" concepts are eventually developed and adopted for SNF because even advanced fuel cycles still generate some waste streams that will require a permanent disposal solution.

- This generation has an ethical obligation to proceed toward developing permanent disposal capacity for high-level nuclear wastes without further delay. Once such capacity is available, materials that clearly have no potential for re-use (such as HLW and some spent fuels) can be disposed, and future decision makers can decide which other materials to dispose of and on what schedule, based on the best information available at that time. But until disposal capacity has been developed, society will have no choice other than continued storage of the wastes. Siting and constructing, one or more permanent disposal facilities will undoubtedly take time, so it will be important to ensure that interim storage arrangements for spent fuel and high-level wastes over the next several decades are robust and safe. In the meantime, we must move forward recognizing that we cannot know all the details of a permanent disposal solution at the outset. Nevertheless, it is urgent that we begin to make tangible progress and begin to restore confidence in our nation's long-term ability to manage these materials. Developing a specific mission plan with a clear, though adaptable, schedule for opening a first repository should be a first priority (and an early performance milestone) for the new implementing organization.

- Various concepts have been proposed for the long-term disposal of high-level radioactive wastes. Of these, deep geologic disposal has emerged as the most promising and technically acceptable option. All countries currently moving forward to develop disposal capacity are pursuing deep, mined geologic repositories. The Subcommittee believes that the United States should proceed expeditiously to seek sites for one or more mined geologic repositories without waiting for the development of alternative disposal technologies, while also pursuing a parallel RD&D effort and the development of safety standards for deep boreholes.

- Retrievability and reversibility are important considerations for designing disposal facilities and the processes used to site, construct, and operate these facilities. There are several sound reasons for requiring, as is the case under current U.S. law, that wastes emplaced in a mined geologic repository be retrievable for a period of time after repository closure. Reversibility—meaning the more generic ability to reconsider and reverse course at any time during the implementation of a policy or program—is likewise important and best achieved by adopting a staged, adaptive approach to developing the elements of a sound waste management system.

5. A NEW ORGANIZATION TO LEAD THE NATION'S WASTE MANAGEMENT PROGRAM

Having concluded, first, that the United States needs to develop one or more facilities for disposing of high-level waste and second, that deep geological disposal is the most promising and technically accepted option available at this time, the Subcommittee next turned to the following question:

> *What changes in the U.S. nuclear waste management program are needed to improve prospects for successfully selecting and developing new disposal sites and what are the relative roles of different entities, including federal, state, county, local, and tribal authorities?*

The consensus view of the Subcommittee is that a new single-purpose organization and a new approach are needed to successfully manage the storage, transportation, and disposal of SNF and high level wastes in the United States.

This section focuses on a key element of the above conclusion – the need for a new organization to lead the nation's nuclear waste management program. In the current U.S. repository program structure, responsibility for program implementation rests with a large cabinet-level agency with multiple competing missions (DOE), subject to annual and uncertain funding and direction provided by Congress. In the Subcommittee's view, the record of the last several decades demonstrates that this approach is not well suited to conducting a steady and focused long-term effort, and to building and sustaining the degree of trust and stability necessary to establish one or more permanent disposal facilities and implement other essential elements of an integrated waste management strategy.

Clearly, multiple factors have worked against the timely implementation of the NWPA and responsibility for the difficulties of the past does not belong to DOE alone. Nevertheless, the experience of the last 30-plus years leads this Subcommittee to agree with a conclusion that has also been reached by many stakeholders and long-time participants in the nation's nuclear waste management program: that moving responsibility to a single purpose organization—outside DOE— offers the best chance for future success.

Subcommittee members recognize that the process of establishing a new organization will not be easy or fast. Given that DOE's Office of Civilian Radioactive Waste Management has been disbanded, it may also be unavoidable. In that case, the question is not whether a new organization is needed but whether it will again be housed within DOE or set up as a separate entity. We believe that creating a new, single-purpose organization—independent of DOE—offers the best opportunity for successful implementation of a long-term strategy for the management and disposition of nuclear waste. Remaining parts of this section elaborate on the rationale for a new waste management organization, options and Subcommittee recommendations for structuring such an organization, and options for ensuring effective governance/oversight, financing issues, and structures for stakeholder participation.

5.1 Rationale for a New Waste Management Organization

Establishing a new organization dedicated to managing the nation's highest-level nuclear wastes would signal a clear break with the often troubled history of the U.S. waste management program. It would also provide an opportunity to start repairing the legacy of distrust left by the federal government's frequent failure to deliver on past statutory obligations and contractual commitments in this area, and allow the new organization an opportunity to conduct the program and stakeholder interactions in a manner that earns trust and confidence.

For example, a new organization dedicated to the safe, secure management and ultimate disposal of high-level wastes could concentrate on this objective in a way that would be difficult for a larger agency that must balance multiple agendas or policy priorities. (At DOE, waste management is only one of several missions within a nuclear program that also includes responsibility for science and technology research and development [R&D] for other forms of energy production, nuclear weapons stewardship, and environmental cleanup. DOE's broader portfolio encompasses an even broader array of technologies and policy objectives.) A new organization that is clearly focused, from the outset, on managing high-level waste and SNF will be in a better position to develop a strong culture of safety, transparency, consultation, and collaboration.[43] And compared to a federal agency such as DOE—where new appointees typically assume top management positions with every change of administrations and often leave in the middle of presidential terms—it should also be able to provide greater organizational stability over time.

Finally, while the Subcommittee recognizes that it will never be possible or even desirable to fully separate future waste management decisions from politics, we believe a new organization with greater control over its finances could operate at a somewhat greater remove from short-term political pressures (the critical issue of how to fund a new organization is discussed in the next section). Not that a new organization should be any less accountable for its actions or use of funds; on the contrary, effective oversight by Congress and by a strong, independent regulator will be critical and is the subject of a later section. But we believe that a new organization, subject to appropriate oversight but with greater control over year-to-year budgets and operations, could more easily maintain the program-level continuity and mission consistency that has often been lacking at DOE.

The Subcommittee recognizes that Congress will need to take legislative action to establish a new waste management organization, address current funding issues, and set a new course for the nation's nuclear waste program. Numerous questions will need to be answered, fundamental changes in current policy will be needed, and the task of starting up a new organization by itself will require both money and time. From an implementation standpoint, this is clearly among the most difficult recommendations advanced by the Subcommittee. Nevertheless, it is also one of the most important, since even the wisest policies can fail without an institutional structure that is capable of implementing them.

The Subcommittee believes that to be successful over the many decades the organization will be required to have a number of key behaviors and attributes, as shown below. Still we must recognize that whatever the structure of a new organization, there is no substitute for competent, inspired leadership. Therefore, the process for selecting the organization's leader and senior managers must place highest priority on identifying and recruiting the absolute best candidates for the positions.

[43] Outside of the United States, almost all implementing organizations for radioactive waste programs are dedicated public or private entities rather than a ministry or department of the national government.

Key Attributes of a New Waste Management Organization

How a new waste management organization behaves and delivers on commitments is more important than what specific organizational form it takes. In presentations, public comments, and written submissions to the Commission, stakeholders and experts repeatedly stressed that actions and behavior, more than policies or promises, would be key to restoring trust in the nation's waste management program and in the institutions responsible for operating that program. In establishing a new organization, policy makers should therefore consider what design features—including what organizational structure and operational ground rules—would promote the kinds of behaviors and attributes that will be most critical to the new organization's success:

- **Mission orientation**—A well-defined, stable mission, and the organizational capability to focus resources, personnel, and attention on that mission, without being diverted by other priorities.
- **Performance**—Ability to achieve and sustain high standards of technical and managerial performance, through a skilled workforce that has the technical and other capacities needed to complete the task and that is supported by a high-reliability, safety-oriented culture.
- **Empowerment**—Sufficient authority and independence from political micromanagement to be able to implement the mission.
- **Continuity**—Stability in terms of organizational structure, culture, and leadership, particularly at the senior levels.
- **Flexibility**—The ability to anticipate and adapt to new challenges, including sufficient organizational independence to do so.
- **Transparency**—A clear, open, and transparent decision-making process.
- **Participation**—Straightforward paths for involvement by all interested parties, with adequate staff and funding dedicated to outreach.
- **Responsiveness**—The willingness and ability to respond effectively to the concerns and expectations of diverse stakeholders and constituencies.
- **Funding**—Assured financing to accomplish the mission.
- **Accountability**—Mechanisms to assure responsible action and to ensure effective oversight by Congress, independent regulators, financial and technical reviewers, and the public.
- **Constancy**—Ability and willingness to make and keep binding contractual and other commitments to host states/tribes/local governments and other stakeholders.
- **Trust and confidence**—Behavior that instills public faith in the organization's activities.

Two of these attributes—flexibility and responsiveness—are of particular importance for improving prospects for a successful waste management program. Not coincidentally, they are also supported by most of the other attributes listed. Flexibility is needed because the program must operate over very long timeframes in which major changes in technology, institutions, and societal values are inevitable. Given that many, if not most, of these changes will be impossible to predict, the importance of creating an institution that has the capacity to adapt is difficult to overstate. At the same time, a new waste management organization must promote the development of, and operate within a system that, continually seeks to understand and reflect the values of those directly affected by the program and of the broader citizenry. Its ability to respond to those values, even as they shift over time, will be extremely important. Accountability to Congress, to other oversight bodies, to key stakeholders, and to the public is also critical to gaining and sustaining trust, as is a consistent commitment to transparency and communication about how decisions are being made and how competing values and interests are being balanced.

5.2 Options for Structuring a New Waste Management Organization

Proposals to establish a new waste management organization are not new. In 1982, the original NWPA directed DOE to study alternative approaches for constructing and operating civilian radioactive waste management facilities, specifically including the feasibility of establishing a private corporation for these purposes. More recently, legislation introduced in the 110th and 111th sessions of Congress[44] would have amended the Atomic Energy Act of 1954 to create a new federal corporation (called the "United States Nuclear Fuel Management Corporation") that would "assume responsibility for the activities, obligations, and use of resources of the federal government with respect to spent nuclear fuel management." Over the nearly three-decade period between the original NWPA legislation and this recent proposal, alternative means for financing and managing the nation's high-level waste program have been extensively studied but never implemented.

Though it is clear to the Subcommittee from its study of this history that a new waste management organization could take a number of forms, we conclude that a federal corporation chartered by Congress offers the most promising model. This is also the organizational form proposed in recent legislation and recommended by an independent advisory committee (the Alternate Means of Financing and Managing [AMFM] Panel) in 1984.[45] We believe that an independent federal corporation with a well-defined mission, access to adequate resources, ability to make binding contractual commitments, and subject to rigorous external oversight is more apt to achieve the combination of attributes discussed in the previous section.[46] The Tennessee Valley Authority (TVA), which was established in 1933 to promote resource development in the Tennessee Valley region, may provide a useful existing example of such a federally-chartered, mission-oriented corporation. Compared to simply creating a new single-purpose federal agency (even one housed entirely outside DOE), we believe a corporate organization will also (a) be less susceptible to political micromanagement, (b) have more flexibility to respond to changes in external conditions, and (c) have a greater ability to manage costs and schedules.

We emphasize, however, that the crucial underlying objective is the establishment of an independent waste management authority, with independent funding, that (1) is empowered to carry out federal responsibilities for the transportation, storage, and disposal of high-level radioactive waste and spent fuel; (2) has the key attributes (discussed above) that seem to be necessary for success in doing so and (3) has effective third party oversight given its independence. While a corporate structure appears to the Subcommittee to offer particular advantages, previous studies have concluded that a number of different organizational forms could also accomplish the job.

Striking the right balance of independence and accountability is the key challenge, whether a new waste management organization is organized as a federal corporation or takes some other form. The Subcommittee envisions a structure in which Congress provides clear policy direction, ongoing oversight, and establishes the necessary funding mechanisms but leaves control of operational decisions and

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[44] In 2010, Senator Voinovich introduced the ''United States Nuclear Fuel Management Corporation Establishment Act of 2010'' (S. 3322) and Congressman Upton introduced a companion bill (H.R. 5979) in the House. There was no legislative activity on these bills in the 111th Congress.

[45] DOE Review Group, Report to the Secretary of Energy on the Conclusions of and Recommendations of the Advisory Panel on Alternative Means of Financing and Managing (AMFM) Radioactive Waste Management Facilities, Undated (Est. April 1985), in the BRC library at http://www.brc.gov/sites/default/files/documents/amfm_doe_response_s.pdf

[46] Belgium, France, Japan, Spain, and United Kingdom have established public companies to implement high level waste management programs. In Canada, Finland, Sweden, and Switzerland, waste producers have set up implementing bodies to undertake these tasks. Only the United States and Germany have assigned the job to a government department. International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), *Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries*, June 2005, http://www.edram.info/fileadmin/edram/pdf/EDRAMWGonWOwnershipFinal_271005.pdf.

resource commitments for implementing the policy direction to the new organization. Those decisions and commitments, and indeed the performance of the organization as a whole, would, of course, be subject to policy, safety, security, technical, and financial oversight by appropriate government agencies and Congress. Operational direction would come from a board of directors appointed by the President and confirmed by the Senate (for staggered six-years terms). Members of this board would be selected to provide a range of perspectives and expertise and to ensure that key stakeholder interests are represented.[47]

In addition to an engaged and highly competent board of directors, a new waste management corporation will need the leadership of a strong chief executive officer (CEO). It will therefore be critically important to define the position and powers of the CEO in terms that will attract candidates with exceptional management, political, and technical skills and experience. Under both the original AMFM Panel proposal and recent legislative proposals, the CEO would be appointed by the corporation's board of directors. The Subcommittee supports this approach. Other important questions concerning the scope of responsibilities for the new organization, oversight, and stakeholder participation are taken up below, while the critical issue of funding is discussed in the next section.

5.3 Scope of Responsibilities for a New Waste Management Organization

The Subcommittee's strong view is that to be successful, a new waste management organization must be clearly focused on issues of direct relevance to its primary mission, which is the safe management and disposal of high-level radioactive wastes.

Specifically, the Subcommittee recommends that the scope of the organization be limited to those functions already assigned to the government in the NWPA, as amended, including:

- Responsibility for siting, obtaining licenses for, constructing, operating, and ultimately closing facilities for the disposal of civilian and defense high-level wastes and spent fuel.

- Responsibility for siting, obtaining licenses for, constructing, and operating centralized facilities for the consolidated interim storage of commercial spent fuel.

- Responsibility for the transportation of commercial spent fuel once it has been accepted from utilities for disposition.

- Responsibility for conducting non-generic RD&D activities related to storage, transportation, and geologic disposal.[48] (Responsibility for generic research in areas such as alternative disposal

[47] The TVA board provides an example of how the need for expertise and stakeholder representation might be balanced. it has nine members appointed by the President and confirmed by the Senate. Key qualifications specified in law include "management expertise relative to a large for-profit or nonprofit corporate, government, or academic structure" and "support for the objectives and missions, of the Corporation, including being a national leader in technological innovation, low-cost power, and environmental stewardship." That is, Board members must be both capable of and invested in ensuring that the Corporation achieves its mission. In appointing members of the Board, the President must consider recommendations from governors of states in the service area; individual citizens; business, industrial, labor, electric power distribution, environmental, civic, and service organizations; and the congressional delegations of the states in the service area. Furthermore, the President must "seek qualified members from among persons who reflect the diversity, including the geographical diversity, and needs of the service area of the Corporation."

[48] Section 302(d) of the NWPA limits use of the Waste Fund to "nongeneric research, development, and demonstration activities under this Act." An example of such nongeneric research is the OCRWM Science and Technology program discussed earlier.

methods and advanced fuel cycle and waste form options should remain with DOE and private industry and should continue to be funded by general appropriations, and by industry funds.)

The Subcommittee heard suggestions that a new federal waste management corporation should also have responsibilities related to the development and potential implementation of reprocessing/recycling capabilities if those prove to be advantageous.[49] Some argue that since developments and decisions taken with regard to reactors and the fuel cycle have direct implications for waste management, it would make sense from a coordination and consultation standpoint to house these two functions together. On balance, however, the Subcommittee concludes that the task of developing and operating facilities for the storage, transportation, and disposal of high-level waste and spent fuel is sufficiently challenging—as demonstrated by the history of difficulties encountered to date—to warrant a sole focus on those activities. From this perspective, it would be best to leave other reactor and fuel cycle developments to DOE and industry, while providing clear direction to the new organization concerning the need to work with industry and DOE to ensure that waste management considerations are integral to future reactor and fuel cycle developments and that the waste management system will have the flexibility to support such developments. [50] The Subcommittee has also taken note of the fact that none of the past studies of organizational options for waste management have recommended broadening the scope beyond storage, transportation, and disposal; in addition, most countries that have confronted this question have opted to separate institutional responsibility for waste disposal and advanced fuel cycle facilities. For example, France, which is one of the principal nations actively engaged in nuclear fuel reprocessing and recycling, has separated responsibility for waste management from other fuel cycle functions and given that responsibility to an independent organization (ANDRA) separate from the government agency (CEA) that is responsible for reactor and fuel cycle RD&D.

5.4 Governance/Oversight Recommendations for a New Organization

This section turns to the issue of accountability in a new organization. As we have already noted, considerations of independence and accountability are fundamentally intertwined and must be carefully balanced. Put another way, a new waste management organization will only be entrusted with substantial operational and financial autonomy if Congress and the American public are confident that safeguards are in place to ensure that the organization behaves responsibly and uses public resources wisely to achieve national policy objectives. For this reason, all analyses and proposals involving new institutional leadership for the nation's waste management program, starting with the AMFM Panel report in the 1980s, have paid considerable attention to issues of governance, oversight, and accountability.

5.4.1 Congressional Oversight

Congress would play a central role in ensuring the accountability of a new waste management organization in several ways. First, Congress would define—through enabling legislation—the mission, structure, responsibilities, and powers of the new organization.[51] Specifically, we recommend that Congress define:

[49] The Upton/Voinovich legislation proposes to make the organization responsible for all fuel cycle options, technologies and facilities, including reprocessing facilities.

[50] Note: responsibility for treatment and storage of defense waste would remain with DOE

[51] This general approach, in which government and not the implementing organization defines the policy framework that will guide future waste management activities is common to most countries with a significant waste management program. A review of 11 countries that are members of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM) shows that in all cases general waste management policy is set by government, rather than the implementing

- The national nuclear waste policy framework within which the organization must operate;
- The institutional form of the new organization;
- Financial resources and funding mechanisms for the new organization;
- The roles of state, local, and tribal governments in siting waste management and disposal facilities, including the nature of public funding for state, local, tribal and other stakeholder participation; and
- The organization's responsibility to promote the social and economic well-being of communities affected by waste management facilities,[52] as well as the general nature of incentives to be provided and the manner in which states, tribes, and localities are to be funded during the siting process.

(As discussed further below, we recommend that the organization's authority would *not* extend to self regulation of any aspects of environmental protection or worker or public health, safety, and security. These aspects of the organization's performance should be overseen by independent state and federal regulatory authorities.)

To provide oversight on an ongoing basis, we recommend that Congress stay involved through the following mechanisms:

- Senate confirmation of the new organization's board of directors;
- Periodic oversight hearings and review of reports on the activities, expenditures, and progress of the new organization (we recommend that the new organization be required to prepare such reports on a regular basis)[53]; and
- Continued policy guidance.

While Congress would define the policy framework at the outset, some mechanism for facilitating later adjustments or course corrections after the initial policy direction is specified in law may be desirable.[54] One option would be to use the Mission Plan already required in the NWPA as a vehicle for ongoing Congressional oversight. The new waste management organization could submit a Mission Plan describing its planned activities, schedules and milestones, and supporting budget to DOE and Congress on a regular basis (e.g. every three to five years). If desired, legislation establishing the new organization could include an expedited process similar to that provided by the Congressional Review Act (CRA) through which Congress could veto a proposed Mission Plan Revision by passing a joint resolution,

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organization. International Association for Environmentally Safe Disposal of Radioactive Materials, Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries, June 2005.

[52] For example, "the economic and social well-being of the people living in [the Tennessee] river basin" is one of the general purposes identified in the legislation that established TVA [48 Stat. 69, 16 U.S.C. sec. 831v]; consequently, TVA sees economic development of the region as a key part of its mission and has an economic development program for that purpose. (http://www.tva.com/econdev/index.htm). Similarly, Enresa, which is Spain's national corporation for radioactive waste management, has established the Enresa Foundation to promote social welfare and socio-economic development, the environment, education, and culture in areas that host Enresa facilities.

[53] The NWPA already requires annual audits of the activities of OCRWM by GAO, a comprehensive annual report by OCRWM on its activities and expenditures, and an annual report to Congress from the Secretary of the Treasury (after consultation with the Secretary of Energy) on the financial condition and operations of the Waste Fund.

[54] Spain, for example, may offer a useful model: the government provides policy direction to the waste management organization, Enresa, through ministerial review and approval of a General Radioactive Waste Plan that is revised and resubmitted every four years.

subject to presidential veto.[55] This approach would allow substantial Congressional control over changes of direction without requiring passage of legislation to approve such changes whenever they are needed.

5.4.2 Management Oversight

In many of the proposals for a new organization advanced to date (including by the original AMFM Panel, the Upton/Voinovich legislation, and this Subcommittee), a first layer of accountability below Congress is provided by a board of directors, whose members would be appointed by the President and confirmed by the Senate. A Board of Directors to which the organization's management is responsible would provide a degree of ongoing management oversight and control that is not normally present with a typical federal agency program, and is particularly appropriate for the management of a businesslike fee-for-service activity such as the high level waste program. The Board would have the usual powers granted such bodies, including establishment of broad policies and objectives (within the statutory framework set by Congress); selection of top managers, establishment of the management structure, and setting personnel policies; approving annual budgets; and accounting to external stakeholders for the performance of the organization. This approach appears to be the norm in other nations' waste management programs. A review of organizational arrangements for radioactive waste management in a sample of 12 other countries shows that in all but one case the implementing organization is overseen by a board of directors or supervisors.[56]

5.4.3 Independent Regulation

The new organization would be subject to the same federal and applicable state health, safety, and environmental regulations as a private corporation, unless otherwise prescribed by Congress. (Regulatory issues are discussed in more detail in Section 8.) The specific division of federal regulatory responsibility should include the following:

- Radiological health and safety—EPA and NRC;
- Other environmental impacts—EPA;
- Transportation (other than transportation cask design certification)—Department of Transportation (DOT); and
- Worker health and safety—Occupational Safety and Health Administration (OSHA) and Mine Safety and Health Administration.
- Security – NRC, DOT and others through implementation of Department of Homeland Security (DHS) standards and requirements.

[55] The CRA requires federal agencies that promulgate rules to submit certain information to each House of Congress and the General Comptroller about the rule. Generally, major rules may not become effective until 60 days after submission to Congress. During those 60 days, Congress could pass a joint resolution to disapprove the major rule. The President could veto a Congressional joint resolution of disapproval. In that case Congress would have 30 days to override the President's veto. If Congress does not override the veto, the rule becomes effective. In legislation establishing the waste management organization and setting nuclear waste policy direction, Congress could provide itself CRA-like authority to review the organization's Mission Plan update.

[56] These eleven countries are Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, Taiwan, and the United Kingdom,

5.4.4 Scientific and Technical Oversight

Many proposals for an independent waste management organization provide for broad independent technical oversight in addition to, and separate from, any specific health and safety or environmental standards that might apply to the waste management facilities built and operated by the organization. The existing NWTRB would be an appropriate organization for providing this type of wide-ranging technical oversight on an ongoing basis. The NWTRB should report to the new organization and the Congress at least twice per year. As now, its members should be selected by the President from a candidate list prepared by the National Academy of Science, and consist of carefully considered mix of scientist and engineers.

Independent reviews of key aspects of the program on an ad hoc basis by independent organizations (e.g., the National Research Council, the Nuclear Energy Agency [NEA], and the International Atomic Energy Agency [IAEA]) can also be useful in providing guidance and enhancing public confidence in the technical competence of the organization's work. The waste management organization should therefore be given the authority and responsibility to implement programs and procedures aimed at facilitating such independent reviews, including authority to fund such activities, where appropriate.

Assuring the relevance, quality, and comprehensiveness of the scientific, technical, and institutional work undertaken by the new organization is important to program excellence. It is also necessary to earn the confidence of the scientific community and larger public. A rigorous, open, and documented peer review process can play a key role in providing this assurance, in conjunction with a rigorous quality assurance program. Peer review provides a mechanism for outside experts to provide independent critical evaluations of analyses, studies, or proposals put forward by the waste management organization. Such evaluations can be used as management tools for verifying or validating the assumptions, results, and conclusions of the organization's work. Done properly, the peer review process can bolster confidence and strengthen credibility; it can also help improve decision-making by bringing other relevant work to the attention of the organization.

For all of these reasons, a comprehensive peer review program should be established for scientific, technical, and institutional work as determined by the implementing organization, using review mechanisms appropriate to the nature and importance of the work. In addition to ensuring that interested parties and stakeholders have timely access to data and analyses, the waste management organization should encourage and support the peer-reviewed publication of work that is of particular importance to in its activities, including site characterization work and analyses aimed at demonstrating the safety and suitability of plans for repository design and operations. The waste management organization should also encourage and support its staff in delivering presentations and papers at scientific and technical conferences and participating in national and international meetings. This will allow the organization's work to benefit from full exposure to the broader scientific community and other interested stakeholders.

We envision that a robust peer review program will not substitute for, but will rather augment, the oversight provided by relevant regulatory authorities, the NWTRB, and other important organizations (i.e., the National Academy of Sciences).

5.4.5 Financial Oversight

Providing the new organization with control of its funding independent of the annual budget and appropriations process, as recommended by the Subcommittee and discussed at length in the next section (section 6), will require independent oversight to ensure that the NWF and other public resources are being used appropriately in support of waste program objectives. Beyond a board of directors, most proposals provide for additional oversight in the form of independent audits of the new organization's

finances along with reviews by the Government Accountability Office (GAO). The NWPA already requires an annual GAO audit of the activities of DOE's OCRWM, as well as a comprehensive annual report by OCRWM on its activities and expenditures and an annual report to Congress from the Secretary of the Treasury (after consultation with the Secretary of Energy) on the financial condition and operations of the NWF. These requirements could simply be extended to the new organization. A mechanism for Congress to review regular updates of the organization's Mission Plan and associated budget (discussed above) would provide an additional vehicle for overseeing the organization's planned use of funds.

Particular attention must be paid to which entity has authority over the level of the nuclear waste fee. Under current law, the Secretary of Energy is required to make adjustments to the fee, as necessary, to ensure recovery of the full costs of managing and disposing of commercial waste. The AMFM Panel recommended that a "Waste Fund Oversight Commission" be established for the specific purpose of ensuring that NWF fees are being used cost-effectively and to approve or disapprove proposed changes to the level of the fee. In its 2001 update of the AMFM study, DOE instead recommended that the Federal Energy Regulatory Commission (FERC) serve this purpose. Giving authority to review and approve fee increases to an independent organization with suitable expertise and staff would enhance confidence that such increases are just and reasonable and are not simply the result of ineffective use of the program's resources. This would be consistent with an approach that treats the waste management organization as, in effect, a public utility with a natural monopoly over a necessary service.

In such cases, it is common for the rates charged by the organization or utility to be regulated by an independent commission. Since the Federal Energy Regulatory Commission (FERC) already exists and deals with rate issues, the Subcommittee recommends that it be used for this function.

5.5 Stakeholder Participation

In passing the NWPA, Congress found that "state and public participation in the planning and development of repositories is essential in order to promote public confidence in the safety of disposal of such waste and spent fuel." The Subcommittee concurs with this finding and believes that appropriate mechanisms are needed to provide for such participation. Two distinct areas that may require distinct mechanisms are interactions with interested stakeholders throughout the nation, and interactions with states, communities, and tribes directly impacted by waste management facility siting. Each is discussed further below. We recognize that there will be a need for significant commitment of staff and resources to stakeholder participation at all of the levels discussed below. To ensure that such resources are provided, enabling legislation must provide clear direction to the waste management organization that stakeholder involvement is to be regarded as one of its core responsibilities. Accordingly, the new organization's plans and activities in this area must be covered in annual reports and long-term plans; in addition, enabling legislation should specify that related costs represent an appropriate use of the NWF.

5.5.1 Interactions with National Stakeholders

There are many stakeholders with an interest in the overall direction and conduct of the national waste management program. These include:

- Utility companies that pay the costs of the program and have an interest in monitoring program activities and costs
- Public utility commissions charged with protecting the interests of utility ratepayers
- Taxpayers who pay the costs of managing and disposing of defense wastes, and who are ultimately liable for damages associated with the federal government's failure to meet its contractual obligations under the NWPA

- States, tribes and local communities that host centralized storage and/or disposal facilities
- States, tribes, and local communities that will be affected by the continued storage of waste at current sites until this waste can be moved to federal facilities
- States, tribes, and local communities affected by the transportation of wastes
- Public interest groups with an interest in radioactive waste management policy and practice
- The nuclear industry
- DOE (in its capacity as the agency responsible for cleaning up former nuclear weapons production sites)
- The U.S. Navy (which generates small but strategically important quantities of spent fuel that will require disposal)
- The non-proliferation and nuclear security policy community

While the board of directors of a waste management corporation would include representatives of key stakeholders (e.g., those who are impacted by and paying for the waste management program), its role would be to carry out fiduciary responsibilities for management oversight rather than to represent stakeholder views. Furthermore, a board of workable size could not include all stakeholder perspectives in any event. To provide an ongoing conduit for input from the full range of stakeholder perspectives identified above, a larger and more widely representative stakeholder advisory committee should be established. Such a committee could be established under the Federal Advisory Committee Act; it would report to the waste management organization's CEO and/or board of directors (in a manner similar to DOE's Environmental Management Advisory Board).[57] This committee would not supplant direct interactions between the waste management organization and specific stakeholders, but would provide an opportunity for the organization to learn from the full range of stakeholders in a way that cannot be achieved through one-on-one interactions. Ongoing dialogue with a stakeholder advisory committee can help the organization identify broadly-acceptable policies and plans, as well as areas of disagreement that remain to be resolved.

The pre-operational phase of the activities of the waste management organization, perhaps the most important time during which external advice will be needed concerns the siting process. Siting high-level waste facilities, particularly repositories, is perhaps the most daunting task a new waste management organization will confront; it is also one that will require extensive public involvement.

While the Disposal Subcommittee considered the possibility that an authority separate from the organization charged with developing and operating waste management facilities would undertake siting, the Subcommittee concluded that this function should remain under the auspices of the waste management organization. There are several reasons, however, for treating siting as a unique function of the organization for which active engagement with a broad range of stakeholders and other experts will be particularly important. To be credible to such a wide range of these stakeholders, the institutions and processes involved in siting must establish a high degree of independence and objectivity. At the same time, keeping responsibility for siting within the waste management organization recognizes that this process cannot be conducted as if it were completely independent of the subsequent development and operation of waste management facilities. Siting decisions will have a major impact on storage and disposal operations, and siting decisions and criteria must meet operational and design standards. Most crucially, the same waste management organization must be accountable on an ongoing basis for living up to all commitments made during the site selection, characterization, and approval process.

[57] The National Academies *One Step at a Time* report also recommended a stakeholder advisory board.

Recognizing that the siting and operational phases of facility development are inextricably linked, the Disposal Subcommittee recommends that during the siting phase of the program the stakeholder advisory committee include a special subcommittee focused on the siting process. Its purpose would be to provide guidance to the waste management organization concerning the design of an overall siting approach and specific issues related to siting, and to provide a conduit and focal point to ensure that stakeholder input on these issues is given serious consideration and acted on as appropriate. Members of such a subcommittee could include stakeholder representatives from the full committee supplemented by other individuals with additional expertise relevant to siting processes, such as qualified academics including social scientists. Whether a separate subcommittee should be established to oversee the siting of centralized storage facilities as distinct from disposal facilities is a question that should be considered by the new waste management organization.

Finally, it will be important for members of the general public to have opportunities to provide meaningful and regular input into the ongoing activities of the waste management program. Requiring that the organization regularly develop and revise a Mission Plan (as discussed above), including a transparent process for actively soliciting and incorporating public feedback, would provide an important mechanism for soliciting and benefitting from broad-based input. The subcommittee believes that regular public input is essential to a successful program and encourages the waste management organization to look for other opportunities to seek and incorporate meaningful input.

5.5.2 Interactions with Affected States, Tribes, and Local Governments

States, tribes, and local communities that are potential or actual hosts of waste management facilities have a special interest in being involved in the process of evaluating the sites and then developing and operating the facilities. As the siting process moves into the site-specific phase, interactions with these potential facility hosts will take on increasing importance. The NWPA makes extensive provisions for coordinated planning and consultation with affected states and Indian tribes. For example, Section 116 of the NWPA requires OCRWM, after it has approved a site for characterization or upon request, to seek to enter into and negotiate consultation and cooperation (C&C) agreements with eligible states and affected Indian Tribes. The purpose of these agreements would be to specify the procedures that will be followed in areas of mutual concern, such as:

- Public health and safety,
- Environmental and socio-economic impacts of a repository,
- Access to and sharing of technical data and expertise,
- Joint surveillance and monitoring of project activities,
- Public education programs,
- Procedures for resolving conflicts and off-site concerns,
- Financial assistance to the states and tribes, and
- Notification of the proposed transport of high-level waste and spent nuclear fuel.

These provisions in the NWPA were modeled on the 1981 C&C agreement that defined the relationship between DOE and the State of New Mexico as it pertained to the development of the WIPP facility.

(While Section 116 relates specifically to repositories, the Act applies these or similar provisions to all the other types of waste management facilities it addresses.)

The Subcommittee recommends that the waste management organization be given the responsibility and authority to negotiate similar agreements going forward. At the same time, we recognize that it may be more fruitful for the waste management organization to begin by engaging local communities before reaching out to state officials. Clearly all levels of government must be involved from an early point in the process. How that process unfolds and in what order different agreements are struck between different parties is not something that can or should be dictated in advance. This is also why the attributes described previously, including flexibility, responsiveness, and transparency, will be so important to the success not only of the siting process but of the waste management organization itself.

In this context, it is notable that the NWPA's current consultation and cooperation provisions apply only to relations between the federal government and state or tribal governments, and do not extend to local governments.[58] In its visits to observe waste management activities in Sweden and Finland, the Subcommittee saw the importance of close involvement with the local communities hosting waste management facilities. Significantly, when a community task force in Oak Ridge, Tennessee evaluated DOE's proposal to site a MRS facility in the area, they made their support for the facility conditional on the adoption of specific measures to enhance local authority. These included provisions for C&C agreements directly between DOE and units of local government, as well as between DOE and the state, and granting preferred status to local governments in interactions between the state, DOE, and NRC regarding the MRS.[59] The Subcommittee therefore recommends that the waste management organization's authority and responsibility to negotiate binding agreements with host states and tribes be extended to local host governments.

5.6 Transfer of Contracts and Liability to a New Organization

A particularly challenging issue that will have to be addressed concerns the handling of existing liabilities under DOE's current contracts with utilities. A number of lawsuits have already been brought by utilities seeking to recover damages arising from the federal government's failure to meet its statutory obligations under the NWPA, which stipulated that DOE would begin accepting civilian used nuclear fuel for final disposition by 1998. To date, the courts have awarded some $1 billion in damages as a result of these suits. DOE's most recent estimate is that current liabilities could total $15.4 billion if waste acceptance were to begin as early as 2020.[60] DOE further estimates that these liabilities could increase by roughly $500 million per year for each year that the acceptance of used commercial fuel slips beyond 2021.[61]

[58] Another section of the Act that provided for a negotiated "benefits agreement" between the federal government and a state or tribe hosting a repository or MRS facility did allow for local government representation on a "review panel" that would (1) advise the Secretary on matters relating to the proposed repository or monitored retrievable storage facility, including issues relating to design, construction, operation, and decommissioning of the facility; (2) evaluate performance of the repository or monitored retrievable storage facility, as it considers appropriate; (3) recommend corrective actions to the Secretary; (4) assist in the presentation of state or affected Indian tribe and local perspectives to the Secretary; and (5) participate in the planning for and review of preoperational data on environmental, demographic, and socioeconomic conditions of the site and the local community. However, local interests accounted for only a small part of the representation on this panel.

[59] Clinch River MRS Task Force, "Position on the Proposed Monitored Retrievable Storage Facility," October 10, 1985.

[60] "Liability Estimate" memorandum to Steve Isakowitz, Chief Financial Officer, DOE, from David K. Zabransky, Director, Office of Standard Contract Management, Office of General Counsel, DOE, October 29, 2010.

[61] Testimony of Kim Cawley, Chief, Natural and Physical Resources Cost Estimates Unit, Congressional Budget Office, on "The Federal Government's Responsibilities and Liabilities under the Nuclear Waste Policy Act," for the Committee on the Budget, U.S. House of Representatives July 27, 2010.

Clearly resolving the treatment of the existing contractual liabilities will require careful consideration in the process of enacting legislation to establish a new waste management organization.[62] A core question will be how to pay for damages accrued until federal facilities are available. A federal court has since found that the NWF cannot be used for this purpose because at-reactor storage is not an allowed use of the Fund under the NWPA and DOE contracts with utilities. As a result, damages are now being paid out of the Judgment Fund, which receives a permanent indefinite appropriation from the Treasury. Clearly, that responsibility for contracts and associated liabilities will have to be made clear going forward.

5.7 Continuation of RD&D in the Interim

Although the subcommittee strongly believes that the new management organization is the key for a successful national integrated waste management program, we recognize that it could take several years for this new organization to be authorized, funded, staffed and ready to proceed. At the same time it is important to keep the waste management program moving forward towards finding integrated solutions that will enable the safe and secure disposal of spent nuclear fuel and highly radioactive nuclear wastes. Thus, while the new organization is being created, the DOE should continue its non-site specific research and development efforts, including research on different geological media and design of better engineered barriers.

For instance, the DOE's Office of Used Nuclear Fuel Disposition Research & Development is implementing the Used Fuel Disposition Campaign. The objectives of the Campaign are to identify alternatives and conduct R&D for transportation, storage and disposal of spent nuclear fuel (in different geological media) from existing and potential future nuclear fuel cycles as well as to provide some technical expertise and inform decision-making processes on the issue. We believe that those and other non-site specific generic activities should be continued.[63]

5.8 Key Findings

- History has demonstrated that the current approach, in which waste management is the responsibility of a large cabinet-level agency with multiple competing missions (DOE), subject to annual and uncertain funding and direction provided by Congress, is not well suited to sustaining the level of performance, trust, and stability needed to implement essential elements of an integrated waste management strategy.

- Options for moving nuclear waste management responsibility out of DOE have been studied for decades. The general conclusion has been that a number of different organizational forms are viable and could work to provide the focus and effectiveness needed to successfully implement program objectives. One concept that features prominently in several past proposals is that of a federally chartered corporation. Such an organization, provided it has a well-defined mission, access to adequate resources, the ability to make binding contractual commitments, and is subject to rigorous external oversight could offer a number of important advantages compared to other alternatives or the status quo.

[62] The Upton/Voinovich bill deals with this issue by providing that contracts and settlements remain the liability of DOE until 10 years after termination of the license of the reactor involved. The new federal corporation would take liability under the existing contracts no later than 10 years after license termination, as well as for all new contracts and any negotiated transfer of liability between DOE and the corporation.

[63] For more details see "R&D Activities for Used Nuclear Fuel Disposition Storage, Transportation & Disposal," presentation by William Boyle, Director, Office of Used Nuclear Fuel Disposition Research & Development, DOE NE, NWTRB winter meeting, February 16, 2011 at http://www.nwtrb.gov/meetings/2011/feb/boyle.pdf

- More important than what form it takes is that a new waste management organization display certain behaviors and attributes (i.e., competence, transparency, flexibility, responsiveness, accountability, etc.).

- For most of the national disposal programs that the Subcommittee studied, the waste management organizations' responsibilities were limited to storage, transportation, and disposal, and were performed by a private or public corporate entity, not a government department

- Societal confidence and acceptance of the siting process can be bolstered through the use of a special subcommittee focused on the siting process as a part of stakeholder advisory committee. To better serve its goal and accumulate more expertise in the siting process, members of the subcommittee could include those who are not members of the advisory committee, but have relevant expertise.

- A new waste management organization will only be entrusted with substantial operational and financial autonomy if Congress and the American public are confident that safeguards are in place to ensure that it behaves responsibly and uses public resources wisely. Mechanisms must be in place for effective Congressional oversight, management oversight (in the form of a board of directors), and regulatory oversight, as well as independent scientific, technical, and financial oversight.

- Other issues that require careful attention in developing guidance for a new, single-purpose waste management organization include the organization's approach to stakeholder participation, facility siting, and interactions with affected state, tribal, and local governments. In particular, it will be critically important to give the new waste management organization the responsibility and the authority and to negotiate binding agreements with affected governments.

- Congress will need to address the transfer of existing DOE contracts and liabilities to the new organization.

- DOE should continue generic, non-site specific RD&D efforts, including research of different geological media and engineered barriers, while the new organization is being formed.

6. FUNDING A NEW WASTE MANAGEMENT ORGANIZATION

6.1 Background

Among the most important provisions of the original NWPA of 1982 was the commitment to establish a secure source of funding for the management and ultimate disposal of spent fuel from the commercial nuclear power sector. Applying the principle of "polluter pays," the Act provided for a fee on nuclear-generated electricity.[64] The fee was initially set in the legislation at 0.1 cents per kilowatt-hour (where it still is); however, the Act requires that the Secretary of Energy review the adequacy of the fee annually and adjust it as needed to ensure that it recovers the full costs of waste management and disposal.

The fee is a *quid pro quo* payment by utilities in exchange for the federal contractual commitment to begin accepting waste for disposal beginning by January 31, 1998. The fee is collected from utilities that own or operate nuclear power plants and generally is passed on to utility ratepayers. Revenues from the fee go into a NWF that was established for the express purpose of covering management and disposal costs incurred by the federal government in assuming contractual responsibility for disposal of the civilian nuclear industry's spent fuel. The clearly stated Congressional intent for this funding mechanism was to "provide an assured source of funds to carry out the programs and … eliminate … annual budgetary perturbations in an evermore constrained Federal budget …" (see text box below). Indeed, the Act's commitment to an expanded and accelerated program to site, license, and construct repositories, and to direct DOE to undertake contractual obligations to begin accepting waste from utilities on a defined schedule, required the existence of an assured funding source to support the activities needed to meet these obligations.[65]

The costs associated with managing and disposing of materials from defense-related nuclear activities, by contrast, were to be paid by taxpayers through appropriations from the Treasury. Originally, these appropriations were to be deposited in the NWF. In practice, however, the funds for the defense wastes have been appropriated directly to the program without passing through the Fund. As a result, the Fund contains only unspent receipts from the nuclear waste fee and accumulated interest. In recent years, the fee has generated approximately $750 million in annual revenues; with interest, cumulative revenues into the Fund over the nearly 30 years that it has existed have totaled some $30 billion. The current unspent balance (known as the "corpus") is nearly $25 billion.

[64] The "polluter pays" principle for high-level waste disposal was first established by the AEC in 1970 when it established rules for the solidification and disposal of high-level wastes from reprocessing. However, the waste generators were going to pay when they actually delivered the waste for disposal, leaving the federal government to come up with the funds needed to develop a disposal system before the government could be reimbursed for this expense by the waste generators. In the NWPA, Congress departed from this approach and opted for an up-front fee to generate the revenues to build the system without having to rely on taxpayer funds, to ensure that adequate funds were available as needed.

[65] U.S. Congress Office of Technology Assessment, *Managing the Nation's Commercial High-Level Radioactive Waste,* OTA-O-171, March, 1985, p. 93, pp. 106-107.

Intent of the Nuclear Waste Fund

Senator James McClure (R-ID), chairman of the Senate Committee on Energy and Natural Resources and floor manager of the nuclear waste policy legislation, outlined the intent of the NWF as follows during the final debate in the Senate on passage of the original 1982 NWPA:

> "The bill contains several new or modified concepts from the bill passed by the Senate in the last Congress. One of the most noteworthy of these is the proposal for an assured full-cost recovery by the federal government from nuclear power-supplied ratepayers for the nuclear waste programs included in the bill. By establishing a 1 mill-per-kilowatt-hour user fee on nuclear generated electricity, this bill for the first time would provide a direct financial linkage between the beneficiaries of nuclear power and the cost for interim management and ultimate disposal for nuclear wastes.
>
> The bill provides for a contractual fee, initially set at a 1 mill per kilowatt-hour, which would be charged on the production of electricity from nuclear power plants. Receipts from this fee would be placed in a separate account in the Treasury established solely for this purpose and would then be appropriated for the waste program on an annual basis. According to the Congressional Budget Office, this fee is adequate to cover the costs of this legislation well into the 1990s. However, the bill requires that the adequacy of the fee be reviewed on an annual basis, and the fee could be modified in the future if receipts fell below costs of the program.
>
> This funding mechanism would provide an assured source of funds to carry out the programs and would eliminate not only annual budgetary perturbations in an evermore constrained federal budget, but the too often repeated shifts of policy direction under succeeding administrations. The nuclear waste policy, programs and required financing would be statutorily fixed and quite predictable under this approach."

Congressional Record-Senate, December 20, 1982, pp. S15655 - S15656

6.2 Constraints on the Use of the Nuclear Waste Fund

Though the intent of the NWF was to provide a dedicated source of funding that would insulate the nation's civilian nuclear waste management program from the vagaries of the federal budget process, it has not worked as intended. A series of actions by successive administrations and Congresses has had the effect of decoupling the collection of revenues through the nuclear waste fee from the appropriation of funds to carry out the purposes for which the Fund was created. As a result, waste management needs have had to compete with other priorities in DOE's annual budget request and in the Congressional appropriations process, subjecting the program to exactly the sort of "budgetary perturbations" that the funding mechanism was intended to avoid. The result has been a program hampered by resource constraints and inconsistent funding—precisely the problems that Congress had intended to fix (see Figure 10 and further discussion in the text box below). These problems have materially contributed to the failure of the federal government to meet its contractual obligations and the resulting large and growing financial liabilities for damages that are paid by the nation's taxpayers. The Subcommittee's strong view is that *unless the funding mechanism established by the NWPA is freed to work as intended, commitments to implement a multi-billion-dollar, multi-decade waste management program will lack credibility, and the delays, rising costs, and growing taxpayer liabilities that have plagued the program in the past will continue.*

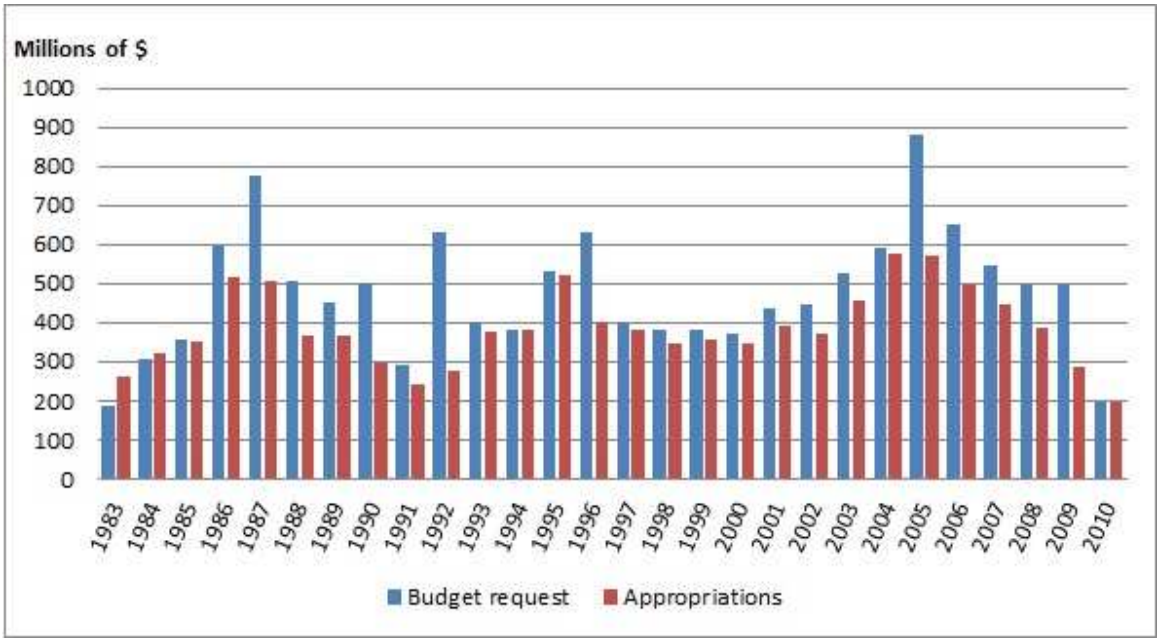

Figure 10. Nuclear Waste Program: Budget Requests versus Appropriations.[66]

Moreover, even if competition with other programs for limited funds were not an issue, the current statutory requirement that makes use of the NWF subject to appropriations has led to unforeseen difficulties caused by the appropriations process itself. Although the current system assures Congress explicit and extensive year-to-year oversight and control, it has clearly proven to be a poor mechanism for financing a very long-term and complex effort. First, the annual appropriations process creates substantial funding uncertainty, which can make it difficult for the implementing agency to make and honor longer-term commitments, retain staff expertise, and exercise independent judgment about programmatic priorities and resource allocation. Second, Congress has increasingly failed to pass appropriations bills in a timely manner in recent years, forcing federal agencies to operate on continuing resolutions for extended periods of time while coping with the delayed availability of requested funds.

A 2005 report on the management and funding of nuclear waste management programs in the 11 member nations of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)[67] noted that the principle applied in all of these nations is that the waste producers pay for the management of their wastes. The main differences among EDRAM members relate to how the necessary money is estimated, collected, and managed. A review of financing mechanisms in these different programs showed that the United States is the only nation where the expenditure of funds collected for waste management is directly controlled by the national legislature.[68]

[66] Data Source: *Summary of the Program Financial & Budget Information*, DOE Office of Civilian Radioactive Waste Management, Office of Business Management, as of January 31, 2010.

[67] Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, UK, and USA.

[68] International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), *Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries*, June 2005, Tables 7.4 and 7.5, http://www.edram.info/fileadmin/edram/pdf/EDRAMWGonWOwnershipFinal_271005.pdf.

The Layering of New Budget Requirements on the Nuclear Waste Fund

Since the establishment of the NWF in 1982, Congress enacted several budget control acts that dramatically reduced the funding flexibility originally envisioned in the NWPA, as follows:

- The Balanced Budget and Emergency Deficit Control Act of 1985, also known as Gramm-Rudman-Hollings (GRH), made the NWF subject to the government-wide budget sequestration process. In the implementation process, the Office of Management and Budget (OMB) decided to "split" the NWF for sequestration purposes, with fee receipts on the "mandatory" side of the budget and expenditures on the "discretionary" side subject to sequestration.
- The 1987 amendments to GRH placed the appropriations from the NWF under the spending cap applicable to all domestic discretionary programs, even though the NWF was self-financed. This had the effect of forcing spending for the NWF to compete with other spending programs, which did not have dedicated funding sources. Also, as a result, OMB dropped its historical practice of setting separate budget planning targets for the NWF, forcing it to compete against other DOE programs within a single DOE budget target for domestic discretionary spending.
- The Budget Enforcement Act of 1990 (BEA) set new caps on discretionary spending accounts. BEA also established new pay-as-you-go (PAYGO) requirements, applicable to mandatory spending and receipts, in order to ensure that the net effects of legislative changes affecting mandatory spending were budget neutral.
- In the Conference Report accompanying the Omnibus Budget Reconciliation Act of 1990, the NWF spending was designated as part of the domestic discretionary appropriation accounts for Fiscal Year (FY) 1991, subject to the spending cap set in the BEA.
- The 1997 Amendments to the Balanced Budget Act extended the caps on discretionary spending accounts and the PAYGO requirements for mandatory spending accounts through FY 2002.

The layering of these new budget requirements seriously eroded the NWF's funding capability in two ways:

- It imposed annual spending and revenue controls on a fund that was designed to finance a 125-year program on a life-cycle cost basis; and
- It made the NWF dysfunctional by creating separate and unrelated rules applicable to the revenue and spending components of the Fund.

The overall effect, in short, has been to prevent the NWF from being used for its intended purpose. Due to PAYGO requirements, increased funding for the waste management program would require funding reductions in other programs within the annual discretionary appropriations caps. The legislative requirement for annual appropriations from the NWF was part of a mechanism to exercise control over the program; however, it was never the intent of Congress to limit the funding needed to implement the program.

Source: Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program, U.S. Department of Energy, August 2001, DOE/RW-0546, pp. 12-13

In sum, the nuclear waste fee and Fund have not functioned as intended to provide the U.S. waste program with adequate and stable funding. The Subcommittee believes that this has played an important role in undermining DOE's waste management efforts to date. Meanwhile, the federal government's failure to deliver on its statutory obligations, with respect to the management of civilian SNF, has prompted the National Association of Regulatory Utility Commissions (NARUC), as well as certain nuclear utilities and the Nuclear Energy Institute (NEI), to pursue legal action against DOE aimed at suspending the collection of NWF fees until such time as a new waste management plan for the country has been finalized. The outcome of this and other pending legal actions remains uncertain at present, but they underscore the growing frustration among state regulators, nuclear utilities, and consumer advocates about the continued lack of progress toward a durable waste management solution.

Section 6.4 discusses some near-term options for addressing the NWF. Our chief point here is that a new waste management organization, to be successful, must have access to the stable source of funding that the NWPA was supposed to provide. This means removing funding for the nation's waste management program from the short-term political and budgetary pressures inherent in the annual appropriations process. A new organization bound by a well-defined mission should be entrusted—subject to an appropriate level of oversight by Congress and relevant regulatory authorities—with greater autonomy and control of its budget over multiple year periods, just as the TVA has control of the use of its receipts from electricity sales subject to Congressional oversight. Accordingly, the Subcommittee recommends that revenues from the nuclear waste fee and the balance in the NWF be made fully available (with appropriate independent party oversight) to a new waste management organization to implement the actions needed to achieve defined program objectives independent of other federal budgetary pressures. This requires three steps:

1. Extricating the NWF from the web of budget rules that have created an unintended and dysfunctional competition between expenditures from the Fund and spending on other federal programs; and

2. Removing funding decisions, to the extent they concern activities related to the civilian wastes for which the nuclear waste fee is being paid, from the annual federal budgeting and appropriations process; and[69]

3. Establishing proper third party oversight, as discussed elsewhere in this report.

6.3 The Need for Legislative Action

The Subcommittee recognizes that fully implementing the above recommendations will require legislative actions by Congress. This would be the case even if the intent were only to change current funding mechanism, including the treatment of the NWF, while leaving aside the question of establishing a new waste management organization. The legislative challenge is further complicated by the fact that under current budget rules, any legislative action that had the effect of reducing NWF receipts to the U.S. Treasury would be subject to PAYGO requirements (see text box on previous page). This means that new revenues or budget cuts would be needed to cover the change in funds flowing to the Treasury.

The Subcommittee also recognizes that there have been numerous legislative proposals to increase access to the fee revenues and the NWF.[70] Rather than attempt to resolve the complex PAYGO and other issues

[69] The Subcommittee recognizes that it will also be important to ensure reliable appropriations for defense-related waste.
[70] For a summary of proposals to change the Nuclear Waste Fund (NWF) funding structure from 1994 through 1999, see Figure 3 in Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program, U.S. Department of Energy, August 2001, DOE/RW-0546. More recently, Senator Hagel introduced a bill in 2007 with provisions specifying that "funds from the Nuclear Waste Fund will not be subject to allocations for discretionary spending under section 302(a) of the Congressional Budget Act or suballocations of appropriations committees under section 302(b)." To address the issue of budget

involved, the Subcommittee strongly recommends that those responsible for management of the budget process and rules in the Administration and Congress devise a workable means to ensure that, in the long run, the corpus of the NWF is available to meet the annual cost peaks that will occur with the construction of waste management facilities. That the balance in the NWF (including accrued interest) would be fully accessible when and as needed was a fundamental premise underlying the commitments made in the NWPA—that premise must be restored. Until then, the most critical step is to ensure that revenues from the fee going forward are available to site, design, and license waste management facilities.

Finally, the Subcommittee is aware that efforts to fix the use of the NWF could be caught up in broader questions concerning the treatment of trust funds in the federal budget more generally. However, DOE has indicated to Congress that proposals to correct the treatment of the waste fee and Fund are unlikely to create wider precedents beyond similar contractual fee-for-service situations (if any exist).[71]

6.4 Proposed Near-Term Administrative Action to Increase Access to Fee Revenues

The Subcommittee recognizes that legislative action to provide full access to the nearly $25 billion balance in the NWF will be difficult in the current political and budgetary climate, despite the fundamental equity and contractual arguments for such actions. Therefore, we urge the Administration to take prompt action aimed at enabling use of the annual nuclear waste fee revenues for their intended purpose while stopping further additions of surplus revenues to the NWF until such access has been guaranteed. We believe this can be accomplished by adopting a combination of measures that are already allowed under existing legislation. [72]

Specifically, the Administration should (1) change the way in which the nuclear waste fee is collected so that only an amount equal to actual appropriations from the NWF is collected each year, with the remainder collected at time of waste delivery, and (2) reclassify the fee receipts from mandatory to discretionary so that they can directly offset appropriations for the waste program. (This specific

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neutrality, the Hagel bill would have further required that adjustments be made "In the allocation of new budget authority to appropriate committees in amounts equal to the fees reclassified as discretionary as a result of the above provision." Legislation introduced by Senator Domenici in 2008 under the title "Strengthening Management of Advanced Recycling Technologies Act" (or SMART Act) would have established a revolving fund using $1 billion of the current NWF, as well as the annual interest on the Fund. The remaining 95% of the current waste Fund, as well as all future fees, would be placed in a legacy fund for the purposes of constructing a geologic repository. Expenditures from the revolving fund for the provisions of the Act could be made without further appropriations but would be subject to limitations in appropriations acts. In this way, the revolving fund could be put to use without being subject to the uncertainty of the annual appropriations process while still retaining the authority of Congress to oversee the NWF. The recent Upton/Voinovich legislation would establish two funds—an operating fund and a reserve fund—for the new waste management organization. The unexpended balance of already appropriated funds, plus accounts receivable and future revenues from NWF fees and appropriations would go to the operating fund. The corpus of the NWF would be transferred as an unfunded asset to the reserve fund (accruing interest from the NWF would go to the operating fund).

[71] "The principle supported by the proposal is specific to the highly unusual contractual arrangement required by the NWPA, and is unlikely to be relevant to many other federal activities. Simply stated, whenever the federal government, pursuant to an explicit statutory requirement, makes a legally binding contractual commitment specified by that statutory requirement to perform a well-defined service in exchange for payments that cover the costs of that service, it should treat those payments in a way that ensures that they are used for the statutorily-specified contracted purpose. It is hard to see how anyone could disagree with that principle. Likewise, it is hard to see how such distinctive-if not unique-statutory obligations could threaten the ability of Congress to weigh competing demands for appropriations in other, unrelated areas." Testimony by Robert H. Card, Under Secretary of Energy, before the hearing on "A Review of the Department of Energy's Yucca Mountain Project, and Proposed Legislation to Alter the Nuclear Waste Trust Fund (H.R. 3429 and H.R. 3981)," held by the Subcommittee on Energy and Air Quality of the House Committee on Energy and Commerce, March 25, 2004.

[72] See extended discussion at Joseph S. Hezier's paper: *Budget and Financial Management Improvements to the Nuclear Waste Fund (NWF),* Background report to the Blue Ribbon Commission on America's Nuclear Future, May 2011. http://www.brc.gov/index.php?q=library/documents/commissioned-papers

combination of measures was identified as one of four feasible interim steps for dealing with the funding problem in DOE's 2001 update of the AMFM report.[73]) Each is discussed further below.

Change the Timing of Nuclear Waste Fee Collections: Under the current approach, the entire 1 mill/kwh fee is collected from contract holders each year (the total collected amounts to approximately $750 million per year) and deposited in the Treasury, independent of the amount actually appropriated from the Fund for use by the waste management program. That annual revenue stream is counted in the budget baseline as an offset to mandatory spending, which raises the criticism that the fee is simply being used to reduce the budget deficit instead of for its intended purposes. This criticism becomes more acute as the gap between annual fee payments and appropriations from the Fund widens. Figure 11 shows the large and growing gap between cumulative nuclear waste fee receipts and appropriations from the NWF.

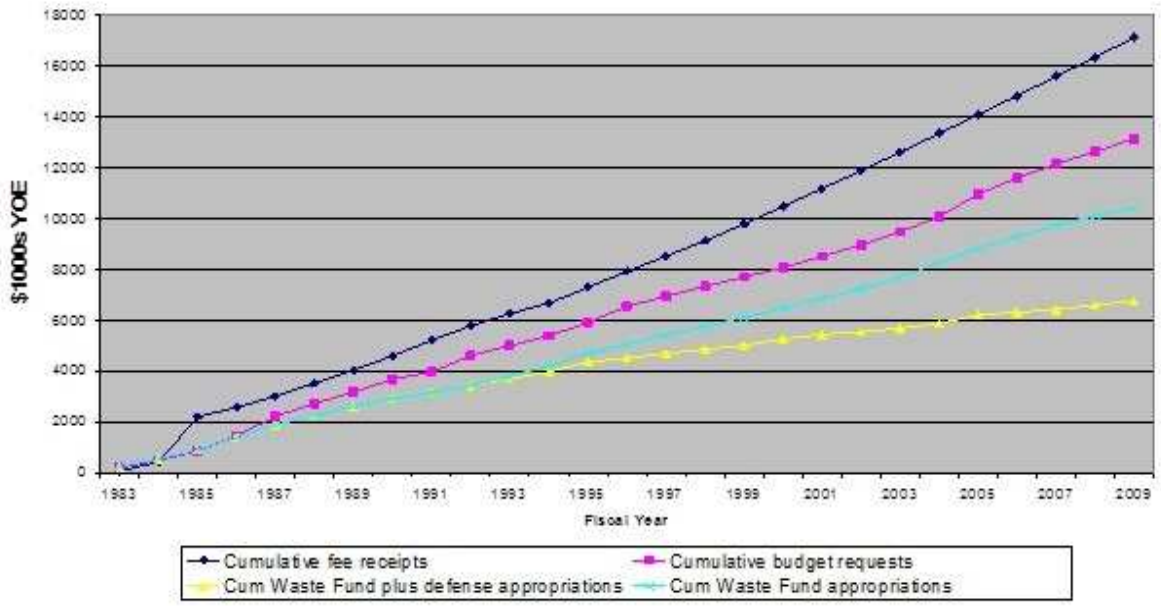

Figure 11. Cumulative Nuclear Waste Fees, Budget Requests, and Appropriations.[74]

As discussed above, deficit control legislation and federal budget rules now make it extremely difficult to access those funds for use by the program, and legislation to increase access to the growing balance in the Fund will be difficult to pass under existing PAYGO rules. The longer annual fee payments continue to accumulate in the Fund, the greater that budget balancing challenge will be.

To stop the flow of waste fees to an inaccessible account in the Treasury, and to put an end to the perception that the fee is simply being used to balance the federal budget, the Administration should adopt an approach proposed by the Secretary of Energy in 1998 as part of a litigation settlement concept.[75] The proposal was to change the timing of fee payments into the NWF through administrative action so as to match the annual flow of cash into the Fund with actual spending from the Fund in support of nuclear waste management activities. In this approach, DOE would offer to amend its contracts with

[73] *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program*, U.S. Department of Energy, August 2001, DOE/RW-0546.
[74] Data source: Office of Civilian Radioactive Waste Management Office of Business Management, Summary of Program Financial & Budget Information as of January 31, 2010.
[75] *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program*, U.S. Department of Energy, August 2001, DOE/RW-0546, Fig. 3.

utilities to allow utilities to retain the portion of the 1 mill/kwh fee that exceeded the annual appropriations level. As soon as the federal government began to accept waste, utilities would pay the deferred fees plus interest at the Treasury rate. The NWPA gives the Secretary of Energy authority to establish procedures for the collection and payment of the fees, and the principle that fee payments can be deferred until delivery of waste has already been established with respect to payment of the one-time fees required for spent fuel generated before the Act was passed.[76] Any changes to fee revenues resulting from this administrative action would have no PAYGO impact.[77] However, by ending the practice of counting revenues from the entire 1 mill/kwh fee in the budget baseline, it would substantially ease the PAYGO burden associated with subsequent legislative action to transfer fee receipts to an independent organization.[78] Furthermore, tying annual fee collections to actual appropriations for the waste program would strengthen the rationale for reclassifying fee receipts as a discretionary offsetting collection, which is the second step required in the recommended interim funding approach.[79]

Reclassify Waste Fee Revenues from Mandatory to Discretionary: As noted in the text box on page 46, the White House OMB decided to "split" the NWF, with fee receipts on the "mandatory" side of the budget and expenditures on the "discretionary" side (subject to budget controls), following passage of the Balanced Budget and Emergency Deficit Control Act of 1985. Subsequent amendments to that Act placed appropriations from the Fund under the spending cap applicable to all domestic discretionary programs, even though the Fund was self-financed. Because fee receipts had been placed on the other side of the mandatory/discretionary firewall, they could not be directly used to offset spending from the Fund. As a result of these actions, spending from the Fund was forced to compete with other spending programs (which did not have dedicated funding sources) for "space" under discretionary appropriation caps.

The above-described step of splitting fee collections by itself does not address the budget balancing problem. A second step is required to reclassify either the fee receipts or NWF spending so that both are on the same side of the mandatory/discretionary spending firewall. DOE's 2001 AMFM update considered both options—reclassifying program spending as mandatory and reclassifying fee revenues as "discretionary offsetting receipts" (which allow them to offset appropriations for the program)—and concluded both were feasible. It appears to the Subcommittee that the latter approach is preferable, since it would establish a funding process similar to that used to fund the NRC (i.e., primarily through user fees that are set at the level of annual budgetary authority established in appropriations bills). To implement this approach, the Administration would re-classify waste fee receipts from mandatory to discretionary. Current practice would require OMB to seek the concurrence of the Congressional Budget Office and relevant Congressional budget committees for this action. In addition, appropriations language would be required to credit the fee to the appropriation; such language could and should be included in the Administration's FY 2013 budget proposal.[80]

The two-step approach we propose would accomplish several things:

- It would stop the continued build-up of the corpus of the NWF, preventing the PAYGO challenge to future legislation from getting worse than it already is.

- By eliminating surplus collections, it would address the concern of utilities and public utility commissions about the misuse of the fee and Fund to balance the budget instead of for the

[76] Joseph S. Hezir, "Discussion of Timing of Payment of NWF Fees," presentation to the BRC Sub-Committee on Transportation and Storage," January 3, 2011, Washington, D.C.

[77] 2001 AMFM Update, p. 19.

[78] Hezir, op. cit.

[79] Ibid.

[80] 2001 AMFM Update.

purposes of the NWPA. Instead, the surplus fee revenue would go into utility escrow funds that would be available when needed to meet the operational costs of disposal, when program expenditures can be expected to exceed fee receipts.

- It would facilitate adequate appropriations for the program in the near term by giving appropriations from the Fund (up to the amount of the 1 mill/kwh fee revenues) a net budgetary impact of zero, since the appropriation would be directly offset by the collection of an equal amount in fee revenues. As noted above, a similar approach is already being used to fund the NRC.

- It would enable a lower PAYGO score for any subsequent legislative action that would affect the use of fee revenues by lowering the baseline projection of fee receipts for federal budget purposes.

- Finally, it would demonstrate the determination of the federal government to make the funding mechanism established in the NWPA work as originally intended.

There are also several things this two-step action would *not* do:

- It would not reduce Congress's role in the budget process for the waste program. Under current practice, OMB would seek the concurrence of the Congressional Budget Office and Congressional budget committees for reclassifying fee receipts, appropriations language would be needed to credit fee receipts against appropriations, and Congressional appropriations committees would continue to control the annual level of program funding through the appropriations process. Legislation will be required to remove this funding from the annual budget process while retaining an appropriate degree of external oversight of program spending, as recommended earlier.

- It would not increase access to the corpus of the NWF. This is an issue that must be addressed in subsequent legislation since DOE's existing contracts with utilities create a legal obligation for the federal government to ultimately expend these funds for the waste management purposes for which they were collected.

- It would not adversely impact the discretionary funding of any single program or agency since the changes would occur on the mandatory side of the budget, although it would—by removing projected fee revenues from the budget baseline—lead to a very small percentage increase in the federal government's nominal annual budget deficit.

Another important need that would be unaffected by efforts to separate the NWF from the Congressional budget process is the need for rigorous program oversight. On the contrary, we believe that such a separation—to be acceptable to Congress and the public—must be coupled with strong provisions to ensure that the waste management program is being implemented effectively and is making appropriate use of the NWF fees with which it has been entrusted. Oversight issues, including, in particular, financial oversight issues, are discussed at length in the previous section.

6.5 Paying for the Defense Waste Share

The preceding discussion has addressed only the portion of waste program costs that are attributable to the management of commercial waste and that are paid for through the nuclear waste fee and NWF. Since current policy presumes that national defense wastes will be disposed of in a repository developed pursuant to the NWPA, a portion of the costs of the program are paid directly by appropriations from the

national defense side of the federal budget.[81] Using a methodology for allocating costs between government-managed nuclear materials and commercial wastes that was first published in 1987,[82] DOE's 2007 Fee Adequacy Assessment estimated the defense share of total program costs at 19.6% for 2007.[83] (The defense share adjusts each year as assumptions change.)

Steady progress on implementing a disposal solution will require that appropriations for the defense share are made as needed to pay the full cost of the disposal of defense wastes. Historically, appropriations from the defense side of the waste management budget have not been nearly as constrained as those from the civilian side. Since the inception of the program through the end of FY 2010, defense appropriations (in nominal dollars) amounted to $3,756 million compared to $6,837 million from the NWF, just over 35% of the total, although the defense share of total program cost over the life of the repository was estimated in 2007 as 19.6%. In the last 10 fiscal years, defense appropriations have represented over 61% of total appropriations for the waste program. [84] Given this history, it is not clear at present that any special provisions are required in order to ensure that appropriations to cover the defense share of repository costs will be available when needed in the future.[85] However, once it becomes necessary to fund the construction of a repository, consideration might be given to mechanisms like multi-year appropriations (as are sometimes used with large defense procurements, such as for the construction of an aircraft carrier) that would enhance the ability to carry out an expensive and complex construction project in a timely and cost-effective manner.

As discussed earlier in this report, current plans for commingling defense and commercial waste are based on a 1985 evaluation that showed a $1.5 billion cost advantage to that approach and no significant offsetting disadvantages. However, a number of developments in the 25 years since that analysis could conceivably alter the assumptions used to arrive at that conclusion. Examples might include the shutdown of all activities that used to produce defense high-level waste (which had the effect of making defense waste disposal a well-defined and bounded task), the successful licensing and operation of the WIPP facility, the establishment of site clean-up commitments that required DOE to remove defense wastes from some sites where they are currently stored by 2035, the increasing unreliability of appropriations for the commercial share of waste disposal costs, disagreements about whether or when commercial SNF would be disposed of, and the need to start over again on a process of finding a repository site under the NWPA.

In view of these developments and in view of the potential complexities of requiring a new waste management corporation to balance the competing needs of commercial and national defense "customers," and to deal with two very different funding arrangements (mandatory fees and discretionary appropriations) while avoiding cross-subsidization, the conclusions reached in 1985 concerning the desirability of co-disposing defense and commercial wastes in the same repositories might warrant reexamination. **Note:** ***As directed by the Commission Co-chairman at the BRC meeting on May 13,***

[81] Section 302(b)(4) stipulates that "No high-level radioactive waste or SNF generated or owned by any department of the United States …. may be disposed of by the Secretary in any repository constructed under this Act … unless such department transfers to the Secretary, for deposit in the NWF, amounts equivalent to the fees that would be paid to the Secretary under the contracts referred to in this section if such waste or spent fuel were generated by any other person." In practice, funds for the defense wastes have been appropriated directly to the program for use each year, with no surplus to be deposited in the Fund.

[82] 52 FR 31508.

[83] *Fiscal Year 2007 Civilian Radioactive Waste Management Fee Adequacy Assessment Report*, U.S. Department of Energy DOE/RW-0593, July 2008.

[84] Information provided by DOE to the BRC. Blue Ribbon Request 1-6-2010 final.docx.

[85] Just as the fees paid by utilities to date are credited in determining whether they are fully "paid up" for purposes of being able to begin delivering waste for disposal, so should the defense waste appropriations to date be credited in determining when the defense share has been fully paid.

2011, the Subcommittee will investigate whether the US should consider reversing the decision made in 1980s to comingle defense and civilian wastes for disposal.

6.6 Key Findings

- The existing nuclear waste fee and NWF have not functioned as intended to provide the waste program with adequate and stable funding. A series of actions by successive administrations and Congresses has had the effect of decoupling the collection of revenues through the nuclear waste fee from the appropriation of funds to carry out the purposes for which the Fund was created. These problems have materially contributed to the failure of the federal government to meet its contractual obligations and the resulting large and growing financial liabilities for damages that are paid by the nation's taxpayers.

- The fact that waste management needs have to compete with other priorities in DOE's annual budget request and in the Congressional appropriations process has created budget uncertainty and instability that have undermined DOE's ability to meet waste management program objectives.

- There have been numerous legislative proposals to increase access to the fee revenues and the NWF. However, efforts to address this issue are complicated by larger budget considerations.

- Pending a more comprehensive legislative solution, there are nearer-term administrative options for changing the timing of fee collections in ways that re-establish the intended linkage between these revenues and the purposes for which they are intended —at least for those fees that will be collected going forward. The Administration should take these actions in its FY 2013 budget proposal.

- Workable means must be devised to ensure that the new waste management organization can access the corpus of the NWF as needed to meet future funding needs, taking into account the fact that these needs can be expected to fluctuate over time and to "peak" at higher-than-average levels during certain years, especially as the actual construction of waste management facilities commences.

- The costs of disposing of defense wastes are paid directly by appropriations from the national defense side of the federal budget. For the last 10 years, defense appropriations (as a share of total waste program appropriations) have exceeded, if anything, the defense share of program costs (according to DOE estimates of the relative magnitude of defense waste to civilian waste disposal costs).

7. A NEW APPROACH TO SITING AND DEVELOPING FACILITIES FOR NUCLEAR WASTE MANAGEMENT AND DISPOSAL

In this section, we turn from the need for new institutional leadership and adequate funding for the U.S. waste program to another central element of our recommendations: **the need for a new approach to siting and developing waste storage and disposal facilities**.

U.S. and international experience suggests that a more flexible, consent-based approach is essential to achieve more timely, cost-effective, socially accepted, and ultimately successful facility siting outcomes than have been typical of the U.S. waste management program to date. The subcommittee has sought to learn from these experiences through public hearings, visits to other nations, reviews of the scientific literature, and Commission-sponsored papers.[86] Additional Commission-sponsored papers on facility siting are still under development and will help inform the recommendations on siting included in the final report of this subcommittee.

The remainder of this section provides context and rationale for designing an improved process to site permanent disposal facilities. We believe that most, if not all, of these lessons learned would also apply to the siting of other facilities (i.e., centralized interim storage facilities and reprocess/recycle facilities).

7.1 Lessons Learned from Repository Programs to Date

Section 2 of this report describes the checkered history of U.S. nuclear waste management policy in general and of the Yucca Mountain repository program established under the 1987 NWPAA in particular. As is evident from even a cursory overview, the record is one of frequent regulatory and legal deadlock; extreme political controversy; steadily escalating project costs; and delays measured in decades. Even the WIPP facility, which is now operating with broad local and state support and is generally viewed as one of the DOE program's successes, took much longer to complete than originally planned and was eventually opened only after many years of regulatory and legislative wrangling. In the case of Yucca Mountain, of course, the process was even more dysfunctional. The problems that plagued Yucca Mountain from the outset are not hard to identify:

- Short-circuiting of the initial site selection process that had the effect of tainting all subsequent state-federal interactions over the project;
- Overly prescriptive requirements and rigid deadlines that made it difficult to respond to stakeholder concerns; and
- Inconsistent program leadership and execution.

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[86] Commissioned papers can be found at www.brc.gov. For example, see: *Nuclear Waste Facility Siting and Local Opposition - Report commissioned by the Blue Ribbon Commission on America's Nuclear Future and prepare,* by Michael O˝Hare, University of California, Research assistance by Isabella Alloisio & Kelly Gorton January, 2011 – 02/23/2011 http://www.brc.gov/index.php?q=document/nuclear-waste-facility-siting-and-local-opposition-report-commissioned-blue-ribbon-commissi

Public Beliefs, Concerns and Preferences Regarding the Management of Used Nuclear Fuel and High Level Radioactive Waste – Hank C. Jenkins, Smith Center for Risk and Crisis Management, Center for Applied Social Research, University of Oklahoma February 2011 - 02/12/2011 http://www.brc.gov/sites/default/files/documents/hank_jenkins-smith_brc_paper_final.pdf

Social Distrust: Implications and Recommendation for Spent Nuclear Fuel and High Level Radioactive Waste Management - Prepared for the Blue Ribbon Commission on America's Nuclear Future, by Seth P. Tuler, Ph.D., Social and Environmental Research Institute, Greenfield, MA and Roger E. Kasperson, Ph.D., George Perkins Marsh Institute, Clark University, Worcester, MA - 02/23/2011 http://www.brc.gov/sites/default/files/documents/brc.social_trust.17feb11.pdf

All of these flaws only served to exacerbate what was arguably the most important and most enduring problem of all—the fact that the project was strongly opposed, from the time Yucca Mountain was named in 1987 as the only site to be studied, by the majority of Nevada residents and by the state's political leaders.

In contrast to Yucca Mountain, experience with the WIPP facility in New Mexico suggests that having a community that demonstrates sustained support for serving as a potential repository host, and a state government that is willing to allow the decision-making process to proceed, can make all the difference. Starting in the early 1970s and continuing to the present, elected officials and other community leaders in and around the WIPP site made it abundantly clear from the outset that they approved of the development and use of the facility to dispose of TRU wastes. This unwavering local support helped to sustain the project during periods when federal and state agencies had to work through disagreements over issues such as the nature of the wastes to be disposed, the role of different entities in providing oversight, and the standards that the facility would be required to meet. That said, the path to successfully licensing and opening WIPP was anything but straightforward and quick. On the contrary, it involved years of legal, regulatory, and political activity and complex, negotiations between the State of New Mexico and the federal government. No one could have designed the process that was ultimately followed ahead of time nor could that process ever be replicated. What the WIPP process affirmatively demonstrates, however, is that with adequate patience, flexibility, and political and public support, success is possible.

Experiences with repository programs in Finland, Sweden, France, and Canada likewise underscore the importance of a transparent, consent-based approach that is built on a solid understanding of societal values.[87] Although the issue of how to dispose of nuclear waste in France was a major national issue by 1960, it was not until the early 1990's that the public and parliamentarians were given a role in the decision-making process (prior to this time the process was largely controlled by the industry and the state). Of these four countries, Sweden and Finland are considerably further along in selecting and developing a repository site; however, Canada provides perhaps the closer analogue to the United States in terms of political structure and culture.

In Finland, plans to develop a geologic disposal facility for SNF at the island of Olkiluoto have the support of the host community, Eurajoki, which could have vetoed its selection as a repository site.[88] Finland's efforts to site a deep geologic repository and undertake associated environmental impact assessments began in 1983, when the government issued a major policy decision on the management of SNF and on the schedule and process to be used for selecting a final repository site.[89] The siting process entailed three steps. First, a country-wide screening study was undertaken between 1983 and 1985. This was followed, from 1986 to 1992, by preliminary site investigations. In the third phase, from 1993 through 2000, detailed site investigations and environmental impact assessments were conducted for four

[87] Another country that has grappled with the siting issue is Germany, which in the late 1990s commissioned an expert committee (not unlike the BRC) to look at the problem of nuclear waste. The German committee developed a relatively straightforward plan in which the siting organization was to do an initial screening of the entire country for geologically suitable sites, based on a short set of criteria. From the subset of potentially suitable sites, weighted criteria were to be used to reduce the number of potential locations to five. At that point, the five affected municipalities were to be asked whether they wished to go forward with a more detailed evaluation. The hope was that at least two sites would survive this next cut, and assuming approval could be obtained from the local communities, the plan was to build two underground facilities for further technical analysis in preparation for a final decision. However, because of a change of government, the German plan was never implemented.

[88] Under Finland's Nuclear Energy Act of 1987, the consent of the host municipality is required for any major nuclear installation (including reactors as well as repositories). Thus, local acceptance was a necessary prerequisite for any decision in principle to approve the Olkiluoto repository. Interestingly, when a proposal for the Olkiluoto repository first came up for a vote by the local town council, it was vetoed. http://www.finlex.fi/fi/laki/kaannokset/1987/en19870990.pdf.

[89] Like the U.S. program, the Finnish program included a siting schedule. However, that schedule allowed considerably more time than in the U.S. case: The schedule set by Finnish government in 1983 called for repository construction to begin in 2010, and targeted 2020 as the date when used/spent fuel would begin to be accepted for final disposal.
See http://www.worldenergy.org/documents/p000915.pdf.

sites. All four sites were found to be technically suitable for the final disposal of SNF, but local support for a repository was strongest in the communities of Eurajoki and Loviisa where nuclear infrastructure already existed. Of these two sites, a larger area for surface support facilities was available at Olkiluoto. In addition, because of the two existing reactors at Olkiluoto, a large portion of the country's SNF was already on the island.

In 1999, Posiva Oy (the company responsible for managing spent fuel in Finland) applied to the Finnish government for a decision-in-principle to go forward with a repository at Olkiluoto. At that point, the government requested statements on Posiva Oy's application from the municipality of Eurajoki and from the relevant regulatory authority. Eurajoki's municipal council voted in favor (by 20 votes to 7) and the Finnish government followed with a positive decision-in-principle in December 2000. After further discussion, Finland's Parliament overwhelmingly ratified the government's decision (by a vote of 159 to 3) in May 2001.

Sweden, likewise, is moving forward with the development of a geologic repository for SNF with the consent of the host community. Initially, Sweden tried to move forward with an approach driven purely by technical considerations. SKB, the company tasked with repository siting and operation, selected eight locations and collected geologic data from those locations without asking the permission of local municipalities. All eight of those municipalities subsequently refused to participate in the siting process when they were eventually asked. Next, SKB asked for volunteer communities but in the end did not receive any. Finally, SKB approached the two technically-appropriate communities that already housed nuclear facilities. Ultimately, this process worked. In 2001, the government approved SKB's proposal to undertake a detailed investigation of these two sites—(1) the existing Forsmark nuclear site near the municipality of Östhammer and (2) Oskarshamn, which was the site of an underground nuclear research laboratory constructed in the early 1990s. Of these two options, Forsmark was ultimately selected in 2009 on technical grounds. The area already hosts a large nuclear power plant and an operating repository for short-lived low- and intermediate-level radioactive waste.

Importantly, either Östhammer or Oskarshamn could have vetoed its selection as a permanent disposal site for high-level waste.[90] However, there was a unique feature in the Swedish approach, at least so far in the world. Before the final site decision was made, there was an agreement that the community not selected would receive a larger amount of money than the community that was selected. The rationale was that the community selected to host the repository would realize additional economic benefits, in the form of construction activity, infrastructure investments, permanent jobs to operate the repository, and ancillary development (e.g., research and fabrication facilities, etc.). Ultimately, the community near Forsmark will receive approximately $60 million for hosting the repository, while the community at Oskarshamn, which was not selected, will receive approximately $180 million for participating in the siting process. At this point, the anticipated start date for repository operations is 2023.

Canada's Nuclear Waste Management Organization (NWMO) was formed in 2002 after the failure of a decades-long, technically-oriented effort to establish a repository. NWMO has adapted lessons from the Finnish and Swedish experience to its approach to nuclear waste management in Canada. The very first step taken by the NWMO was to ask how its attempt to develop a repository would be any different from

[90] The Swedish Act on the Management of Natural Resources gives municipalities a veto over siting permits. While the government has the right, under certain circumstances, to disregard such vetoes, neither SKB nor the Swedish Parliament favored siting a repository without the consent of the selected municipality. The government's choice not to exercise its override authority, in other words, represents a discretionary policy decision. SKB RD&D Programme 1998, p. 30 (http://www.skb.se/upload/publications/pdf/RD&D98webb.pdf), and Rolf Lidskog & Ann-Catrin Andersson, The management of radioactive waste: A description of ten countries (http://www.edram.info/en/edram-home/joint-activities/status-report-skb-report/index.php), p. 71.

those of the past. The conclusion was reached that NWMO should first seek to understand the deeply-held values of citizens, and only then review its options in light of that citizen input.[91]

Members of the Disposal Subcommittee have had an opportunity to hear firsthand from leaders of the Canadian, Finnish, and Swedish nuclear waste management programs. Members also heard from local government officials during a visit to Finland and Sweden in October 2010 and to France in February 2011. In contrast to the U.S. situation, these officials expressed a high degree of confidence in the site identification and selection processes used to locate a repository and in the institutions responsible for implementing and overseeing those processes. They stressed that several elements were critical in establishing a foundation for trust:

- A clear and understandable legal framework
- The availability of financing for local governments and citizen organizations that wish to be engaged in the process
- A concerted effort to promote knowledge and awareness of the nuclear waste issue and plans for addressing it through vehicles such as:
    - Seminars, study visits, and reviews conducted by the local government
    - Information to and consultation with local inhabitants
    - Socioeconomic studies and evaluations of impacts on local businesses
- Openness and transparency among and within the implementing organization, the national government, local governments, and the public.

How these elements might be included in a new approach to siting facilities for nuclear waste and spent fuel management and disposal in the United States is the subject of the next section.

7.2 Key Elements of a Phased, Adaptive Approach to Siting and Developing Facilities

Based on the history of waste management efforts at home and abroad, the Subcommittee believes that the United States must commit to flexibility, constant improvement, and the continuous incorporation of lessons learned in its efforts going forward. "Learning by doing" has produced substantial improvements in the reliability, safety, and performance of commercial nuclear reactors in the United States. It has also contributed to an impressive track record of safe transport and handling with respect to the transfer of defense TRU wastes to the WIPP facility in New Mexico. Compared to the prescriptive approach used in attempting to develop a repository for spent fuel and high-level waste at Yucca Mountain, other nations—notably Canada, Sweden, and Finland—appear to be doing better with an adaptive, staged management approach.

The notion that a phased, adaptive approach could produce better outcomes for this nation's nuclear waste management program also is not a new one. In a comprehensive 2001 report on the status of efforts to

[91] In a presentation before the Commission, Liz Dowdeswell, former President of the NWMO, summarized the organization's perspective this way: "We believed that fundamentally the selection of an approach for long-term management was really about developing a contract between science and society, a contract that would allow all of us to continue to benefit from technology, but also would mitigate risk and, most importantly, would respect the values of our citizens."

provide for the disposition of high-level waste and spent fuel,[92] the National Academies concluded that "geological disposal remains the only long-term solution available" and recommended that national waste management programs "should proceed in a phased or stepwise manner."

As a follow-on to this report, DOE sponsored a second National Academies study to detail options for a staged program. The resulting report, published in 2003,[93] described two approaches to staging: (1) "Linear staging, involving a single, predetermined path to a well-defined end point, with stages viewed as milestones at which cost and schedules are reviewed and modified as needed" (this is the approach that in the Academies' view characterized the current U.S. program); and (2) "adaptive staging, which emphasizes deliberate continued learning and improvement and in which the ultimate path to success and the end points themselves are determined by knowledge and experience gathered along the way."[94] The report concluded by recommending that adaptive staging should be the approach used in geologic repository development.

The Subcommittee concurs strongly with the National Academies' recommendation. In our view, moreover, events since 2003 only bolster the case for a phased, adaptive approach because they demonstrate that without political buy-in and trust, progress toward a resolution of the nation's waste management challenges cannot be sustained. Put simply, we believe a phased, adaptive approach is more conducive to building and maintaining public support for the long and demanding process of locating, designing, constructing, and operating facilities for the management and disposal of nuclear materials.

One important implication of pursuing an adaptive staging approach is that the focus is on initial operation of a repository rather than on rapidly disposing of a large inventory of waste.[95] This follows from the National Academies' description of the characteristics of a successful geologic repository program, one in which, among others, is that "initial waste emplacement has taken place with plans for reversibility."[96]

It is very important to recognize that these requirements in turn imply a need for substantial buffer storage capacity in the waste management system. Such buffer capacity would decouple the program's ability to accept waste from the emplacement of that waste in a repository for permanent disposal. This in turn would provide the flexibility needed to develop repository capacity in a more gradual and stepwise manner. Issues concerning the role of storage in a successful, integrated waste management system are being addressed by the Transportation and Storage subcommittee.

Explicit recognition that a repository will be developed in stages, and that later stages will incorporate lessons from earlier ones as well as new technological improvements that become available, also implies the need for robust investments in continuous learning going forward. This would include sustained support for science and technology development that can improve the operation of the waste management system.

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[92] National Academies, *Disposition of High-Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges*, Summary, 2001.

[93] *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, National Academies, Washington, D.C., 2003.

[94] *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, National Academies, Washington, D.C., 2003.brief summary, http://www.brc.gov/sites/default/files/documents/nas_one_step_at_a_time_summary.pdf

[95] "If adopted, Adaptive Staging would lead DOE to …Focus more strongly on achieving the degree of technical and societal consensus needed to begin waste emplacement, rather than on the emplacement of all waste." *One Step at a Time*, pp. 7-8.

[96] Ibid., pp. 22-23.

Features of Adaptive Staging

Every first-of-a-kind, long-term, and complex project develops in stages. With time, stages and schedules are inevitably revised in light of experience and knowledge gathered along the way. However, many national repository programs, including the U.S., have so far set rigid milestones to full-scale waste emplacement and repository closure.

The National Academies' 2003 *One Step at a Time* report recommends adaptive staging, a flexible approach where the "ultimate path to success and the end points themselves" are outlined at the beginning of the program and all parties, including stakeholders, acknowledge that the program can be revised as it progresses. Adaptive staging is less "error-prone" than a rigid approach, ensuring that early decisions do not commit the project to a path that later proves inappropriate or unsafe. It also allows the current generation to manage waste using the best available knowledge without foreclosing options if future generations decide to take a different approach.

A central feature of adaptive staging is a series of assessment periods or "decision points." During these periods, project managers actively collect and evaluate information, including stakeholder input, to develop options for the next stage of the project; reassess the safety of the repository; make their findings public; and engage in dialogue with affected communities and other stakeholders.

According to the 2003 report, adaptive staging is characterized by the simultaneous presence of seven attributes:

1. **Commitment to systematic learning**. Project managers intentionally seek, are open to, and learn from new knowledge and stakeholder input. Stages are designed specifically to increase available scientific, technical, societal, institutional, and operational knowledge.
2. **Flexibility.** Project managers are able and willing to reevaluate earlier decisions and redesign or change course when new information warrants.
3. **Reversibility**. Project managers are able to abandon an earlier path and reverse the course of action to a previous stage if new information warrants.
4. **Transparency.** The decision-making process and the basis for decisions are documented and accessible in real-time and plain language to all stakeholders.
5. **Auditability.** Documentation for the basis of decisions is complete and made available to all interested party for review purposes.
6. **Integrity.** Technical results are accurately and objectively reported and all uncertainties, assumptions, and indeterminacies are identified and labeled.
7. **Responsiveness.** Project managers seek and act on new information in a timely fashion.

It is important to emphasize that the presence of these elements is not meant to delay the program but to allow and encourage learning from experience. Although adaptive staging may result in higher initial costs and a slower pace of waste emplacement in the beginning, it can be more efficient—from both a cost and time standpoint—over the long run because it allows for potential problems to be corrected before they become expensive and time consuming.

7.3 Specific Steps in an Adaptive, Staged Facility Siting and Development Process

Experience in other countries and from the WIPP facility in the United States suggests that the identification of potential host communities in an adaptive, phased, and ultimately consent-based process should start with the implementing organization encouraging expressions of interest from a large variety of communities that have potentially suitable geology to host a safe and secure disposal facility. As these communities become engaged in the process, the implementing organization must be flexible enough not to force the issue of consent while also being fully prepared to take advantage of promising opportunities when they arise. Throughout, meaningful consultation with stakeholders to inform of the siting process and make needed adjustments (much as was done by the NWMO in Canada) will be critical to building credibility and confidence in the implementing organization.

Affected states, tribes, and communities will reasonably expect incentives for helping to address the important national issue of nuclear waste management. To be most effective, such incentives must be provided in ways that are creative and attentive to their symbolic content. In addition, neighbors and others impacted by nuclear waste management facilities need assurance of reasonable compensation for real costs. Experiences in Sweden, Finland, and elsewhere have shown that it may not be possible or even advisable to specify such incentives and funds up front; rather, in keeping with an adaptive approach, these determinations are best left to the discretion of the implementing organization and potential host governments—including communities surrounding the host community. These stakeholders will be in the best position to determine what incentives are both appropriate and in their best interests.

Prior to launching the consent-based siting process, the implementing organization should develop a set of basic initial siting criteria designed to ensure that time and resources are not wasted in the investigation of sites that are clearly unsafe, unsuitable or inappropriate for waste facility development. For instance, these criteria could eliminate sites where valuable minerals are abundant or where are drinkable water resources exist, or sites that are too difficult to excavate. At the same time, it will be important to communicate plainly with local communities and stakeholders about the nature of the risks involved in hosting a facility and about options for addressing and managing those risks. As the siting process continues and as various candidate sites pass these initial screening criteria, additional sets of criteria should be applied to eliminate all but the most suitable sites for further characterization. Obviously, as a candidate site is characterized in greater and greater detail it will be necessary to demonstrate not only that the preliminary criteria are satisfied, but that all applicable environmental, health and safety, and other requirements set forth by the responsible regulatory authorities can be met.

The Subcommittee takes the view that any site, provided it has met all regulatory requirements and has been selected with consent at a local and state level should require no additional approval, including Congressional approval.[97] This approach is consistent with an overall framework that gives the new implementing organization—subject to Congressional oversight— the authority to make binding agreements with regard to developing key parts of the nuclear waste management system. As with other details of establishing a new management approach and a new implementing organization (see discussion in the previous section), the specific requirements for moving forward with a particular site would have to be set forth in new legislation.

Lastly, the Subcommittee recommends that pilot, test, and demonstration facilities (including an in situ research and demonstration laboratory) be located at the proposed disposal site as part of repository

[97] Unless provisions of an agreement would require additional legislative authorizations not already provided in the law establishing the waste management organization.

construction. Pilot facilities will make it possible to conduct tests aimed at improving operational efficiency and safety and demonstrating retrievability. An underground test laboratory or a demonstration alcove will help ensure a continuing commitment to R&D for the purpose of confirming and improving performance and safety and to reduce residual uncertainties. [98]

We recognize that reasonable milestones are important to keep the program focused and ensure that it is moving forward. The Finnish waste management program demonstrates the usefulness of milestones as a mechanism to help sustain steady and meaningful progress. As an adaptive phased approach requires both clear programmatic planning and flexibility, we recommend that the implementing organization establish reasonable time horizons for the major stages of the program. As one example, the implementing organization might contemplate a stage of, say, 15 to 20 years to accomplish site identification and characterization and to conduct the licensing process. The implementing organization will be responsible for setting overall and intermediate milestones for each stage of the process. Of course, unforeseen circumstances will occur and siting could take a longer or shorter period of time. This is why the program requires flexibility. Program milestones should be laid out in a regularly updated Mission Plan (as discussed earlier) to allow for review by Congress, the Administration, and stakeholders, and to provide verifiable indicators for external oversight of the organization's performance. Any needed changes would be presented in Mission Plan revisions for review as appropriate.

7.4 Support for Participation

A noteworthy feature of the Swedish repository program is that funds from the nuclear waste management organization are set aside to be awarded to non-governmental organizations (NGOs) involved in the siting and repository development process. These funds are used by the NGOs to investigate technical and other aspects of the nuclear waste management program.

In the course of the Subcommittee's deliberations, many participants and commenters emphasized the importance of citizen participation. As a letter to the Commission from the South Carolina Governors' Nuclear Advisory Council and others stated, "citizen participation results in better and quicker decisions that are accepted by the larger public."

This contention is supported by a 2008 report of the National Academy of Sciences, titled "Public Participation in Environmental Assessment and Decision Making," which concluded: "When done well, public participation improves the quality and legitimacy of a decision and builds the capacity of all involved to engage in the policy process. It can lead to better results in terms of environmental quality and other social objectives. It also can enhance trust and understanding among parties. Achieving these results depends on using practices that address difficulties that specific aspects of the context can present."

For a complicated and technically-involved issue like the development of a nuclear waste repository, the inability of citizens and citizen groups to access the necessary technical expertise can be a major barrier to participation. In a large country like the United States, sheer distance can also be an issue; important meetings, conferences, and other events are regularly held in far-flung locations, and travel and lodging expenses can be beyond the means of individuals and groups who would otherwise wish to participate.[99]

Perhaps even more important, states and affected communities—in order to gain trust and confidence in the decisions taken by the waste management organization—must be empowered to meaningfully participate in

[98] This is very well demonstrated in Sweden where at first an underground rock laboratory was created. Also, The National Academies "*One Step at a Time*" report (described in the previous chapter) recommends that a demonstration alcove be developed early in the operational phase in parallel with other underground operational activities.
[99] For this reason, the BRC has provided funding for key NGO and community stakeholder to travel to its deliberative meetings.

the decision-making process. This means being in a position to evaluate options and provide substantive input on technical and operational matters of direct relevance to their concerns and interests. Accordingly, we believe it will be important to provide funding for independent monitoring and testing on the candidate repository site, provided that such activities do not interfere with the waste management organization's activities or compromise the integrity of the site.[100] (This limitation is needed because one important means of testing used in characterizing potential repository sites is drilling boreholes, which have the potential for degrading the isolation capabilities of the site if their location is not carefully controlled.)

In sum, the Subcommittee believes that a new U.S. waste management organization should adopt the Swedish practice and set aside funding for participation by citizens, citizen groups, and other NGOs. The availability of funding should be widely announced and reasonable criteria should be established against which to evaluate applications for financial support.

7.5 Role of States, Tribes, and Communities in an Adaptive, Consent-Based Siting Process

It has long been accepted that states, tribes, and local governments should play an important role in siting nuclear waste management and disposal facilities.[101] As one early study put it: "If the federal government is to make progress toward a permanent solution of the radioactive waste problem, it cannot go it alone—citizens will insist on assurances (other than federal assurances) that proposed actions will not involve undue risks to the host states."[102]

In the debates leading up to the original NWPA of 1982, Congress considered a wide range of options for formalizing the states' role in repository siting—from merely providing for consultation to giving states a complete veto over proposed projects within their borders. Ultimately, the formula adopted in the NWPA included provisions for "consultation and cooperation," combined with some state oversight rights and the ability to veto a proposed site. The state veto, however, was subject to Congressional override—an option that was exercised when Congress overrode Nevada's veto of the Yucca Mountain site in 2002.[103]

In the United States so far, states have generally resisted—in some cases very strongly—efforts to site high-level waste and spent fuel disposal and away-from-reactor storage sites within their borders.[104] By contrast, some local governments and tribes have viewed these facilities more positively—and in some cases have supported them strongly—primarily on the basis of anticipated job creation and economic

[100] Section 116 of the NWPA provides for grants to states and affected units of local governments for a number of purposes, including "any monitoring, testing, or evaluation activities with respect to site characterization programs with regard to such site," while Section 117 adds the proviso "except that such monitoring and testing shall not unreasonably interfere with or delay onsite activities." Funding for monitoring, testing, or evaluation activities is also provided for affected tribes. Under these provisions, over $4 million was provided to Inyo County, CA for the Inyo Regional Ground Water Monitoring Program, and over $31 million was provided to Nye County, NV for a Science & Verification Program that included the Nye County Early Warning Drilling Program, which provided data used in the Yucca Mountain project (Office of Civilian Radioactive Waste Management Office of Business Management, Summary of Program Financial & Budget Information as of January 31, 2010).

[101] For example, a report from 1980 on the subject pointed out that states have a "constitutional responsibility to ensure the health and safety of their citizens," as well as "jurisdiction over local authorities and land use," and that states therefore believed "it is both undesirable and impartial for disposal procedures to be wholly federally determined" (Pat Choate and John Bowman, Radioactive Waste Management: State Concerns, A Report to the Office of Technology Assessment from the Academy for Contemporary Problems, p. 3, 1980).

[102] Ibid p. 11.

[103] An absolute state veto had been opposed by the State Planning Council established by President Carter to provide advice on intergovernmental relations, as well as by others. U.S. Congress Office of Technology Assessment, Managing the Nation's Commercial High-Level Radioactive Waste, OTA-O-171, March, 1985, p. 180.

[104] The state of Nevada's bitter opposition to the proposed Yucca Mountain repository is well known, but other examples abound. In Utah, efforts to site a private centralized storage facility were blocked when the Utah delegation successfully pushed for Congressional designation of a wilderness area that prevented access to the proposed site. Utah took this action despite its tradition of hostility toward past federal efforts to designate wilderness lands and national monuments within the state.

development benefits. Indeed, some of the most supportive communities have been those with a long history of hosting nuclear facilities. Local support, however, has not usually been sufficient to overcome state-level opposition. This suggests that to be successful, a new waste management organization must find ways to address state concerns while at the same time capitalizing on local support for proposed facilities.

What those concerns might be and how the tensions inherent in the federal–state and federal–tribe relationship might be successfully navigated in different siting contexts is impossible to anticipate in advance. Clearly, locating and constructing a permanent disposal facility for SNF and high-level waste will require complex and possibly lengthy negotiations between the federal government and other relevant units of government. The Subcommittee concludes that the roles, responsibilities, and authorities of local, state, and tribal governments must be an important element of those negotiations. Further, we conclude that all affected levels of government (e.g., local, state, tribal, etc.) must have, at a minimum, a meaningful consultative role in important decisions; additionally, states and tribes should retain—or where appropriate, be delegated—direct authority over aspects of regulation, permitting, and operations where oversight below the federal level can be exercised effectively and in a way that is helpful in protecting the interests and gaining the confidence of affected communities and citizens. We recognize that this approach represents a departure from the approach taken toward Yucca Mountain in the 1987 NWPAA. We also recognize that defining a meaningful and appropriate role for states, tribes, and local governments is far from straightforward, given that the Atomic Energy Act of 1954 grants the federal government exclusive authority to regulate the possession and use of all radioactive materials, including wastes. Nevertheless, we believe it will be essential to affirm a role for states, tribes, and local governments that is at once positive, proactive, and substantively meaningful without increasing the potential for further conflict, confusion, and delay. In discussions about how one might strike this balance, the concept of "meaningful consultation" has emerged as an important term of art—one that can and has allowed for a more or less expansive view of state and tribal roles and responsibilities under different circumstances.

Here, as in other aspects of facility siting, it is instructive to look to the WIPP experience, since that project was controversial at the state level for many years despite strong support from the local Carlsbad business community. After years of delay and state–federal disagreements, an important breakthrough came when Congress required EPA (not DOE) to certify that the facility met applicable standards for permanent waste disposal, including requirements under the Resource Conservation and Recovery Act (RCRA) for the disposal of mixed hazardous and radioactive waste.[105] This meant that the State of New Mexico retained authority to regulate mixed waste at WIPP and that the New Mexico Environment Department had to issue a Hazardous Waste Facility Permit for the repository. Even though the state did not have direct regulatory authority over the radioactive components of the waste being brought to the facility,[106] this development made an enormous difference in terms of giving state officials and residents beyond the local community confidence that the facility was safe. Similarly, DOE's decision to work cooperatively with Carlsbad and the Western Governors' Association to develop a safe transportation program for WIPP was extremely helpful in addressing transportation-related concerns. The resulting Western Governors' Association WIPP Transportation Safety Program Implementation Guide includes many procedures that would otherwise be considered "extra-regulatory" and could not be mandated by the states without federal consent. And finally, the establishment of the federally-funded, university-housed Environmental Evaluation Group was important for gaining the trust of state officials and the local community because it provided an independent and credible source for technical information and review of the WIPP project.

[105] Mixed waste is waste that contains, in addition to radioactive materials, materials that are defined as hazardous under RCRA (an example would be a chemical such as toluene).

[106] Current federal law—including aspects of the Atomic Energy Act, the Commerce Clause, and the doctrine of intergovernmental immunity on federal reservations—has the effect of preempting almost all forms of state regulation over a high-level waste facility.

Trust, in fact, is often the core issue whenever different parties are involved in a complex adjudicatory process—and it can be especially difficult to sustain when much of the power or control is viewed as being concentrated on one side. In a recent news article, former Governor Michael Sullivan of Wyoming pointed to a lack of trust as one of the central issues that led him to veto a proposed monitored retrievable storage facility in Wyoming in 1992. According to the article, Sullivan said that "the same problems that existed 20 years ago still exist today. Among them is the lack of trust that western states have of the federal government to either follow through on a long-term policy or to actually work in a state's own interest."[107] The WIPP example suggests that having some degree of direct state- or local-level control (in the WIPP case, this was possible through RCRA) can be helpful in instances where faith in federal agencies is lacking. In some cases, states have pursued formal agreements with the federal government that can be enforced in the courts, if necessary. In 1995, for example, the State of Idaho entered into an agreement with DOE and the U.S. Navy that allows DOE to ship a limited quantity of used fuel from the Navy's nuclear-powered fleet to INL for interim storage over a 40-year period. The agreement also obligates DOE to move all used fuel into dry storage by 2023 and to remove all naval used fuel from Idaho by no later than 2035. If DOE fails to meet any of the agreement milestones at any point, the State may ask the U.S. District Court to halt any further used fuel shipments to INL. The State of Washington recently entered into a similar agreement with DOE concerning the storage of wastes at Hanford.

The same issues of trust, consultation, and control arise in the context of the federal government's interactions with Indian tribes, another important stakeholder group in the context of nuclear waste management decisions. In fact, because many existing and proposed nuclear sites are either on or near tribal lands, tribal governments have been involved in nuclear technology and nuclear waste issues for decades. The 1982 NWPA requires consultation with states and affected Indian tribes and specifically addresses the participation of tribes in repository siting decisions. In the wake of the 1987 NWPAA, several tribes expressed interest in exploring the possibility of hosting nuclear waste on at least an interim basis. As was the case with local communities, however, these expressions of interest generally met with opposition at the state level.

Unlike local communities or state governments, tribes have a unique "government-to-government" relationship with the United States. Their right to make their own laws and be governed by them is limited only by their status as dependent domestic nations and by federal law. States have a limited role in Indian affairs. They do not have the power to regulate Indian tribes or tribal lands unless such powers are delegated to them by the federal government. Since 1975, moreover, federal policy has supported tribal self-determination. This means that meaningful consultation with tribal governments is required in the development of federal policies and practices that may impact tribal lands, people, or resources. The existing State Tribal Government Working Group (STGWG) provides an example of one mechanism for facilitating regular consultation between states and tribes and the federal government. Established in 1989 at the request of 10 state governors, the group grew to include 15 states and 10 tribes who would meet with DOE to discuss the federal government's cleanup activities at facilities that have been or are still part of the nation's nuclear weapons complex. STGWG now meets twice annually. As with states, some precedent also exists for giving tribes a degree of regulatory control over specific facilities or operations in the nuclear waste management system. In 1991, the Shoshone-Bannock Tribe attempted to stop the shipment of commercial spent fuel across its reservation in Idaho. A lawsuit resulted and while the courts concluded that federal law (in this case, the Hazardous Materials Transportation Act) did not allow the tribes to ban spent fuel shipments from crossing their land, it did allow them to develop regulations for those shipments.

Besides conducting a process that is consent-based, transparent, and responsive to state and local governments' need for meaningful input and control, it will be important to demonstrate that the decision

[107] http://wyofile.com/2011/02/sullivan-i-was-right-to-veto-nuclear-waste/.

to host a facility can deliver real benefits (economic and otherwise) to the state and local community. These policies will help maximize project benefits for host communities and boost confidence that decision-makers are in touch with local values and concerns. In the past, DOE often did not make the most of these opportunities. For example, WIPP was managed for years by DOE personnel located in Albuquerque rather than at an office in Carlsbad near the facility. It was only late in the process that DOE relocated its top WIPP management to Carlsbad. Likewise, the TRANSCOM tracking system used in the transportation program was originally based out of Oak Ridge, Tennessee. It was later relocated to Albuquerque and finally moved to Carlsbad in 2005. Similarly, DOE maintained its headquarters for Yucca Mountain in Las Vegas, nearly 100 miles from the proposed repository.

In addition to locating waste management-related activities in the affected state and community, these states and communities could also be given preference in the siting of other federal projects (provided they are otherwise suitable to host those projects). Section 174 of the NWPA already requires the Secretary of Energy to give "special consideration to proposals from states where a repository is located" in siting federal research projects, and that authority could be broadened to include other major federal investments and activities, such as other energy-related development and demonstration projects or laboratories. This approach can provide additional benefits to host communities and states without requiring new appropriations or increasing the cost of already planned programs or projects.

In sum, whatever the specific authorities and resources of a given community, state, or Indian tribe, experience shows that determined opposition at any level of government can at a minimum significantly complicate and delay, and in many cases defeat, best efforts to site a facility. In this context, it is difficult to overstate the importance of support for a facility or site at the state, tribe, and local level (obviously, public acceptance is not the only criterion; to be considered, any site must also meet safety and technical criteria and other requirements).

The Subcommittee therefore recommends that the process for allowing host communities to make initial expressions of interest must carry no obligations and must make the barriers to expressing such interest as low as possible. A constructive engagement period must be flexible enough that the implementing entity does not need to force the issue but can remain fully prepared to take advantage of siting opportunities when they arise.

The Subcommittee recognizes that more than one community, state, or tribe might be affected by a proposed repository. The waste management organization should therefore be directed to consult with any state, affected unit of local government, or Indian tribe that it determines may be so affected and to include any reasonable and appropriate provisions relating to their interests in negotiated agreements, as the Nuclear Waste Negotiator was directed and empowered to do.[108]

The NWPA provides for states to be able to veto a DOE-selected repository site (or storage site) but it also allows for Congress to override such a veto. The Subcommittee, however, is recommending a very different type of consent-based site selection and development process. We believe that this approach would obviate the need for a state-level veto, just as the veto/override provisions of the NWPA would not have applied to a repository or MRS facility sited through the Nuclear Waste Negotiator process established in the 1987 amendments.

Finally, to engage in meaningful consultation on matters related to nuclear waste storage, transport, and disposal, and to carry out their proper regulatory roles and responsibilities in this context, local, state, and tribal governments need access to sound, independent scientific and technical expertise. The example of the Environmental Evaluation Group in the WIPP context underscores how important it is that all parties

[108] NWPA, Sec. 403. (b).

to the negotiation over future nuclear waste disposal facilities be empowered to critically review decision-relevant material, reach their own conclusions, substantiate their decisions, and exercise their prerogatives in a constructive and effective way.

7.6 Key Findings

- U.S. and international experience suggests that a more flexible, phased, and consent-based approach is likely to achieve more timely, cost-effective, socially accepted, and ultimately successful facility siting outcomes than have been typical of the U.S. waste management program to date. Programs in Canada, Finland, and Sweden, in particular, offer useful insights for redesigning the U.S. approach to siting.

- Site screening criteria should be developed prior to the siting process by a new implementing organization in consultation with stakeholders.

- The new waste management organization should be responsible for establishing overall and intermediate program goals and milestones. These goals and milestones should be articulated in a regularly updated Mission Plan. The need for clear goals and milestones to ensure that the program is moving forward must be balanced with the need for flexibility to ensure that the program can adapt to unforeseen circumstances.

- Any site for a consolidated interim storage or permanent disposal facility that has met all regulatory requirements and has been selected with consent at the local and state level should require no additional approval, including Congressional approval.

- Once one or more sites are selected, pilot, test, and demonstration facilities (including in situ R&D facilities) should be located in parallel with other underground activities and operations undertaken at the site(s) to improve performance and safety and reduce residual uncertainties.

- States, tribes, and local governments have an important role to play in siting and developing of regulations for nuclear waste management and disposal facilities. That said, the Subcommittee believes the veto/override provisions of the NWPA would not be needed in the context of the kind of consent-based siting process we have proposed. Experience with the siting of nuclear facilities and other controversial infrastructure suggests that giving affected state, local, and tribal governments a degree of input and control in regulatory decision-making is critical to winning their support.

- The waste management organization should consult with any affected state, unit of local government, or Indian tribe, to include all reasonable and appropriate provisions relating to their interests in negotiated agreements. The roles, responsibilities, and authorities of local, state, and tribal governments must be an important element of the negotiations with these governments.

- For a complicated and technically-involved issue like the development of a nuclear waste repository, the inability of citizens and citizen groups to access the necessary technical expertise and to cover other expenses (i.e., traveling to meetings) can be a major barrier to participation. For this reason, making funding and other resources—including access to independent sources of scientific and technical expertise—available to these groups will be critical to enabling their active participation in the siting process.

8. REGULATING THE PERFORMANCE OF WASTE MANAGEMENT FACILITIES

The 1987 NWPAA state that "the federal government has the responsibility to provide for the permanent disposal of high-level radioactive waste and spent nuclear fuel to protect the public health and safety and the environment…. Appropriate precautions must be taken to ensure that these [radioactive] materials do not adversely affect the public health and safety and the environment for this or future generations."

The NWPA charged EPA and NRC with developing and implementing regulations to ensure that this responsibility would be met.[109] Under the Act, EPA is responsible for issuing "generally applicable standards for protection of the general environment from offsite releases from radioactive material in repositories." These standards apply to the management and storage of waste during the operational period, as well as to the performance of a disposal facility during the post-closure period (i.e., after waste is no longer being actively emplaced). The Act also directs the NRC to issue "requirements and criteria" to be used in approving construction, operation, and closure of repositories. These criteria, which may not be inconsistent with the standards issued by EPA, must require a repository to use a system of multiple barriers and must include any restrictions on the retrievability of the emplaced waste that the NRC deems appropriate. In addition, the NRC is responsible for regulations dealing with nuclear materials safeguards and security and with protection of facility workers from radiological exposures. Other categories of worker protections are the responsibility of OSHA. The remainder of this section discusses the regulations for final disposal, safeguards and security, and operational health and safety.

8.1 Issues and Challenges in Setting Regulatory Standards for Disposal Facilities

The greatest challenges in developing regulations for the disposal of high-level waste and spent fuel relate to protecting public health and safety policy and the environment over the extremely long time periods of concern after a repository has been filled and closed. This section discusses these challenges as they relate to the role of regulations in assuring that the health and safety objectives of the NWPA are met by any future facility for the long-term disposal of high-level radioactive waste in the United States. We begin by reviewing the general aims of geologic disposal, as articulated in international policy guidance.

In its 2006 *Safety Requirements* report, the IAEA elaborated on the basic aims of geological disposal:

- To contain the waste until most of the radioactivity, and especially that associated with shorter lived radionuclides, has decayed;
- To isolate the waste from the biosphere and to substantially reduce the likelihood of inadvertent human intrusion into the waste;
- To delay any significant migration of radionuclides to the biosphere until a time in the far future when much of the radioactivity will have decayed; and
- To ensure that any levels of radionuclides eventually reaching the biosphere are such that possible radiological impacts in the future are acceptably low.

[109] EPA also has sole responsibility under other legislation for regulations to address other types of non-radiological health risks and environmental impacts.

The IAEA also went on to state, however, that "The aim of geological disposal is *not* to provide a guarantee of absolute and complete containment and isolation of the waste for all time" (emphasis added).

The task for regulators is to translate these general aims into specific "standards," by which we mean the technical performance requirements that must be met to license a facility for the safe disposal of SNF and high-level waste. Governmental authorities in a number of countries have developed such standards; in addition, leading international organizations such as the NEA[110] and the IAEA have published useful recommendations or guidance in this area. A survey of these efforts reveals considerable variation in the details of different countries' approaches, as well as a number of common themes and emerging trends. This section summarizes recent general guidance on key aspects of disposal regulations for geologic disposal from the IAEA and NEA, as well as current approaches in individual countries like the United States, Canada, Finland, and Sweden.

It should be noted that pursuant to the NWPA and subsequent legislation, EPA and NRC have established *two* sets of federal regulatory standards for high-level radioactive waste disposal repositories in the United States (see text box on the following page). While there are differences between them, both are generally seen as highly protective of human health and the environment. One set of standards was developed specifically for Yucca Mountain. The other set of standards applies to all other sites and was essentially complete by the time Congress directed the development of Yucca Mountain-specific standards in 1992. The standards would, unless changed in formal rulemaking, be applied to any future disposal concept or site. [111] Since there was a substantial evolution in regulatory philosophy during the development of the Yucca Mountain regulations, it is to be expected that the regulations for other repositories, finalized nearly 20 years ago, would be revisited to support the development of repositories at new sites in the future. In the discussion of regulatory issues and approaches in this section, therefore, we will focus on relevant aspects of the Yucca Mountain regulation as being most representative of current thinking.

8.1.1 Health Protection Objectives

Since long-term protection of human health is one of the core functions of geologic disposal, effectiveness in limiting the public's future exposure to radioactivity is generally considered to be one of the most important criteria used in deciding whether to move forward with a particular repository site and design. In the United States and internationally, two general approaches to limiting exposures have been proposed for nuclear waste repositories:

1. A dose-based or risk-based standard (the two are essentially equivalent in practice) that limits the exposure to individuals resulting from radiation releases from the repository; or

2. A release-based standard that limits the amount of radioactive material that is allowed to escape the repository.

To date, several countries and international advisory bodies have developed numeric criteria—either in the form of a dose constraint, a risk limit, or sometimes both—for human health protection in the context of geologic disposal. (The only example of primary reliance on a release-based standard is EPA's 40 CFR Part 191, applicable to repositories other than Yucca Mountain. [112]) Dose constraints are commonly given in millisieverts (mSv) per year (where 1 mSv equals 100 millirems), while risk limits are typically expressed in terms of the probability that an exposed individual would suffer adverse genetic or health

[110] The NEA is an agency of the Organization for Economic Cooperation and Development (OECD), which includes the world's major industrialized economies.

[111] EPA portion of the general standards are also applied to the WIPP and are currently in use there.

[112] This standards has been successfully applied at the WIPP.

impacts (i.e., cancer). Dose constraints can be converted to risk limits and vice versa (e.g., a dose constraint of 0.3 mSv per year translates to a risk equivalent of 1 in 100,000 per year or 10^{-5}/yr).

U.S. Repository Regulations

"Generic" EPA and NRC Regulations

EPA standards for all sites other than Yucca Mountain are defined under 40 CFR Part 191, "Environmental Radiation Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (with additional "implementing criteria" specifically for WIPP found in Part 194.33). This regulation was first issued in 1985, remanded by a federal court for reconsideration of certain provisions, and reissued in 1993 to apply only to geologic repositories other than Yucca Mountain (see below).

The core of Part 191's disposal standard is a "containment" requirement designed to protect populations by limiting the cumulative releases of key radioactive isotopes over the 10,000-year period following closure of a repository. Compliance is to be demonstrated by use of quantitative performance assessments that take into account "all significant processes and events" to show that there is a "reasonable expectation" (not absolute proof) that cumulative releases for a number of specific isotopes will have a low likelihood (less than one chance in 10 for low releases and less than one chance in 1,000 for higher releases). The EPA regulation also includes an individual protection requirement, which stipulates that for 10,000 years there should be a reasonable expectation that no member of the public will receive an annual dose greater than 15 millirems (150 microsieverts), considering only the undisturbed performance of the repository (rather than all significant processes and events, as required for the containment standard).

NRC regulations for all sites other than Yucca Mountain are defined under 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geological Repositories." These regulations were originally issued in 1983 (before EPA's standards had been completed) and revised in 1987 to reflect the NWPAA Act of 1987. NRC's regulation incorporates EPA's generally applicable standards by reference, and includes additional performance requirements for specified individual barriers in the repository system.

More Recent Yucca Mountain Regulations

The Energy Policy Act of 1992 directed EPA to issue an individual dose-based standard for Yucca Mountain, based upon and consistent with recommendations by the NAS. The process to develop this EPA standard (40 CFR Part 197) and matching NRC implementing regulations (10 CFR Part 63) was complex—it involved the NAS study, multiple lawsuits, and another court remand that required EPA to reconsider certain provisions it had initially proposed. Thus, it was not completed until 2008. The EPA Yucca Mountain standard limits doses to members of the public (not total releases of specified radioactive materials) and extends to 1,000,000 years (consistent with a recommendation of the NAS study), with a 15 millirem limit for the first 10,000 years and a 100 millirem limit thereafter. The NRC Yucca Mountain regulations incorporate the new EPA standard and drop the performance standards for individual repository barriers that are contained in the generic regulations (10 CFR Part 60).

Based on recommendations developed by the International Commission on Radiological Protection, current NEA and IAEA guidance recommends a dose constraint of 0.3 mSv/year. Dose limits in place for different countries' waste management programs range from less than 0.1 mSv/year up to 1.0 mSv per year—an order of magnitude difference. (By comparison, regulations for the proposed Yucca Mountain repository in the United States established an annual peak dose constraint of 0.15 mSv for the first 10,000 years and 1.0 mSv[113] for the period after 10,000 years and up to 1 million years.[114]) However, *the*

[113] The recommended dose limit for members of the public from all practices is an effective dose of 1.0 mSv in a year. The 0.3 mSv criterion for a repository is derived through a process called apportionment, which divides the total dose limit into a

stringency of a given standard depends critically not only on the numeric level of the standard but on the timeframe over which it is applied, the methodology that is used to demonstrate compliance, and the standard of proof (or level of confidence) that is required for the demonstration. Each of these parameters is discussed further below.

8.1.2 Regulatory Timeframe

The long-lived nature of the radiological hazard posed by SNF and high-level waste creates a tension between the objective of protecting future generations on the one hand, and the inherent practical difficulties of making very long-term predictions about human and natural systems on the other hand. As a result, the question of appropriate timescales for purposes of risk assessment and regulatory compliance determinations remains a subject of active national and international debate.

The longest regulatory compliance timeframe contemplated in existing national-level programs (United States, Belgium, Germany, and Switzerland) is 1 million years. In the United States, the EPA initially proposed a compliance timeframe of 10,000 years for the proposed Yucca Mountain repository; however, this limit was later increased to 1 million years.[115] Meanwhile, several countries have not yet decided this issue, while others have opted for shorter timeframes (10,000 to 100,000 years) or avoided the use of a hard "cut-off" altogether.

NEA and IAEA have not issued guidance on timeframes, although the IAEA has cautioned that "[c]are needs to be exercised in using the criteria beyond the time where the uncertainties become so large that the criteria may no longer serve as a reasonable basis for decision making"[116]. Different approaches to this issue could include developing different kinds of criteria for different timeframes. For example, Finland has developed specific release limits for several different types of radionuclides to apply in the long term, beyond the period for which the dose constraint applies. Alternatively, a practical goal for very long timeframes may be to demonstrate that the proposed facility is at very low risk for catastrophic disruptions leading to large releases of radioactivity. Along these lines, Swedish regulations call for a risk analysis that illustrates "the long-term development of the repository's barrier functions and the importance of major external disturbances…such as earthquakes and glaciations" beyond 100,000 years, but also state that "a strict quantitative comparison of calculated risk in relation to the criterion for individual risk in the regulations is not meaningful." Compliance Methodology

8.1.3 Compliance Methodology

As critical as the form and stringency of the standards to be applied to a disposal facility is the decision about what approach or methodology will be used to determine whether they have been met. As discussed earlier (see text box on page 69), current U.S. regulations rely primarily on a compliance demonstration based on a probabilistic performance assessment to project repository performance for comparison with quantitative standards. Over the last decade, however, the concept of a "safety case" has become

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smaller limit for any individual practice so that the total from all allowed practices would be below the overall limit. EPA adopted the total limit for the very long term based on a view that it would not be necessary to allow for other human-produced sources of exposures in the far future.

[114] To put these numbers in perspective, the National Commission on Radiation Protection estimates that the average American is currently exposed to approximately 6.2 mSv (620 millirems) of radiation per year, of which roughly half is from natural background sources and half is from man-made source.
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[115] The change came in response to a legal challenge charging that EPA was required by law to follow the recommendation issued by the NAS in 1995 that compliance should be measured at the time of peak dose within the period of geologic stability for Yucca Mountain, which the NAS found to be on the order of 1 million years.

[108]IAEA, 2006, *Geological Disposal of Radioactive Waste: Safety Requirements*.

[116] IAEA, Geological Disposal of Radioactive Waste, IAEA Safety Standards Series No WS-R-4, IAEA, Vienna, 2006

increasingly prominent.[117] Definitions of this term vary, but the general idea involves integrating multiple arguments and lines of evidence that together build a convincing qualitative and quantitative case for the safety of the proposed facility over the relevant timeframe(s) rather than relying primarily on quantitative calculations to show compliance with narrow numeric criteria.[118] (While U.S. regulations make reference to DOE's "safety case," the fact that this reference occurs only once—in the context of "the data, assumptions, and modeling upon which DOE bases its safety case, and upon which the Commission bases its licensing judgments"[119]—underscores the centrality of quantitative modeling in the current U.S. approach to compliance demonstration.)

8.1.4 Standard of Proof for Compliance Demonstrations

The "standard of proof" for compliance demonstration, as well as for the selection of an implementation approach, should be viewed as integral to a long-term repository performance standard. While EPA repository regulations (both general and Yucca Mountain-specific) require the use of quantitative performance assessments to show compliance with quantitative standards, they also recognize the inherent limitations of such assessments. In issuing its initial repository standards, EPA stated that "unequivocal proof of compliance is neither expected nor required because of the substantial uncertainties inherent in such long-term projections." Thus, the Agency instead required only a "reasonable expectation" that compliance will be achieved. EPA included the same standard of proof in the Yucca Mountain regulation.

EPA explicitly chose not to use the traditional NRC standard of proof, "reasonable assurance," for the post-closure compliance demonstration because the phrase "reasonable assurance" (which was developed in the context of operating facilities under active institutional controls during their lifetimes) "... has come to be associated with a level of confidence that may not be appropriate for the very long-term analytical projections that are called for by [the disposal standard]. The use of a different test of judgment is meant to acknowledge the unique considerations likely to be encountered upon implementation of these disposal standards." In contrast, NRC used "reasonable assurance" for both pre-closure and post-closure standards in 10 CFR Part 60 and during most of the development of the Yucca Mountain regulations. In the final version of its Yucca Mountain regulations (10 CFR Part 63), however, NRC dropped the "reasonable assurance" standard of proof in favor of "reasonable expectation" with respect to the post-closure period, while retaining the "reasonable assurance" standard for the operation of the facilities during the pre-closure period.

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[117] See, for example, Rodney C. Ewing, "*Standards & regulations for the Geological Disposal of Spent Nuclear Fuel and High Level Waste*," prepared for the Blue Ribbon Commission on America's Nuclear Future, March 4th, 2011 http://www.brc.gov/sites/default/files/documents/ewing_brc_white_paper_final.pdf

[118] Canada's regulations, for example, call for developing a long term safety case that combines a safety assessment with complementary arguments based on (1) appropriate selection and application of assessment strategies, (2) demonstration of system robustness, (3) the use of complementary indicators of safety, and (3) any other evidence available to provide confidence in the long term safety of the proposed system. Similarly, Finnish regulations call for a safety analysis that includes (1) a description of the disposal system and definition of barriers, (2) an analysis of the future evolution of the system, (3) definition of performance targets for individual barriers, (4) functional description of the disposal system by means of conceptual and mathematical modeling, (5) analysis of activity releases and resulting doses from radionuclides that penetrate the barriers and enter the biosphere, (6) estimates of the probabilities of activity releases and radiation doses arising from unlikely disruptive events, (7) uncertainty and sensitivity analyses, and (8) comparison of the outcome of the safety analysis with safety requirements.

[119] U.S. Nuclear Regulatory Commission, Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final rule. 55732 Federal Register November 2, 2001 at 55766.

8.1.5 Other Protection Requirements

Protection of the natural environment (along with, but distinct from, human health *per se*) is widely accepted as an important objective of geologic disposal; however, there has been less convergence internationally around how to assess this objective and develop appropriate criteria. A recent (2010) NEA review of regulatory developments pertaining to geologic disposal describes a number of national and international efforts—some ongoing—to develop ways of accounting for the long-term protection of flora and fauna. Meanwhile, existing regulations in Canada, Finland, Sweden, Switzerland, and the UK address impacts on non-human organisms and biodiversity in qualitative terms; several countries also require that these impacts be explicitly included in future risk and performance assessments. In addition, EPA's standards for the disposal of high-level radioactive waste and TRU waste include a separate groundwater standard designed to protect groundwater as a resource.

8.1.6 Developing New Standards for New Repository Sites

The Disposal Subcommittee has heard a range of views from witnesses concerning the appropriate regulatory elements to be applied to future geologic repository development efforts. However, we have not attempted to develop specific recommendations concerning the form and stringency of regulatory standards for geologic disposal facilities in the United States. It is clear to us that after more than 30 years of experience developing and applying EPA and NRC regulations—both for repositories in general and for WIPP and Yucca Mountain in particular—the critical questions have been identified even if there is not yet full agreement on how they should be answered (see text box below). The Subcommittee has not attempted to reach consensus about how to resolve these questions since they involve societal value judgments that should be mediated through the regulatory development process. In sum, we believe existing regulatory authorities—notably EPA and NRC—can draw from an extensive literature and considerable regulatory experience to make the determinations that are appropriate and necessary to guarantee safe and secure nuclear waste disposal in this country.

Without making specific recommendations regarding the standards to be applied to geologic repositories or other waste management facilities, the Subcommittee does offer a number of general principles or propositions to guide the development of future regulations:

1. The standard and supporting regulatory requirements to license a geologic repository should be generic—that is, applicable to all potential sites.

   While there may be advantages to developing standards and requirements that recognize the specific features and characteristics of a particular site, experience with Yucca Mountain indicates that this approach can create suspicions that the regulations are simply being tailored to make a pre-selected site work. Generally-applicable regulations are more likely to earn public confidence. In addition, having a generic standard will support the efficient consideration and examination of multiple sites.

2. Regulatory standards and requirements for compliance demonstrations (including the required level of confidence in the demonstration or "standard of proof") should not go beyond what is scientifically possible and reasonable.

   Both the standards themselves and the process used to demonstrate that they have been met must be credible to the scientific community and the public. The Subcommittee has heard the view that some aspects of the current Yucca Mountain regulations lack credibility in both areas. A specific concern is the requirement that the compliance demonstration be primarily based on a complex quantitative projection of repository performance for 1 million years. While making calculations over such a long time horizon might be appropriate as a part of establishing a broader safety case, the Subcommittee

believes that over-reliance on million-year calculations can reduce credibility rather than enhance it. We note again the IAEA's warning that "care needs to be exercised in using the criteria beyond the time where the uncertainties become so large that the criteria may no longer serve as a reasonable basis for decision making."

Whatever the time frame, the standard of proof for compliance should likewise be based on what is scientifically achievable. As discussed above, both existing sets of generic repository and Yucca Mountain-specific regulations emphasize that absolute proof in the normal sense of the word is not possible over long time periods. They therefore stipulate that compliance determinations should be based on a "reasonable expectation" that the standards will be met. This is the standard of proof defined by EPA[120] and ultimately adopted by the NRC for its Yucca Mountain regulations. The Subcommittee has heard that this approach has proved workable in both the WIPP and Yucca Mountain contexts; accordingly, we recommend that it be carried over into new regulations.

Key Questions in Setting a Regulatory Standard for Deep Geological Disposal

- What should the basis be: a desired level of protection or what is reasonably achievable using today's technology?
- For how long must compliance be demonstrated?
- Who is to be protected—individuals or populations?
- What is the desired level of protection?
- What is the measure of compliance (e.g., doses to individuals vs. releases to the environment)?
- How should compliance be demonstrated—primarily through quantitative calculations or through a broader safety case that involves qualitative as well as quantitative considerations?
- What level of confidence is required?
- How should the potential for human intrusion be addressed?
- How should retrievability be addressed?
- Can compliance take credit for institutional controls and if so, for how long?
- Should groundwater be separately protected?
- Should there be performance requirements for sub-elements of a repository (e.g., the waste package or the geologic setting)?

[120] EPA's position on reasonable expectation was challenged as being arbitrary and capricious in the lawsuit that led to the remand of parts of 40 CFR 191 in 1987. Nevertheless, EPA's position was upheld by the Court: "Given that absolute proof of compliance is impossible to predict because of the inherent uncertainties, we find that the Agency's decision to require "reasonable expectation" of compliance is a rational one. It would be irrational for the Agency to require proof which is scientifically impossible to obtain. Any such purported absolute proof would be of questionable veracity, and thus of little value to the implementing agencies. Nor can we say that this provision is arbitrary and capricious because it will afford the implementing agencies a degree of discretion, since such imprecision is unavoidable given the current state of scientific knowledge" (Natural Resources Defense Council v. U.S.E.P.A., 824 F.2d 1258).

3. Rules for demonstrating compliance and for documenting the required level of confidence in the compliance demonstration (i.e., the standard of proof) should be defined at the same time that the performance standards are developed.

   Rules for demonstrating compliance (including meeting the standard of proof) are an integral part of any regulatory standard. These rules should be developed as a part of the process for developing the overall standard and should be applied in the way that was expected when the performance standard was adopted. This is particularly important when different agencies are charged with implementing the standard (NRC) and setting the standard (EPA). In these cases, the potential exists for different agencies to apply different regulatory philosophies to the same standard.[121]

   In addition, the subcommittee recommends that as part of the license application the implementing organization develop a safety case that describes the full extent of data and information, analysis, and circumstances that underpin the conclusion that a candidate repository site should receive a license to construct and operate. Such a safety case may include but should go beyond the traditional performance assessment. The safety case should include a narrative and be constructed so as to be understandable to the educated, interested observer who may not be a subject expert. It should be organized to take full advantage of all relevant information, including that which goes beyond the narrower regulatory standards. It could include, as examples, discussion of natural and analogues or the results of field tests that provide a richer and easier to understand "case" of why the candidate repository site is likely to meet or exceed regulatory requirements. In preparing the safety case, all assumptions, uncertainties, conservatisms, etc., should be made explicit and the discussion including sensitivity analyses where appropriate should include assessments of potential consequences if these assumptions prove to be incorrect. The regulatory authority should include the safety case in reaching a judgment on the suitability and licensability of a candidate site.

4. Standards for a disposal facility should explicitly recognize and facilitate an adaptive, staged approach to development.

   Current EPA and NRC regulations were developed before international thinking about repository development shifted in favor of a more staged, adaptive approach (this is also the approach the Subcommittee is recommending in the United States). While the current regulatory structure is not necessarily incompatible with a staged, adaptive approach, future regulations should be designed to accommodate a process in which decisions about design, construction, and operations might be kept open beyond the initial license application.[122] In general, adaptive staging could make the licensing process more complex by increasing the number of changes made in the course of the process. This in turn would increase the number of regulatory review steps and the potential need for license amendments.[123] A revised regulatory structure for future repository development should be designed, with express attention to providing the flexibility needed to support this kind of process.

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[121] "As a historic matter, differences in the NRC and EPA standards are rooted in the two agencies' philosophical approach to setting limits. EPA has tended to set very aggressive goals (often based on best technology) but has been very forgiving when best efforts at compliance with the goals are made (thus: "Reasonable Expectation"). The NRC, on the other hand, has set more achievable, science-based, standards and has been very strict in enforcing the standards once set (thus: "Reasonable Assurance"). Report of the American Nuclear Society on the EPA proposed standard for the Yucca Mountain High Level Waste Repository, November 1999, http://www.ans.org/pi/news/sd/944200800-report.html.

[122] National Research Council, *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, Washington, D.C., 2003, p. 92.

[123] *Ibid*, p. 91.

5. Safety and other performance standards and regulations should be finalized prior to the site-selection process.

   If site selection occurs before final performance standards are defined, there are two risks. The first is that time and effort could be spent on a site that should have been ruled out as unsuitable earlier in the process. The second risk is one of perception. The public and other stakeholders could suspect that standards are being adjusted to fit the site. These considerations argue for setting generic standards that would be applicable to any facility wherever it is located, *before* any particular site is selected for further study. In developing such regulations, however, it will be important to avoid setting excessively detailed and rigid requirements that could prove unworkable when applied to an actual site or that could have the effect of screening out potentially suitable and otherwise promising sites.[124]The Subcommittee believes there is no reason to wait to start the process of developing generic regulations for future geologic repositories. As discussed below, we are not recommending any change in the current allocation of regulatory responsibilities and authorities that would require enabling legislation. Given that we are recommending a flexible process for finding new repository sites, standards development need not delay early progress on the siting front. Moreover, the fact that the regulatory issues to be resolved have been well defined and extensively analyzed over more than 30 years of EPA and NRC experience in this area, and the fact that some of the key issues have already been tested in court and in the regulatory process, should help expedite the process of developing generic repository performance standards.

6. EPA and NRC should coordinate closely in the development of new repository regulations.

   Problems of coordination between EPA and the NRC in developing repository standards have been widely cited as having contributed to negative perceptions of, and loss of confidence in, the Yucca Mountain project. The Commission has heard proposals for a fundamental redrawing of regulatory roles and responsibilities for repositories at the federal level (e.g., by consolidating all regulatory authority in the NRC or the EPA). In this case, there would be no need for coordination between different sets of regulations. Broadly speaking, however, our examination of the roles of the NRC and EPA, with respect to nuclear waste management under existing law, suggests that while there are opportunities for improvement in the EPA/NRC regulatory process and in the working relationship between these agencies, the general division of roles and responsibilities that currently exists is appropriate and should be preserved.

   While we are not recommending a change in the regulatory roles of EPA and NRC, we believe that the protracted and sometimes uncoordinated process of developing current EPA performance standards on the one hand, and NRC regulations for implementing those standards on the other hand, should not be repeated. For example, the Subcommittee has heard testimony that the processes used to develop standards in the past were confusing and frustrating to the public,[125] and that more

[124] In 1990, in the midst of ongoing debates about the EPA and NRC repository regulations, the National Research Council warned against the risks of establishing excessively rigid regulatory requirements before data on actual sites were available. *Rethinking High-Level Radioactive Waste Disposal*, Board on Radioactive Waste Management, National Research Council, 1990.

[125] According to a statement submitted by Steve Frishman: "The regulatory arena associated with deep geologic disposal of high-level radioactive waste and used nuclear fuel has been subject to an array of policy changes, changes in philosophy, and internal struggles within and between the two affected regulatory agencies – the NRC and the EPA. The interested and affected public often has been confused about the roles of the respective agencies, and the motivation, scope and meaning of the regulations proposed, while being confined in their responses to the review and comment provisions of the Administrative Procedures Act (APA), and ultimately the federal courts. Having been a participant in this process, at the affected state

coordinated and dedicated efforts are needed in the future to draw not only on the expertise of EPA and NRC but also on input from the knowledgeable public. We have also heard that public disagreements between these agencies over matters of regulatory philosophy can confuse the public and undermine confidence in the regulatory system,[126] and that it is important that such disputes be resolved promptly. [127]

The Subcommittee believes that a more coordinated and open process should be used to develop new generic regulations for future repositories, and that that any differences in regulatory philosophy between the two agencies be laid out clearly and resolved as early in the process as possible. We further believe that actions to coordinate the development of new disposal regulations can be undertaken by the Executive Branch without any additional action needed by Congress.

Specifically, we recommend that the administration identify an agency to take the lead in defining an appropriate process (with opportunity for public input) for developing a repository safety standard.[128] The same lead agency should coordinate the implementation of this standard-setting process with the aim of developing draft regulations. This process should be designed to accomplish the following:

- A clear definition of the regulatory issues to be resolved,
- A comprehensive identification of alternative approaches to resolving these issues,
- A thorough and fair analysis of the alternatives,
- A clear explanation of the regulatory choices that are made, and
- A shared understanding between the two agencies and with other stakeholders about the compliance demonstration methods and standard of proof that are to be used in implementing the standards.

We also recommend that the administration and Congress ensure that NRC and EPA have sufficient resources to complete this process in a thorough and timely way. The cost of delays in being able to move ahead with finding new repository sites would certainly be far higher than the cost of a process to establish the necessary standards as soon as possible.

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government level, for its entire nearly 30-year history, has been frustrating, to say the least." Summary of Statement by Steve Frishman, Consultant, Agency for Nuclear Projects, State of Nevada, before the hearing on "A Review of the Department of Energy's Yucca Mountain Project, and Proposed Legislation to Alter the Nuclear Waste Trust Fund (H.R. 3429 and H.R. 3981)," held by the Disposal Subcommittee of the BRC, September 1, 2010, Washington D.C. (http://brc.gov/Disposal_SC/docs/sep-01_mtg/Summary%20of%20Steve%20Frishamn%20to%20the%20Disposal%20Subcommittee.pdf).

[126] At a hearing in Maine concerning spent fuel stored at the shutdown Maine Yankee reactor site, an elected official described open disagreement between EPA and NRC about whether the final cleanup standard for decommissioning of the site should be 15 mrem or 25 mrem. According to this official, her constituents did not understand the technical basis for the disagreement, but the simple fact that there was a dispute between the regulatory agencies undermined public confidence in the regulatory system and the ability to safely store spent fuel at the Maine Yankee site. This ongoing dispute between the EPA and NRC was also mentioned in a paper prepared for the Commission by Dr. Rodney Ewing and described in a GAO report in 2000.

[127] Presentation by Robert Neill, December 2, 2010.

[128] For example The Subcommittee has also heard a proposal that would involve forming a panel of experts from each agency and from academia or the private sector to conduct a process in accord with the Administrative Procedures Act. The aim would be to produce a report that could be used as the basis for an integrated set of disposal safety regulations to be adopted by both EPA and NRC (as was proposed by Steven Frishman at the Subcommittee meeting on September 1, 2010 (see: http://www.brc.gov/sites/default/files/meetings/attachments/summary_of_steve_frishamn_to_the_disposal_subcommittee.pdf) Other options such as regulatory negotiations might be possible.

7. EPA and NRC should also develop a regulatory framework and standards for deep borehole disposal facilities.

   As noted earlier in the report, the subcommittee has also identified deep boreholes as a potentially promising technology for geologic disposal that could increase the flexibility of the national system for nuclear waste management, and therefore merits research, development and demonstration.. While a regulatory framework and safety standards for deep boreholes would have a large commonality with those for mined geologic repositories, the technologies also have key differences. For this reason the subcommittee recommends that the EPA and NRC should develop a regulatory framework and safety standard for deep boreholes to support RD&D efforts leading to licensed demonstration of boreholes.

8.2 Security and Safeguards of Nuclear Disposal

Robust security arrangements are needed at storage and disposal facilities for spent nuclear fuel and high-level waste, as well as during the transport of these materials, to prevent unauthorized access and acts of sabotage or theft. From a security standpoint, the most sensitive stages at a deep geological repository are when materials are above ground (transported or in a pre-load stage) and during the pre-closure period when materials are emplaced in the disposal facility, but the facility itself is not sealed and could therefore be accessed more easily. As the IAEA has recommended, the regulatory authority will need to provide guidance to the implementing organization concerning the effective application of security measures. Such measures could include physical protection, control and accounting, and verification procedures. Recognizing the importance of international safeguards commitments, the United States should ensure that future geologic disposal facilities are offered for IAEA safeguards, consistent with the Yucca Mountain requirements at 10 CFR 63.47.

8.3 Occupational Safety and Health

Another important area of regulation for waste management facilities pertains to the health and safety of facility workers and personnel, rather than to the protection of the general public. Currently, responsibility for occupational safety and health at nuclear facilities is the shared responsibility of the NRC, the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) and (in some cases) the Mine Safety and Health Administration.

In the United States, experience with constructing two deep geological facilities, WIPP in the 1980s and the Yucca Mountain Exploratory Studies Facility (ESF) in the 1990s, provides useful insights for managing the kinds of occupational safety and health risks involved in constructing and operating facilities of this kind.[129] Constructing facilities deep underground is in and of itself a complex undertaking

[129] During the construction of WIPP, one construction worker was fatally injured in 1984 when he fell 1000 feet down a 6-foot diameter borehole. See: "Safety Violations Led to WIPP Worker's Death", *Albuquerque Journal*, July 4, 1984, p. D-2. Overall this was the one traumatic fatality in an estimated 17,000 person-working years needed to construct the facility. Since WIPP opened in 2000, there have been no significant accidents involving workers. In the case of Yucca Mountain, concerns were raised about the adequacy of the industrial hygiene procedures in place to protect workers from silica exposure. A study of some 413 individuals (out of almost 3000) who worked at Yucca Mountain between 1993 and 2002 found three individuals with silicosis, however all of these individuals had previously worked in mines and two of them had been diagnosed before working at Yucca Mountain, so it was difficult to determine whether and to what extent exposures at Yucca Mountain might have contributed to their condition. The other case was a new diagnosis, but that worker also reported previous mining experience so it was not possible to attribute his disease solely to exposure at Yucca Mountain. The study was performed between 2003 and 2005 out of almost 3000 individuals who had been known to have worked in some capacity at Yucca Mountain in during the study. (See *An Investigation into the Silica Exposure of Yucca Mountain Project Workers*. Special Hearing before a Subcommittee of the Committee on Appropriations, US Senate, Las Vegas, March 15. 2004. Available at: http://www.gpo.gov/fdsys/pkg/CHRG-108shrg94749/pdf/CHRG-108shrg94749.pdf.) In contrast to Yucca Mountain, the WIPP facility is mined out of halite (salt) deposits. There has not been any study of whether mining halite has had any adverse health

that poses inherent risks. The major risks to workers at a deep geological repository are the same as those associated with any large-scale underground construction project; they include, principally, traumatic injuries from working around heavy equipment and explosives, lung disease from both dust and diesel exhaust fumes, and noise-induced hearing loss. That said, current construction procedures and technologies make it possible to minimize the risk of traumatic injuries, suppress dust and other respiratory irritants, and protect workers' hearing.

Although the overall occupational safety record for both the WIPP and Yucca Mountain facilities was generally better than would be typical for most comparable civil engineering work, these projects were not without risk. During the construction of the WIPP facility, for example, one worker fell down a shaft and was killed. This single incident translates into a fatality rate of about six per 100,000 working years, or about one-fourth the average fatality rate for all mining activities at that time. Also, in 1987 the hoist at WIPP had two near-miss failures even though the risk of this type of accident had been assessed at the very low probability of one in 60 million.

8.4 Key Findings

- Oversight by an independent, outside regulator is a critical link in ensuring that nuclear materials are safely managed and disposed of in ways that protect public health and the environment.

- Currently, most regulatory responsibility for nuclear waste facilities and activities rests with EPA and the NRC. Both agencies set standards intended to limit the potential for members of the public to be exposed to radiological risks from nuclear wastes. EPA has sole responsibility for regulations to address other types of environmental impacts and primary responsibility for regulating the performance of a disposal facility during the post-closure period. The NRC is the primary regulator for the period covering facility construction, licensing, and operation and for protecting facility workers from radiological exposures. Other worker protections are the responsibility of OSHA.

- Different countries have taken different approaches to the multi-faceted and technically complex task of setting regulatory standards for disposal facilities. Issues to be decided include not only the form and stringency of the standard but the timeframe(s) over which the standard applies and the approach or methodology that will be used to determine compliance. Over the last decade, the concept of a "safety case" has become increasingly prominent. Definitions vary, but the general idea is to integrate multiple arguments and lines of evidence to build a convincing and broadly understandable qualitative and quantitative case for the safety of the proposed facility over the relevant timeframe(s).

- At this time, there are two sets of federal regulatory standards for radioactive waste disposal sites in the United States. One was developed specifically for Yucca Mountain; the other generic set applies to a repository at any other site and would, unless changed, be applied to future disposal sites. Differences between these standards and between the EPA and NRC approaches more generally have sometimes emerged as a point of contention in past debates over proposed facilities and policies.

- General principles or propositions to guide the development of future regulations should include the following: (1) generic standards and regulatory requirements should be applicable to all

impact on workers at WIPP, even though there are significant salt dust exposures in the facility and even though exposure to salt dust is considered a risk factor for cardiovascular, gastric and kidney diseases.

potential sites; (2) compliance determinations should be based on the "reasonable expectation" standard and should not go beyond what is scientifically possible and reasonable; (3) rules for demonstrating compliance should be defined at the same time that the performance standards are developed; (4) standards for a disposal facility should explicitly recognize and facilitate an adaptive, staged approach to repository development; (5) safety and other performance standards and regulations should be finalized prior to the site-selection process; (6) EPA and NRC should coordinate closely in the development of new repository regulations and; (7) a regulatory framework for geologic disposal in deep boreholes needs to be developed.

- The current division of roles between the two agencies is appropriate, but coordination needs to be improved.

- The assessment of whether a candidate repository site meets regulatory requirements should be based in part on the construction of a robust "safety case."

- Robust security arrangements must be provided at storage and disposal facilities for SNF and high-level waste, as well as during the transport of these materials, to prevent unauthorized access or acts of sabotage or terrorism. The United States should also offer to place all future disposal facilities under IAEA safeguards.

- Experiences with both the Yucca Mountain Project and WIPP demonstrate a good occupational safety record. However, the additional risks associated with emplacing materials underground and working around packages that contain highly radioactive material require an additional layer of radiological safety requirements and efforts to foster a strong workplace safety culture.

9. CONCLUSION

A half century of civilian nuclear power production, and an even longer legacy of defense-related nuclear activities, have left the United States with a substantial inventory of SNF and high-level radioactive waste. Having benefited from the activities that produced these materials, this generation has an ethical obligation to dispose of them in a safe and environmentally responsible manner and in a reasonable timeframe. The recent disaster in Japan has cast a harsh light on our collective failure (over more than 40 years) to come to grips with the nuclear waste problem. It reminds us that delay and deferral also have consequences—that the failure to decide is also a decision, with its own costs and risks. Public awareness of those risks has undeniably changed as a result of Fukushima. The problem is not that our political leaders and government institutions haven't tried to find a solution nor is the problem that we lack a technical answer for managing the hazardous radioactive materials present. Efforts to site a deep geological repository for the permanent disposal of SNF and high-level waste in the United States date back 50 years. Deep geologic isolation continues to be the most promising and technically accepted disposal option available today. It is also the option all other countries with civilian nuclear waste management programs are pursuing with two countries—Finland and Sweden—having already been successful in identifying sites for deep, mined geologic repositories The United States has not lacked the understanding, the technology, or even the resources to implement deep geologic disposal. What we have lacked is the collective political will to locate, characterize, and win broad acceptance at all the levels needed—not only nationally, but also at the local and state level—to move forward decisively with one or more particular repository sites.

The mistakes that have led to the current impasse are easy enough to identify. Almost from the beginning, DOE's waste management program was hampered by:

- Inconsistent funding,
- Lack of mission constancy,
- Frequent changes of leadership and policy direction,
- Inflexible and unrealistic deadlines, and
- Overly prescriptive requirements.

The result was a program that too often fell short of meeting commitments, that too often failed to operate in a transparent manner, and that ultimately lost the trust of the public and key stakeholders. Success from this point on will require a decisive break with this legacy.

The Subcommittee is making several recommendations that we believe are critical to getting the U.S. nuclear waste management program back on track, restoring the confidence of the American people in the program, and achieving tangible progress toward a long-term solution for SNF and high-level waste.

First, we believe responsibility for the U.S. waste management program must be transferred to a new, single-purpose organization. That organization must have the leadership, the authority, the political independence, the resources and independent oversight to pursue its mission effectively and to establish a new track record of consistently delivering on commitments.

Second, resources in the NWF and from the ongoing collection of NWF fees must be made fully available to the new organization to be used for the purposes for which they are intended—that is, to provide a secure and dedicated source of funding to cover the cost of safely managing and disposing of civilian

nuclear waste. Specifically, this means (1) extricating the NWF from the web of budget rules that have created an unintended and dysfunctional competition between expenditures from the Fund and spending on other federal programs, (2) removing waste program funding decisions from the annual federal budgeting and appropriations process, and (3) pairing full access to the NWF and fees with robust accountability and oversight mechanisms to ensure that these resources are used effectively to advance waste program objectives.

Third, a new management approach is needed to successfully site and develop geologic disposal facilities and other major components of the waste management system. Based on experience here and in other countries, we concur with an earlier finding by the National Academy of Science that an adaptive, staged approach offers the necessary flexibility and capacity for learning and self-correction to successfully navigate a multi-decade process marked by a high degree of complexity, indeterminacy, and uncertainty. In the United States, opposition to the siting of facilities—particularly at the state level—has been a consistent and often intractable barrier to progress. Experience with WIPP and with repository siting programs in Finland and Sweden suggests that a stepwise, consent-based strategy that affords states and communities a high-degree of consultation and control may succeed where past efforts have not.

The Subcommittee recognizes that none of these three steps will be easy to implement; nor do they, individually or in combination, guarantee success. Put simply, we can't be sure that what has worked at other times and in other places will work again in the new circumstances our nation confronts today and in the decades ahead. We are sure, however, that there is no good alternative to trying. Based on the full spectrum of perspectives we have heard, and particularly in light of the ultimate success of the WIPP facility, the Subcommittee is optimistic that a new approach can work—not only because an indefinite prolonging of the status quo is unacceptable (which it is) but for a whole set of more positive reasons. The key will be to find solutions that serve not only our national interest, our public policy goals, and our obligation to future generations, but the particular interests of those states and communities that are willing be a part of them. Our search for those solutions must begin anew and without further delay.