Transportation and Storage Subcommittee
Report to the Full Commission

DRAFT

Blue Ribbon Commission on America's Nuclear Future (BRC)
Washington, DC
May 31, 2011

PREAMBLE

The Transportation and Storage Subcommittee of the Blue Ribbon Commission on America's Nuclear Future (BRC) was formed to examine issues related to the transport and storage of spent nuclear fuel (SNF) and high-level waste (HLW) in the United States. It has been co-chaired by Drs. Richard Meserve and Phil Sharp. Other Commissioners on the Subcommittee include Mr. Mark Ayers, Ms. Vicky Bailey, Dr. Albert Carnesale, Sen. Pete Domenici, Dr. Ernest Moniz, and Mr. John Rowe. BRC co-chairs, Rep. Lee Hamilton and Gen. Brent Scowcroft, have participated as members *ex officio*.

The Subcommittee met on numerous occasions to hear testimony from stakeholders and other experts, and to discuss the issues before the Subcommittee. A wide variety of organizations, interest groups, and individuals have provided input to the Subcommittee at these meetings and through the submission of written materials. Copies of these submissions, along with records and transcripts of past meetings, are available at the BRC website (www.brc.gov).

This draft report highlights the Subcommittee's findings and conclusions as of May 2011, and articulates a set of consensus recommendations for further consideration by the full Commission. It also provides a summary of the background and context, technical considerations, and stakeholder input that have informed the Subcommittee's findings and recommendations.

The Subcommittee welcomes comment on this 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 main question before the Transportation and Storage Subcommittee was whether the United States should change its approach to storing and transporting spent nuclear fuel (SNF) and high-level radioactive waste (HLW) while one or more permanent disposal facilities are established.

To answer this question and to develop specific recommendations and options for consideration by the full Commission, the Subcommittee held multiple meetings and deliberative sessions, visited several sites in the United States where SNF and HLW are being stored, and heard testimony from numerous experts and stakeholders. The Subcommittee also benefited from commissioned papers on several relevant topics; these papers are available on the BRC website at www.brc.gov.

As this report was being prepared, on March 11, 2011, a massive earthquake occurred off the coast of the Tōhoku region of Japan. The earthquake triggered an immense tsunami that devastated the eastern coast of Japan. More than fifteen thousand people are known to have been killed, and approximately nine thousand remain unaccounted for. Damages are still being tallied but could amount to several hundreds of billions of dollars.

According to Japan's Nuclear and Industrial Safety Agency (NISA), the earthquake and subsequent tsunami affected nuclear reactors at four sites along the eastern coast.[1] The most serious impact occurred at the Fukushima Daiichi Nuclear Power Station, which sustained extensive damage to its reactors, spent fuel pools and other infrastructure. The station lost primary and backup power, and over several days suffered additional damage from hydrogen gas explosions and fires. Significant amounts of radiation were released, contamination has been detected offsite, and citizens were evacuated from a large area around the plant.

BRC members and staff are deeply saddened by this tragedy. Employees of the Fukushima Daiichi plant and officials of the Japanese government, with the help of military and civilian experts and assets from the U.S. and other nations, are continuing unprecedented efforts to prevent further damage to the plant and to deal with the aftermath of the disaster. As the emergency phase transitions to mitigation and cleanup, many questions have arisen about the specific events that occurred at the plant and what actions were taken. Some of these concern spent fuel in storage pools, and related design and safety issues that might have implications for storage in the U.S. The Subcommittee notes that the Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), and industry have begun extensive investigations into these matters. In addition, we recommend that Congress request that the National Academy of Sciences (NAS) conduct its own separate assessment of lessons learned from Fukushima and their implications for conclusions reached in earlier NAS studies on the safety and security of SNF and HLW storage arrangements, once the necessary information from the Fukushima accident is available. We understand that such an assessment will take time and likely cannot be completed before the Commission is required to issue its final report. In the meantime, however, the Subcommittee will continue to monitor developments closely and, to the extent that preliminary assessments become available, we may offer additional or revised recommendations to the full BRC as warranted.

With that important prefatory note, we turn now to the Subcommittee's main conclusions and recommendations, summarized below.

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[1] Nuclear Regulatory Commission, presentation to the Advisory Committee on Reactor Safeguards, April 7, 2011 (hereinafter referred to as "NRC ACRS Briefing."

<u>Recommendation #1</u>: *The United States should proceed expeditiously to establish one or more consolidated interim storage[2] facilities as part of an integrated, comprehensive plan for managing the back end of the nuclear fuel cycle. An effective integrated plan must also provide for the siting and development of one or more permanent disposal facilities.*

This is the Subcommittee's central and most important recommendation—without it, the other recommendations advanced here are unlikely to be meaningful or successful. We have concluded there are several compelling reasons to establish consolidated interim storage on a regional or national basis while progress is made toward implementing a permanent disposal solution.

First, consolidated interim storage preserves options while other aspects of an integrated waste management strategy can be developed. Given the long lead time needed to open a permanent disposal facility, consolidated storage would help reduce the cost and security burdens associated with storing spent nuclear fuel and high-level wastes at numerous dispersed sites. At the same time, a strategy that incorporates interim storage (i.e., storage for multiple decades up to a century or more) as a central element is consistent with preserving the option of recycling spent fuel if and when the circumstances make it advantageous.

Second, proceeding with consolidated storage would provide opportunities to build experience in many areas with direct relevance for the development, operation, and performance of other elements of an integrated management plan for both commercial and DOE spent fuel. For example, developing consolidated storage would help build experience with designing and executing a successful siting process; may lead to improved methods and technologies for the handling, packaging, and transportation of radioactive materials; and would provide a platform for R&D to better understand how the storage systems currently in use at both commercial and DOE sites perform over time.

Third, access to consolidated storage would make it possible for shutdown plant sites, which are serving no useful purpose (other than storing spent fuel), to be completely decommissioned and put to other beneficial uses.

Fourth, the merits of away-from-reactor storage for SNF may be enhanced in light of the events at Fukushima. A consolidated storage facility could be located where there is a very low probability of extreme events—unlike reactors, for example, it need not be near a large source of water, and could be located well away from densely populated areas. This observation should not be taken as a comment on the adequacy of current interim storage arrangements in the United States, which we continue to believe are generally safe and robust. The nuclear industry and the NRC are currently reexamining and re-analyzing SNF inventories, storage configurations, equipment, and procedures to ensure that current storage methods remain safe, and to improve system performance in the event of an emergency. Results from these assessments may strengthen the case for developing consolidated storage capacity. We believe consolidated storage capacity could be developed relatively quickly if the Administration and Congress made it a priority.

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[2] Throughout this report, the Subcommittee uses the terms "consolidated storage" or "consolidated interim storage" to mean storage of fuel at one or more facilities, away from the reactor sites of origin, for storage pending final disposal or other permanent waste disposition. We use these terms with some qualifications. "Centralized interim storage" is the term more commonly used, but "centralized" implies use of one facility at a centrally located site, and this may or may not be the preferred solution. "Interim storage" has a very specific meaning in a section of the NWPA that has since expired, but "interim" in common usage is preferable to other words such as "temporary" or "provisional," since the time interval contemplated may last several decades or longer.

Finally, the Subcommittee believes it is essential that success in siting and developing one or more consolidated storage sites *support*, not detract from, the vigorous pursuit of a successful disposal solution. By taking a first tangible step toward meeting its longstanding commitment to manage SNF and HLW, the federal government would address a major source of political pressure, and legal and financial liability, which will otherwise complicate efforts to move beyond the current impasse in the nation's nuclear waste management program.

Decades of failed policies, missed deadlines, and a climate of distrust have seriously eroded confidence in the nation's ability to manage these materials responsibly. In this context, demonstrating that it is possible to muster the policy direction, technical expertise, and institutional competence needed to site and operate a consolidated storage facility (while also seeking final disposal capability) would by itself be enormously valuable. This is not a "new" recommendation; interim storage has been proposed by numerous expert panels going back over 30 years. The Subcommittee concurs and believes it is time, finally, to implement this long-awaited and sensible interim management solution.

In making this recommendation, we recognize that the broader challenge will be to establish appropriate linkages between interim storage and permanent disposal in which both objectives are seen as essential and complementary components of a comprehensive strategy for managing all aspects of the back end of the nuclear fuel cycle. In the Nuclear Waste Policy Act (NWPA), Congress recognized that both temporary storage and ultimate disposal are necessary. Certainly, efforts to develop consolidated storage must not hamper efforts to move forward with the development of permanent disposal capacity. Just as progress on consolidated storage is important for progress on permanent disposal, the reverse is also true: efforts to site one or more consolidated storage facilities will succeed only in the context of a corollary disposal program that is effective, focused, and sustains the trust and confidence of key stakeholders and the public.

Recommendation #2: ***Recognizing the substantial lead-times that may be required in opening one or more consolidated storage facilities, dispersed interim storage of substantial quantities of spent fuel at existing reactor sites can be expected to continue for some time. The Subcommittee has concluded that there do not appear to be unmanageable safety or security risks associated with current methods of storage (dry or wet) at existing sites. However, to ensure that all near-term forms of storage meet high standards of safety and security for the multi-decade-long time periods that they are likely to be in use, active research should continue on issues such as degradation phenomena, vulnerability to sabotage and terrorism, full-scale cask testing, and other matters.***

Based on an extensive review of expert opinion and technical information, the Subcommittee has concluded that there do not appear to be unmanageable safety or security risks associated with current methods of storage at existing sites, whether at shutdown or operating plants. Further, we believe the United States has the technical and institutional capacity to provide for the safe and secure storage of SNF at existing or new reactors even for prolonged periods of interim storage (100 years or more). However, we emphasize that the ability to store spent fuel for an extended period does not lessen the requirement for a vibrant, high-priority repository program dedicated to establishing permanent disposal capability in a timely manner.

Assuring safe and secure storage of SNF and HLW over extended periods of time will require continued public and private efforts—including efforts by the Nuclear Regulatory Commission (NRC), DOE, and industry organizations such as the Electric Power Research Institute (EPRI) —to conduct rigorous research and oversight and continuously incorporate lessons learned from new developments and from extraordinary or unexpected events such as the accident at Fukushima. For example, it will be important to continue exploring fuel degradation mechanisms, particularly since many current safety assessments are based on examinations of fuel with lower burnup than is now “standard” and do not account for storage times of the length now being contemplated. Further research may identify unanticipated problems with extended fuel storage (e.g., unexpected corrosion rates)—and ensure that problems are detected and appropriately mitigated if they emerge. In addition to efforts at consolidated storage facilities to better understand the behavior of dry storage systems and their contents over time (see Recommendation #1), it would be useful to explore the feasibility and utility of enhancing instrumentation in dry storage systems at existing dispersed sites to provide insights on the evolution of these systems as they age.

To provide effective oversight, regulatory authorities and nuclear plant operators, designers, and vendors must also be able to adapt quickly to new or unanticipated risks, such as emerged in the crisis at Fukushima. That crisis is still ongoing, and it may take many months before a thorough investigation is complete and potential safety implications are fully understood. However, as discussed more fully in Section 3, the NRC and industry have quickly implemented both near-term assessments and longer-term analyses to understand what happened and take any needed actions to address safety issues at U.S. plants. In addition, the Subcommittee is recommending that the NAS—which has undertaken a number of past assessments of these issues—be authorized to conduct an independent investigation of the events at Fukushima and their implications for safety and security requirements at SNF and HLW storage sites, once information about the accident is available. Recognizing that all of these initiatives will take some time, the BRC will continue to monitor information about Fukushima as it emerges and modify our final recommendations as appropriate.

Similarly, the NRC is reexamining its security requirements for storage sites and transportation and may conclude that enhanced security measures should be required in the future. As part of this process the NRC should examine the advantages and disadvantages of options such as “hardened” on-site storage (HOSS) that have been proposed to enhance security at existing storage sites. Obviously, any hardened system could be implemented more cost effectively at a consolidated storage facility than at existing sites due to economies of scale. Finally, continued vigilance and research is needed to stay abreast of evolving security risks and terrorism or sabotage threats, particularly as storage times increase and spent fuel becomes potentially more susceptible to theft or diversion.[3]

Subcommittee members with appropriate clearances have been briefed by officials from DOE, NRC, and other agencies regarding issues of fuel storage and transportation safety and security. These briefings have also covered related research efforts and the additional security measures that have been implemented at some sites. We are confident the NRC’s current analytical and regulatory processes, are adequate to make needed assessments, and to adapt as appropriate.

<u>**Recommendation #3**</u>**:** ***Spent fuel currently being stored at decommissioned reactor sites should be “first in line” for transfer to a consolidated interim storage facility as soon as such a facility is available.***

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[3] Over time, spent fuel “cools” thermally and radioactively and requires less shielding to be handled directly. In this way it loses some of the characteristics that would make it difficult to remove and transport for unauthorized purposes. Depending on burnup, spent fuel may no longer be self-protecting after a century or so of storage.

Affected utilities and DOE or a new waste management organization should be given flexibility to make arrangements that will lead to the early acceptance of spent fuel from shutdown plants at a consolidated storage facility.

The rationale for giving priority to decommissioned reactor sites is straightforward: The benefits of removing spent fuel from these sites—in terms of reduced costs, management burdens, and security issues—are simply much larger than at still-operating reactors where an active on-site presence and various security measures must be maintained in any case. Continued interim storage at decommissioned sites also imposes a burden on local communities, since it delays the opportunity to develop those sites for other uses and requires ongoing maintenance of emergency response capabilities. While there are only nine commercial reactor facilities (plus the DOE-managed fuel storage site at the Fort St. Vrain reactor in Colorado) that are currently shut down and used for the sole purpose of storing spent fuel, that number will grow rapidly as reactor operating licenses (with extensions) expire.

More generally, future decisions about how to prioritize or sequence the transfer of spent fuel from commercial reactor sites to one or more consolidated storage facilities should be driven first by safety and risk considerations, and then by issues related to cost. The Subcommittee recognizes that existing contracts have created a "queue" in terms of federal commitments to accept materials from specific utilities. DOE has authority to modify this ordering in certain circumstances, but doing so may require the Department and current contract holders (i.e., utilities) to re-negotiate some of these commitments. The existing acceptance queue was not set up to maximize efficiencies or to minimize the risks of fuel handling and transportation, but DOE could modify the queue to do so. There may also be circumstances where expedited removal of fuel from an operating reactor might be needed. The Subcommittee believes a more flexible approach would benefit all parties involved.

Recommendation #4: ***A new integrated national approach is needed to revitalize the nation's nuclear waste program. A new organization charged with developing one or more permanent disposal facilities should also lead the development of consolidated storage and transportation capabilities.***

The BRC Disposal Subcommittee is developing options and recommendations for the formation of a new organization that would assume primary responsibility for the nation's spent fuel and high-level nuclear waste program. Consolidating responsibility for storage and transportation capacities within the same organization, as is currently the case under the NWPA, makes sense in the context of pursuing an integrated strategy and improving overall prospects for success. The Transportation and Storage Subcommittee defers to the Disposal Subcommittee to make recommendations to the full Commission on specific aspects of a new organization, including options for the nature, contracting authority, governance, and financing of such an entity.

The Subcommittee notes, however, that efforts by any new governmental or quasi-governmental organization to renew progress on consolidated interim storage should not impede or discourage other private-sector fuel storage initiatives that may arise. Commercial entities and potential host communities should be free to engage in voluntary discussions to develop interim storage alternatives, if they wish to do so. A new waste management entity could contract with such parties to provide waste management services, if desired.

Finally, it is important to emphasize that efforts to move forward with developing consolidated interim storage capacity should not be delayed until a new waste management organization is up and running.

This is both because establishing a new organization will take time, and because DOE remains for now (and will likely remain for some time until the law is changed) the entity that is contractually liable for accepting spent fuel from commercial power plant operators. Several steps to implement this central Subcommittee recommendation could and should be taken in the near term. DOE and various expert panels over the years have developed a substantial body of design and planning work for an interim storage facility. Collecting and updating this material could be useful to a new entity if it is directed to establish such a facility. Specific steps the Department could take under existing authority include performing systems and design studies; providing information on fuel storage and transportation to states, tribes and communities that on their own initiative are investigating the possibility of hosting a spent fuel storage facility; and working with industry and the NRC to standardize dry cask storage systems. Utilities and the Department of Justice could easily arrange to expedite these discussions and plans in a manner that will not affect pending litigation.

Recommendation #5: ***Although the regulatory standards may differ, the general principles that the BRC recommends for the siting and development of permanent disposal facilities should apply to the siting and development of interim storage facilities, and to planning for transportation needs. Processes used to develop and implement all aspects of the spent fuel and waste management system should be science-based, consent-based, transparent, phased, and adaptive. They should also include a properly designed and substantial incentive program.***

Past efforts to site a monitored retrievable storage facility for spent fuel and high-level radioactive waste have not been any more successful than efforts to site a permanent repository—and for some of the same reasons. Since local communities and other stakeholders will have many of the same concerns about a consolidated storage facility that they would have about a permanent disposal facility, attention to process and to the importance of establishing trust among affected constituencies will be critical to success in either case.

As with siting fixed facilities, planning for associated transportation needs has historically drawn intense interest. Transport operations typically also have the potential to affect a far larger number of communities. The Subcommittee believes that state, tribal and local officials should be extensively involved in transportation planning and should be given the resources necessary to discharge their roles and obligations in this arena. Accordingly, DOE should (1) finalize procedures and regulations for providing technical assistance and funds for training to local governments and tribes pursuant to Section 180(c) of the NWPA and (2) begin to provide such funding, independent from progress on facility siting. While it would be premature to fully fund a technical assistance program before knowing with some certainty where the destination sites for spent fuel are going to be, substantial benefits can be gained from a modest early investment—especially given that the current sites from which spent fuel will be shipped are known.

Recommendation #6: ***The current system of standards and regulations governing the transport of spent fuel and other nuclear materials appears to be functioning well, and the safety record for past shipments of these types of materials is excellent. However, planning and coordination for the transport of spent fuel and high-level waste is complex and should commence at the very start of a project to develop consolidated storage capacity.***

Spent fuel has been transported safely and securely in the United States and elsewhere for many decades. While the current system appears to be functioning well, past performance does not guarantee that future transport operations will match the record to date, particularly as the logistics involved expand to accommodate a much larger number of shipments.

Planning and providing for adequate transportation capacity while simultaneously addressing related stakeholder concerns will take time and present logistical and technical challenges. Given that transportation represents a crucial link in the overall storage and disposal system, it will be important to allow substantial lead-time to assess and resolve transportation issues well in advance of when materials would be expected to actually begin shipping to a new facility. Historically, some programs have treated transportation planning as an afterthought. No successful programs have done so.

Recommendation #7: ***To successfully implement a new strategy for managing the back end of the fuel cycle, a new organization will need reliable access to financial resources. The Subcommittee recommends that the Administration and Congress take action to provide full access to the Nuclear Waste Fund for the purposes for which it was intended, including funding consolidated interim storage and transportation as an integral part of broader waste management efforts. Ongoing litigation between DOE and the utilities regarding fuel acceptance should be resolved expeditiously.***

Despite the existence of a dedicated user-financed Nuclear Waste Fund created for the express purpose of covering future spent fuel management costs, a series of administrative and legislative actions have forced the DOE waste program to compete with other programs for funding through the regular year-to-year Congressional appropriations process. This has resulted in inconsistent and sometimes inadequate funding of the nation's nuclear waste program. To succeed, a new waste management organization must be able to access the Nuclear Waste Fund and must be in a position, subject to appropriate oversight, to exercise discretion over the use of those funds in advancing the nation's waste management objectives. As with the cross-cutting issue of establishing a new organization, the Disposal Subcommittee is addressing the question of funding more generally, including changes to the use of Nuclear Waste Fund, and will be making recommendations for consideration by the full Commission.

Meanwhile, this Subcommittee recognizes that DOE and utilities have been engaged in protracted litigation over the Department's failure to perform its obligations under the contracts to accept spent fuel beginning in 1998. Dozens of lawsuits have yet to be tried, some utilities have reached settlements with the government, and courts have reached judgments in other cases that find DOE in "partial breach" of its contracts. This means the U.S. government must pay damages incurred by utilities as a result of DOE's failure to begin accepting commercial spent fuel beginning in 1998. To date, damages in the amount of $956 million have been paid from the taxpayer-funded Judgment Fund, which is overseen by the Department of Justice. In addition, the Department of Justice has spent $168 million in litigation costs.[4] DOE currently estimates that total damages could amount to $16.2 billion if DOE were to begin

[4] Testimony of Assistant Attorney General Michael F. Hertz before the Blue Ribbon Commission, February 2, 2011.

accepting spent fuel in 2020.[5] DOE has previously estimated that liabilities will increase by roughly $500 million annually if the schedule for starting spent fuel acceptance slips beyond 2020.[6]

Because most of the major recurring issues have been resolved in litigation, the Subcommittee recommends that the federal government pursue good faith settlement negotiations and minimize the continued use of taxpayer funds in litigation with outcomes that are now predictable. Mediation or arbitration, structured in accordance with precedents already set by the courts, might be a viable alternative approach.

Current provisions of the NWPA allow the use of the Nuclear Waste Fund for monitored retrievable storage. The Subcommittee recommends that any legislation to implement consolidated storage as an integral component of the federal waste management system, incidental to final disposal, ensure that these provisions remain applicable. Consolidated storage clearly would allow the government to begin meeting its contractual obligations to remove waste from commercial reactor sites.

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[5] Memorandum to Steve Isakowitz, Chief Financial Officer, U.S. Department of Energy, from David K. Zabransky, Director, Office of Standard Contract Management, Office of General Counsel, U.S. Department of Energy, October 29, 2010.

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

CONTENTS

FIGURES

TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
BRC	Blue Ribbon Commission on America's Nuclear Future
BWR	boiling water reactor
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPRI	Electric Power Research Institute
GAO	Government Accountability Office
GNEP	Global Nuclear Energy Partnership
HOSS	hardened on-site storage
INL	Idaho National Laboratory
ISFSI	Independent Spent Fuel Storage Installation
MIT	Massachusetts Institute of Technology
MPC	Multi Purpose Canister
MRS	Monitored Retrievable Storage
MTU	metric tons of uranium
NAS	National Academy of Sciences
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
NWTRB	Nuclear Waste Technical Review Board
O&M	operations and maintenance
OCRWM	Office of Civilian Radioactive Waste Management (DOE)
PWR	pressurized water reactor
SNF	spent nuclear fuel
TAD	Transportation-Aging-Disposal (canister system)
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION AND STRUCTURE OF REPORT

To organize its investigation of whether changes are needed in the nation's current approach to storing spent nuclear fuel (SNF) and high-level waste (HLW), the Subcommittee began by asking a series of related questions:

- What role should storage play in an integrated U.S. waste management system and strategy in the future?
- Are there technical or regulatory uncertainties related to the ability to store existing and future spent fuel and high-level waste safely and securely for an extended period of time (100 years or more) and then transport it safely and securely to another location?
- How should plans for storage be linked to progress on the development of disposal capacity and possible advanced fuel cycles?
- How should needed storage capacity be provided (who should be responsible, where should storage be located, and how should facilities be funded)?
- What process(es) should be used to select new storage sites (if any), and what are the relative roles of federal, state, local, private, and tribal entities?
- What are the key issues that will affect the ability to transport spent fuel and high-level waste now and in the future at the scale that will eventually be required?

The sections that follow are generally organized according to this same set of questions. For each one, we lead with a discussion that provides background and context and summarizes the results of the Subcommittee's research to date. We close each section by highlighting our main conclusions.

2. THE ROLE OF STORAGE IN AN INTEGRATED STRATEGY FOR MANAGING THE BACK END OF THE NUCLEAR FUEL CYCLE

2.1 Background and Context

Irradiated nuclear fuel, commonly referred to as "used" or "spent" nuclear fuel,[7] is a byproduct of the fission reactions that occur in nuclear reactors. At nuclear power plants in the United States, reactor cores are loaded with anywhere from 100 to 1,000 fuel assemblies at a time. A commercial fuel assembly is a square bundle of long metal rods each of which holds a stack of uranium oxide pellets. The uranium in these pellets has been enriched to contain 3% to 5% of the isotope U-235, as compared to 0.7% in natural uranium or about 90% in nuclear weapons. A typical fuel assembly, depending on the type of reactor for which it is intended, contains between 0.2 and 0.5 metric tons of uranium.

After four to six years inside a reactor, a typical commercial fuel assembly will no longer sustain the desired level of fission reactions and must be replaced. At this point the uranium fuel in the assembly is considered used or spent. Spent fuel assemblies, when they are first removed from the reactor core are highly radioactive and thermally hot. As a rule, they are immediately transferred to a steel-lined, water-filled storage pool within the plant facility (see Figure 1), which helps to shield the radiation and cool the spent fuel. These pools were not intended or designed for permanent storage; the assumption was that spent fuel assemblies would spend a few years immersed in the pools before being transferred out for reprocessing or final disposition.

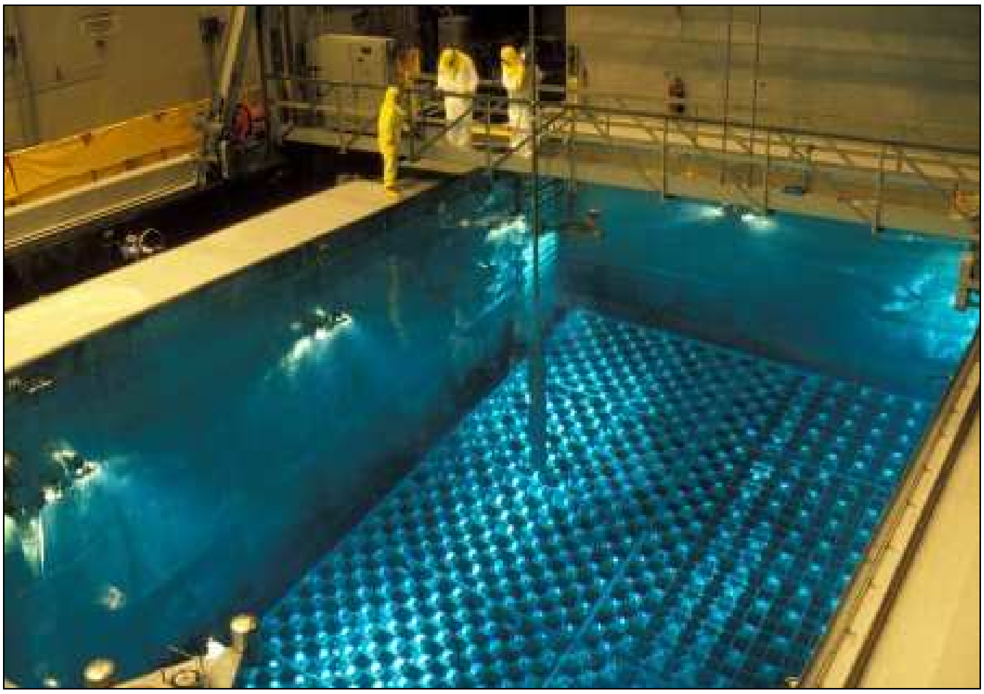
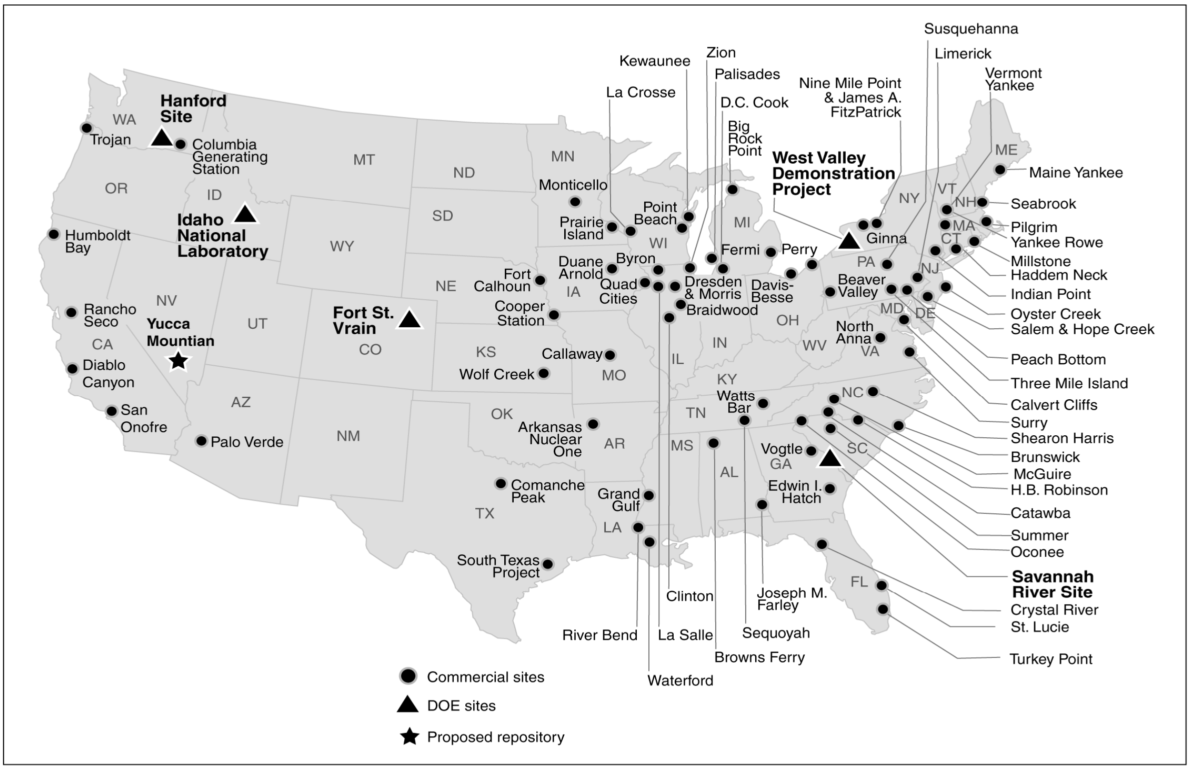


Figure 1. Spent Fuel Storage Pool

[7] 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. The different terminology reflects a profound policy debate as to whether the fuel is a waste (hence "spent") or a resource to be recovered through recycling (hence "used"). We use the older terminology, albeit without prejudging the answer to the policy debate.

When Congress passed the Atomic Energy Act in 1954 and established the framework for today's civilian nuclear energy industry, spent fuel was expected to be reprocessed for use in breeder reactors.[8] 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. Starting in the 1970s, however, plans for commercial reprocessing in the United States waned due to proliferation concerns and because of economic considerations. By this time, utilities were beginning to run into space constraints in terms of the design capacity of their water-filled storage pools. Over the next 20-plus years, as progress toward a permanent repository fell further and further behind schedule and as plant operators reached the limits of what they could accomplish by reconfiguring pool storage facilities to create more space,[9] utilities began to move spent fuel at some reactor sites out of wet storage into on-site dry cask storage. Over roughly this same timeframe DOE also began moving much of its spent fuel inventory from wet to dry storage. Figure 2 show current locations for commercial and DOE-owned spent fuel and high-level waste that had been planned to be sent to the Yucca Mountain facility, before that project was cancelled by DOE.



Source: DOE.

Figure 2. Locations of Spent Fuel at Commercial and Federal Facilities[10]

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[8] "Breeder" reactors are designed differently from conventional nuclear power plants and can produce more fuel than they consume. While some commercial-scale breeder reactors have been developed, economical operation has been difficult to achieve.

[9] Some of the initial steps taken to address wet pool storage constraints included re-racking the spent fuel assemblies and moving them into denser storage configurations to create more room. See Electric Power Research Institute, *Industry Spent Fuel Storage Handbook,* July 2010, found at http://my.epri.com/portal/server.pt?Abstract_id=000000000001021048, 2-1 (hereinafter referred to as EPRI Handbook).

[10] General Accountability Office, GAO-10-48, *Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives*, Nov. 2009. Note: Locations are approximate. DOE has reported that it is responsible for managing

In the U.S., dry cask storage involves sealing the spent fuel assemblies—after a period of initial cooling in wet storage—inside steel canisters or baskets that are then placed in massive concrete or steel casks. At plants that have implemented this form of storage, the casks are typically placed on concrete pads in an open air enclosure on site where they can be monitored on an ongoing basis (see Figure 3). The first commercial research program on dry cask storage began at the Surry Nuclear Power Plant in 1986 as part of a cooperative demonstration program established by the Nuclear Waste Policy Act of 1982 (NWPA).[11] Additional early studies were conducted at the Idaho National Laboratory (INL).

Today, dry cask storage is considered to be the preferred option for extended periods of interim storage (i.e., multiple decades up to 100 years or possibly more). As inventories of spent fuel from past operations continue to grow, utilities are increasingly moving to implement dry storage at reactor sites. Thus, although less than one-fourth of the nation's commercial spent fuel stockpile is currently being stored in dry casks, the Electric Power Research Institute (EPRI) estimates that all operating power reactors will have dry storage facilities in operation by 2025.[12] Figure 4 shows EPRI's projection for the expected amount and distribution of commercial spent fuel in dry versus wet storage over the next several decades.[13]

Figure 3. Dry Cask Storage Facility at the Decommissioned Maine Yankee Reactor Site

nuclear waste at 121 sites in 39 states, but DOE officials reported that several sites have only research reactors that generate small amounts of waste that will be consolidated at the Idaho National Laboratory for packaging prior to disposal.

[11] EPRI Handbook at 2-6.

[12] EPRI Handbook at 2-1.

[13] The figure is from a presentation to the Blue Ribbon Commission by Dr. John Kessler of EPRI. In his presentation, Dr. Kessler predicted that utilities "will continue with on-site storage on a plant-by-plant basis—barring clear, compelling national guidance." Accordingly, he urged that used fuel storage "be integrated at the national level." As discussed in the section on findings and recommendations, the Subcommittee concurs with this recommendation.

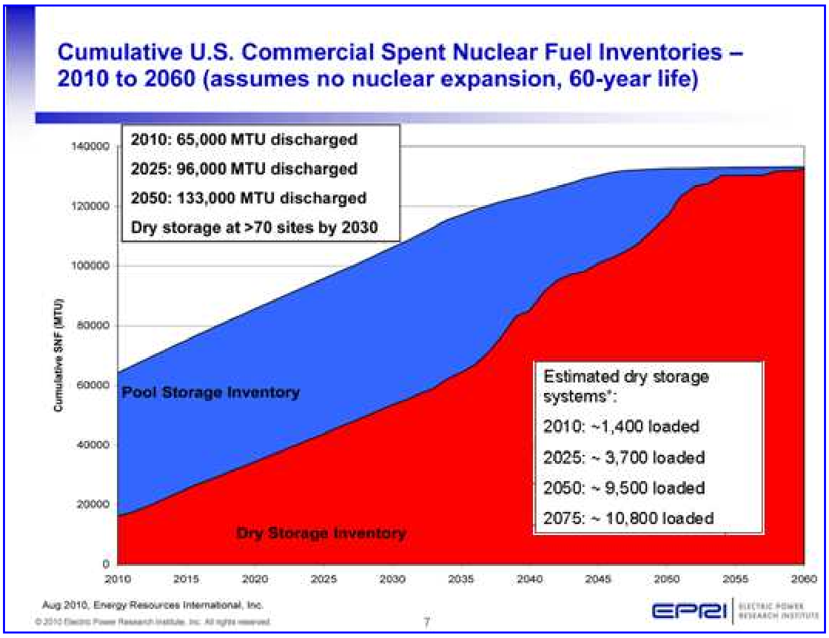

Figure 4. EPRI Projection of Cumulative Spent Nuclear Fuel from Commercial Nuclear Power Plants in Pool Storage and Dry Storage, 2010 – 2060[14]

The safety and durability of current on-site interim storage arrangements, and related technical and regulatory considerations, are discussed in a later section of this report. For purposes of this introductory discussion, the main point is that on-site interim storage is a necessary component of the back end of the nuclear fuel cycle, since it is unlikely to be feasible under any circumstances to transfer SNF and high-level waste as soon as it is generated—with no intervening cooling period—to another facility for immediate reprocessing or final disposal. Rather, the issue of on-site interim storage has drawn more attention as it has become clear that the time-frames involved in this stage of the fuel cycle are considerably longer than first contemplated when the nuclear energy industry was launched more than a half century ago.

The events at the Fukushima Daiichi plant may provide additional insights into the approaches used in assessing wet storage versus dry storage. Like many plants in the U.S., Fukushima Daiichi had both wet and dry storage systems in place. The storage pools at the Fukushima reactors are located adjacent to the reactor vessel, as depicted in Figure 5 below.

[14] As used in Figure 3, the term "dry storage systems" refers to individual storage casks or canisters.

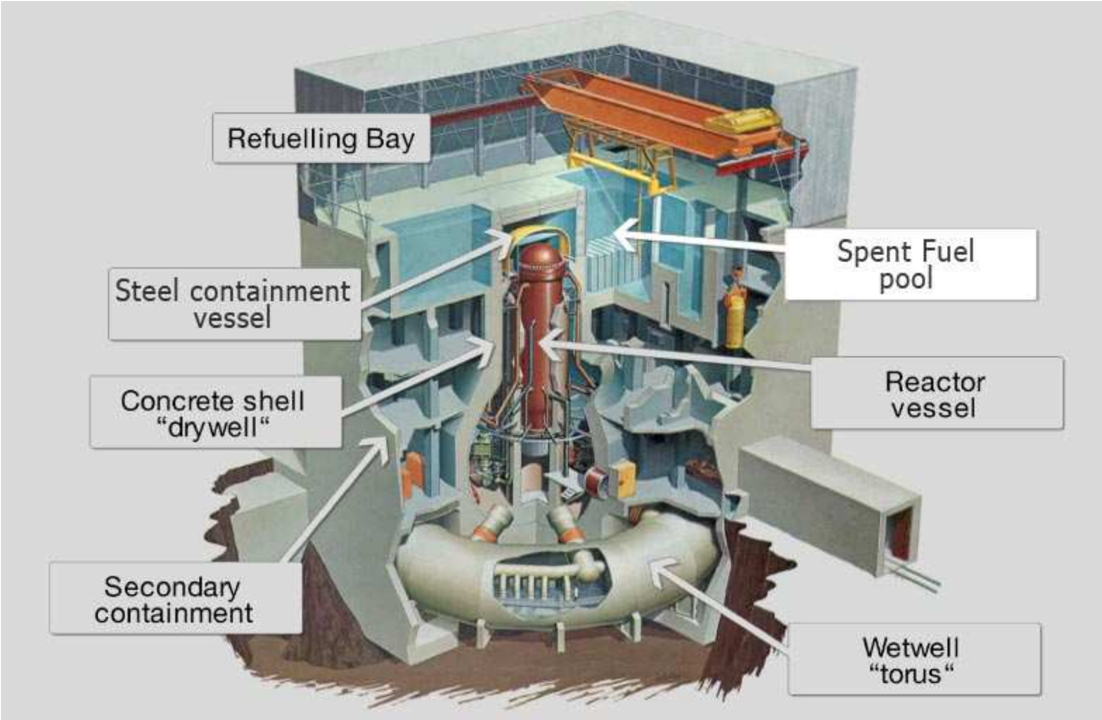

Figure 5. Schematic of BWR Reactor (Source: IAEA)

When irradiated fuel is first removed from the core, it must be moved under water from the core to the pool through submerged gates. The water provides necessary shielding because the fuel is thermally and radioactively hot. If a reactor needs maintenance, the fuel core may need to be unloaded to the pool while that work is performed. Fukushima Daiichi's Unit 4 reactor core had been unloaded about three months before the earthquake and tsunami struck,[15] and when the power systems failed, the cooling system stopped in the spent fuel pools. Temperatures in the pools rose and water levels dropped, probably due to a combination of evaporation and leakage. When spent fuel in pools loses the shielding and thermal protection of being immersed in water, high levels of ionizing radiation are emitted that can be dangerous to responders in the vicinity. Under certain conditions the exposed fuel can oxidize or burn and send a plume of contaminated material into the environment. At this time (May 2011), the Subcommittee does not have enough information to draw conclusions about what may have happened at the Fukushima pools, but it is known that water levels in one or more pools dropped significantly, and that recurrent injection of additional water for cooling has been necessary.[16]

The facility also had a shared pool away from the reactors and nine spent fuel dry storage casks on-site. These casks hold fuel in sealed steel canisters, which unlike fuel in pools is cooled passively by air circulation. Initial inspections and assessments indicate there was no significant damage to the shared pool or these casks resulting from the earthquake and tsunami.[17]

[15] NRC ACRS Briefing at 8.
[16] NRC ACRS Briefing at 8.

[17] NRC ACRS Briefing, supplemental statement by Earl Easton, NRC Spent Fuel Project Office, April 7, 2011.

Naval SNF Management in Idaho

Spent fuel is also generated for noncommercial purposes, including motive power for the U.S. Navy's nuclear fleet. The Naval Nuclear Propulsion Program (NNPP) is responsible for the design, maintenance, and safe operation of nuclear propulsion systems throughout their operational life cycles. A crucial component of this mission—spent fuel handling—occurs at the end of a nuclear core's useful life. Naval cores are removed from ships and transported in approved shipping casks, by rail, to the Naval Reactors Facility (NRF) located at INL.

Upon arrival at the NRF, a loaded cask enters the Expended Core Facility (ECF). The cask is opened and assemblies are individually unloaded, using a heavily shielded container, into a large water pool for examination and storage. Every assembly is visually examined to ensure there are no abnormal conditions that would affect disposal. Some of this fuel has been in operation and sealed in the reactor for well over 20 years, unlike commercial assemblies that operate about 4 to 6 years before removal from the core. Some assemblies receive more detailed examinations to obtain information that is used to improve core designs and extend core life. Following examinations and subsequent storage to allow decay heat to abate, assemblies are loaded into baskets that provide structural support and spacing to prevent criticality.

Loaded baskets are transferred out of the water pool and into a canister loading facility. In this facility, baskets (two or three depending on fuel type) are loaded into a canister which has been designed for storage, transportation, and ultimate disposal. The current canister has a 1-inch thick stainless steel wall and was designed to meet the disposal requirements proposed for the Yucca Mountain repository. Loaded canisters are drained, evacuated, dried of liquid, backfilled with helium and welded shut. Following extensive quality assurance tests, canisters are lifted into steel-lined concrete overpacks and moved into a separate building for storage. Indoor storage minimizes degradation of the overpack and makes preventive maintenance and monitoring easier.

NNPP is planning to build a facility to load canisters into a shipping cask for rail shipment to a geologic repository or interim storage facility, in accordance with the Idaho Consent Decree and Settlement Agreement.

To summarize, spent fuel pools are essential to operating a reactor. Some fuel must be stored, or be able to be removed from the core and stored, in a water-filled pool, in proximity to the reactor. These pools are not highly complex systems from a technical standpoint, but they do require ongoing monitoring, maintenance, and power to operate the systems and keep the water and fuel cool. There may be issues about spent fuel inventory, storage configuration, thermal analysis and other factors that will emerge as investigation into the Fukushima incident continues.

Given the backlog of SNF and high-level waste that already exists in the United States and given any realistic assessment of the time required to site, construct, license, and begin operating facilities for the final disposition of these materials, on-site interim storage timeframes on the order of 60 to well over 100 years must be contemplated, at least for the oldest fuel from the earliest commercial and DOE reactors. This is not an altogether bad thing, insofar as extended storage can serve a number of useful functions (enumerated below). But it does mean that storage must be approached as a major component of the back end of the nuclear fuel cycle in its own right—one that has a distinct and important role to play in devising an integrated strategy and system for managing the nation's spent fuel and high-level waste challenges in a responsible and cost-effective way.

3. TECHNICAL AND REGULATORY CONSIDERATIONS FOR EXTENDED INTERIM STORAGE[18] AND TRANSPORT

3.1 Technical Issues

As noted in the previous section, current institutional arrangements and technologies were not designed for the lengthy interim storage timescales that now appear inevitable for at least some portion of the nation's spent fuel and high-level waste inventory. While these arrangements are believed to be safe and secure, they were not part of a comprehensive strategy, but rather reflect *ad hoc* decisions taken by waste generators facing very limited alternatives.

The nuclear industry and various federal entities are conducting ongoing research and other activities to ensure that current storage systems provide adequate safety and security protection over extended periods of time. EPRI, for example, has initiated an Extended Storage Collaboration Program to research the technical basis for long-term dry storage of SNF. This program is being conducted with the involvement of the Nuclear Regulatory Commission (NRC), DOE, the Nuclear Energy Institute (NEI), individual utilities and dry storage system vendors. Under current policy, spent fuel can be stored for up to 120 years. Dry storage systems must meet performance criteria in terms of keeping temperatures within designated limits, providing radiological protection, physically confining material within the cask, ensuring that criticality events involving the fuel cannot occur, and enabling retrieval at some future date (for eventual transport and disposal or other final treatment). The EPRI research project, which is being conducted in three phases, is examining a number of degradation mechanisms that could, over multiple decades, potentially affect the integrity of interim systems for storing spent fuel, including:

- Potential changes in thickness or flexibility of the fuel cladding caused by long-term temperature and pressure within the fuel (known as "metal creep");
- Reorientation of chemical compounds (specifically "hydrides") within the fuel;
- Corrosion of the cladding and fuel;
- Degradation of the neutron shielding; and
- Drying and cracking of the concrete overpacks.

Preliminary indications suggest that as spent fuel ages and cools, its characteristics change in ways that are generally positive from a management standpoint. Metal "creep" rates, corrosion rates, and radiation levels are expected to diminish over time. Other mechanisms, however, may present problems. These include additional precipitation of hydride compounds; increased brittleness of the cladding material; and the potential for the more brittle fuel to break during storage, handling and transportation.[19]

[18] As used here, "extended interim storage" means storage for very long periods of time (up to a century or more).
[19] Presentation by Dr. John Kessler, EPRI, to the BRC Storage and Transportation Subcommittee, Aug. 10, 2010 (found at http://www.brc.gov/Transportation_Storage_SC/docs/TS_SC_08-19_mtg/17_EPRI%20%20Extended%20Storage%20-%20August%202010%20-%20final.pdf).

The Nuclear Waste Technical Review Board (NWTRB) recently issued a report[20] that identified a number of high-priority areas where research is needed to better understand the risks and impacts associated with extended fuel storage:

- Long-term changes in mechanical cladding behavior, especially for higher-burnup fuels;
- Modeling time-dependent aging and degradation conditions such as temperature profiles, material stresses, and gases within the cask;
- Modeling age-related degradation of the metal canisters, casks, and internal components;
- Inspection and monitoring to verify actual conditions over time;
- Verification of predicted mechanical performance of fuel during handling and transport following extended storage; and
- Design and demonstration of dry-transfer fuel systems that will be needed for eventual removal of the fuel.[21]

Little is known about either environmental conditions or the state of the spent fuel inside existing dry storage systems because instrumentation inside these systems is generally limited or non-existent. Knowledge of key parameters such as (but not limited to) gas pressure, the release of volatile fission products, and moisture would be useful.

3.2 Regulatory Issues

In 2010, the NRC—recognizing that progress on opening a permanent repository was going to continue to be delayed—updated its "Waste Confidence Decision" to state that at-reactor or away-from-reactor spent fuel could be stored safely for up to 60 years after an operating reactor's license (with extensions up to 60 years) was terminated.[22] And though the Commission expressed "reasonable assurance" that a mined geologic repository "will be available in the foreseeable future,"[23] it also directed the NRC staff to begin researching the potential environmental impacts of interim storage over even longer timeframes—more than one hundred or even several hundred years.

Even as it approved this extension of the acceptable timeframe for interim storage, however, the Commission was careful to note that it was not endorsing the indefinite storage of spent fuel at reactor sites. Rather, it reaffirmed its view that ultimate disposal in a mined geologic repository is still needed. Meanwhile, the NRC's Waste Confidence Decision—and the underlying judgment that extended interim storage of spent fuel in wet or dry configurations can be implemented safely—is important because it

[20] United States Nuclear Waste Technical Review Board, *Evaluation of the Technical Basis for Extended Dry Storage of Used Nuclear Fuel*, Dec. 2010 (available at http://www.nwtrb.gov/reports/reports.html).
[21] *Id*. at p. 125.
[22] 10 CFR 51.23(a).
[23] Nuclear Regulatory Commission, Staff Requirements Memorandum, Sept. 15, 2010 (found at http://www.nrc.gov/reading-rm/doc-collections/commission/srm/meet/2010/m20100915.pdf.)

enables the avoidance of a requirement to resolve this issue in each individual licensing action .[24] On February 14, 2011, several states filed suit against the NRC over its waste confidence finding.[25]

In June 2010, the NRC announced it was undertaking a comprehensive review of regulations related to extended storage and transport. Specifically, NRC staff were directed (in the agency's SRM-COMDEK-09-0001 document) to undertake a thorough review of spent fuel storage and transportation regulatory programs. This review is examining several issues:

- The adequacy of existing mechanisms for ensuring safe and secure storage and transportation for extended periods beyond 120 years;
- Research to bolster the technical bases of the NRC regulatory framework;
- Risk-informed and performance-based enhancements;
- State-of-the-art technology incentives;
- Comparing and harmonizing international standards; and
- Stakeholder participation and collaboration.

This review began in 2010 and will be conducted in phases through 2017.[26]

3.3 Constraints and Requirements for Dry Storage at Existing Reactor Sites

In the course of the Subcommittee's investigations, the question arose whether there are reactor sites where the physical location, operating boundary area, or any other purely technical or engineering issues placed constraints on whether and how much dry storage would be available. The BRC staff was unable to identify any reactor where such constraints would preclude the expansion of a dry storage spent fuel installation, even with license extensions. That said, the process of gaining approval for these facilities can be contentious and has sometimes provoked strong local opposition.

At present, NRC-licensed "independent spent fuel storage installations" or "ISFSIs" are located either in the "protected areas" of nuclear power plants or in owner-secured areas elsewhere on the plant property. As of October 2010, the location breakdown for current and planned ISFSI locations was as follows:[27]

- 31 ISFSIs located inside a protected area (power reactor site);

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[24] Nuclear Energy Institute press release, "Industry Applauds NRC Approval of revision of Waste Confidence Rule," Sept.15, 2010 (found at http://www.nei.org/newsandevents/newsreleases/industry-applauds-nrc-approval-of-revision-of-waste-confidence-rule).

[25] Matthew L. Wald, "3 States Challenge Policy on Storing Nuclear Waste," *New York Times*, Feb.15, 2011 (available at http://www.nytimes.com/2011/02/16/nyregion/16nuke.html?_r=1&scp=2&sq=Nuclear&st=cse)

[26] Presentation of Mr. Michael Waters, Division of Spent Fuel Storage and Transportation, at the NRC Spent Fuel Storage and Transportation Licensing Process Conference, June 23, 2010 (found at http://adamswebsearch2.nrc.gov/idmws/DocContent.dll?library=PU_ADAMS^pbntad01&LogonID=9a87d7d8ac79764ade6e860bf60321d3&id=101810115).

[27] Electronic mail from Steven P. Kraft, Nuclear Energy Institute to Alex Thrower, Blue Ribbon Commission on America's Nuclear Future, Oct. 8, 2010 (found at http://www.brc.gov/sites/default/files/comments/attachments/isfsi_location_information.pdf)

- 16 ISFSIs located in separate secure areas away from the reactor but on the reactor sites;
- 10 ISFSIs at shutdown sites in secure areas (nine former commercial reactors sites plus the Fort St. Vrain site which is managed by DOE);
- 8 ISFSIs currently underway/in construction inside a power reactor protected area; and
- 5 ISFSIs currently underway/in construction in separate secure areas.

State and Local Government Roles in Setting Conditions for the Addition or Expansion of Dry Cask Storage Capacity at Existing Reactor Sites

State agencies are generally heavily involved in the construction and expansion of dry cask facilities for storing SNF, although they do not "license" such facilities. States generally regulate in three areas: (1) public convenience and necessity; (2) environmental issues unrelated to safety and security; and (3) rates. A few examples from specific reactor sites are described below.

Vermont Yankee: Vermont's legislature requires a "certificate of public good" to permit Vermont Yankee to store SNF in a dry cask configuration. The certificate was issued by the Vermont Public Service Board in April 2006 but plant owners had to satisfy several additional requirements, among them providing additional financial assurances for long-term storage; updating plans for removal in the event the federal government does not provide for final disposal; studying local terrain features, and limiting the amount of spent fuel that could be generated under the plant's then-current operating license. Vermont Yankee was specifically prohibited from storing spent fuel from other plants at the site (absent approval from the legislature).[28] In May 2010, the Vermont Senate voted not to extend the plant's operating license beyond March 2012. The Town of Vernon is considering whether to impose a tax on dry casks to help replace anticipated losses to its tax revenue base.[29]

Prairie Island: Minnesota law requires plant operators to obtain a "certificate of need" to construct and operate an ISFSI. After extensive public debate and litigation, the legislature in 1994 voted to allow 17 dry casks to be constructed; this was expanded to 48 in 2003 because limited storage capacity would have otherwise required the plant to cease operations. Certificate conditions include utility investments in renewable energy and payments to the Prairie Island Indian Community to allow the Tribe to purchase land away from the facility.[30]

Oyster Creek: in 1993, the owners of the Oyster Creek plant in New Jersey were required to obtain a zoning variance to construct an ISFSI at that site. The township granted the change in April 1994, and opponents of the facility sued—unsuccessfully—in state court. As of September 2010, the plant had loaded 20 casks; the ISFSI has room for 28 more.

Connecticut Yankee: in 2001, plant owners filed an application with the Town of Haddam to re-zone a portion of the plant's property to permit construction of an ISFSI. After extensive litigation, Haddam entered into a settlement agreement that permitted construction to move forward, but prohibited storage of spent fuel from any other site.[31] Construction of the facility began in 2003 and loading was completed in March 2005.[32]

[28]EPRI Handbook at 9-6.
[29]Garafolo, Chris, *Brattleboro Reformer*, "Vernon Seeks to Tax Dry Cask Storage," Dec. 15, 2010, found at http://www.reformer.com/localnews/ci_16860918).
[30] EPRI Handbook at 9-3.
[31] EPRI Handbook at 9-5.
[32] The Yankee Companies, "Connecticut Yankee Fuel Storage" (factsheet), 2007 (found at http://www.connyankee.com/html/fuel_storage.html).

To develop on-site dry storage capacity, utilities must examine various site-specific features (i.e., terrain that may require modifications) and consider their proximity to nearby populations to assess the need for additional shielding (i.e., berms).[33] In general, the NRC does not consider berms or shield walls to be part of the cask systems being licensed but if an expansion would change the "controlled area boundary" and the estimated dose to workers and the public, a general licensee may include such shielding.[34]

Other site-specific requirements for dry cask storage that must be assessed include:

- Site-specific characteristics such as the potential for flooding and seismological activity.
- The availability of near-site and at-reactor facilities (rail or barge) to facilitate the delivery of large, heavy components that are fabricated off-site. This could affect the delivery of metal cask systems and concrete overpacks fabricated off site, as well as the eventual transport of spent fuel off site.
- The capacity of the main and auxiliary reactor building overhead cranes that are used to service the spent fuel pool. This crane capacity must be adequate to support dry storage loading operations or be able to be upgraded.
- Whether cask handling activities comply with a site's design basis for handling heavy loads.
- The effect of radiation from the dry cask storage facility on worker dose estimates and off-site dose estimates.
- Whether the floor loading capability of the reactor building cask access area and support capability of the decontamination or other cask lay down area are adequate to support the system selected.[35]

3.4 The Need for Greater Standardization of Dry Storage Systems

In 1989, the MRS Review Commission[36]observed that "unless a standardized storage form or package is required by DOE or NRC, utilities will respond to their interim storage needs on an individual, cost-effective basis." The Commission went on to identify three ways that such standardization might be accomplished:

- DOE or NRC could specify standard requirements for the waste form or package used in dry storage;
- DOE could develop and provide to the utilities, or require utilities to purchase, a fleet of standardized dual-purpose casks; or

[33]EPRI Handbook at 6-3.
[34]EPRI Handbook at 7-17.
[35] EPRI Handbook at 6-5.
[36]The MRS Commission was established by the Nuclear Waste Policy Amendments Act of 1987 to examine the need for a monitored retrievable storage (MRS) facility in the United States. The term "MRS" has specific meaning in the NWPA, but is analogous to "consolidated interim storage" as that term is used in this report.

- An MRS facility could be built early, thereby reducing the number of utilities that would need to provide additional at-reactor storage using a variety of fuel forms and packages.

DOE did not subsequently specify standard requirements for the storage of spent fuel. However, the Department did make two efforts to develop standardized cask systems that could be provided to utilities for interim storage, subsequent transportation to a repository, and disposal without further handling of the fuel. These were the Multi Purpose Canister (MPC) design in the mid-1990s, and the Transportation-Aging-Disposal (TAD) canister specification that is included in the Yucca Mountain license application. Conceptual specifications were successfully developed in cooperation with utilities and cask system vendors, but neither was implemented for reasons unrelated to the technical merits of either concept.

The case for standardizing dry storage systems has strengthened since the MRS Commission reached its conclusions in 1989. At the time, projections indicated that the maximum amount of fuel anticipated to be in dry storage, if a MRS facility or repository were delayed by 10 years beyond the then-planned date of 2003, was around 14,000 metric tons of uranium (MTU). However, the EPRI estimates discussed in the previous chapter (see Figure 4) show that the amount of spent fuel in dry storage as of 2010 already exceeds the MRS Commission's projections. At present around 1,400 casks or canisters, representing more than 20 different dry storage system designs, are being used to store this fuel across some 32 states. Moreover, the quantity of spent fuel in dry storage is expected to continue to rise, with the rate of increase accelerating significantly after 2030 as growing numbers of reactors are retired and the fuel assemblies being held in their pools are transferred to dry storage systems. The number of dry storage system designs in use will continue to grow as fuel burnups increase and design optimization continues. Overall, the number of individual casks/canisters in use at reactor sites could increase to 3,700 (over 150%) by 2025 and to around 9,500 by 2050. Figure 6 shows trends in dry storage systems.

Dry Storage System	**Capacity per cask (assemblies)**		**Capacity per cask (MTHM)**	
	BWR	PWR	BWR	PWR
Typical pre-2000 system	52	24	9.4	10.8
Typical present-day system	65 (avg.)	32	11.7	14.4
Future systems (max. currently licensed)	87	37	16.7	15.7
Transport-Aging-Disposal (TAD) systems	44	21	7.9	9.5

Figure 6. Dry Storage System Trends (provided by the Nuclear Energy Institute)

Absent any national guidance to promote standardization, this evolution of at-reactor dry storage "systems" will continue to reflect the time- and site-specific decisions of individual utilities about how best to meet their storage needs. However, transporting and handling large numbers of different storage units and designs will involve additional costs (e.g., many different types of transportation overpacks and handling systems) that might be avoided by adopting more standardized systems. The

Subcommittee believes that if a new waste management organization is established, it should work with utilities and the nuclear industry to develop a mutually acceptable approach to standardizing dry storage in the future, including incentives for utilities to use systems that would reduce overall system costs.

3.5 Safety and Security[37] Concerns for Interim Storage and Transportation of Spent Fuel

3.5.1 Storage Security considerations

Over the last decade, safety and security concerns specifically related to acts of terrorism or sabotage have received increased attention from agencies charged with regulating the interim storage and transport of nuclear materials.[38] Following the terrorist attacks on September 11, 2001, the NRC issued more than 70 security and threat advisories to its licensees to enhance threat awareness and security. In October 2001, the NRC initiated a series of classified studies that analyzed potential vulnerabilities and mitigation strategies at plants.

With respect to the security of spent fuel storage, the NRC requires plants to demonstrate physical protection of pools through force-on-force testing. This testing involves simulated assaults on nuclear power plants in which the adversary force is attempting to cause reactor or spent fuel damage. Since late 2004, and as required by federal law since 2005, NRC-supervised testing is conducted at each operating power reactor once every 3 years (the operators conduct much more frequent tests on their own). The testing frequently includes simulated attacks on spent fuel pools. The NRC reports to Congress every year on the results of these tests, including both public and non-public versions of these reports.[39]

The NRC is also primarily responsible for security requirements at ISFSIs. Like the security at the reactor itself, licensees must implement a “layered defensive strategy” that includes on-site protective forces with appropriate skills, weaponry, and other response equipment, and security systems. The strategy must include procedures to defend against physical attacks, insider threats, and cyber attacks. Security systems also provide for means to detect, assess, and communicate information about potential threats to local law enforcement authorities in the event of an attack. Not surprisingly, security systems are tailored to the specific site, since relevant characteristics—such as the distance from storage facilities to the plant boundary—can vary from site to site. The NRC requires protective forces to be trained, and frequent performance drills to be conducted. Licensees must also conduct internal assessments of force effectiveness, though the NRC also conducts periodic independent reviews of site protective force training and force effectiveness.[40]

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[37] Following the National Academies usage, we use the term “safety” to refer to measures that protect spent nuclear fuel storage facilities against failure, damage, human error, or other accidents that would disperse radioactivity in the environment, and the term “security” to refer to measures to protect spent fuel storage facilities against sabotage, attacks, or theft.

[38] Material for this section was developed from presentations to the BRC Transportation and Storage Subcommittee by Mr. Philip Brochman, NRC Office of Nuclear Security and Incident Response, Sept.23, 2010 (found at http://www.brc.gov/sites/default/files/meetings/presentations/a1_brochmanstorage.pdf)

[39] Electronic mail from Dr. Brittain Hill, NRC, to Alex Thrower, BRC staff, Feb. 23, 2011 (found at http://www.brc.gov/sites/default/files/comments/attachments/post_9-11steps_b_hill.pdf).

[40] Additional background about NRC’s security programs is available at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/security-enhancements.pdf).

The NRC is currently undertaking a rulemaking to (a) examine the effectiveness of security orders imposed after the September 11, 2001 terrorist attacks; (b) apply lessons learned from previous NRC inspections at facilities; and (c) ensure regulatory clarity and consistency between general and specific ISFSI licensees. The NRC issued a draft "regulatory basis" document in December 2009 and has received numerous comments on proposed technical approaches. Among other issues, the NRC is considering whether to require licensees to have a comprehensive "denial" capability on site—that is, to retain security forces and weaponry sufficient for facility personnel to repel an attack on their own—or instead to require a detect/assess/communicate strategy that would rely on assistance from local, state and federal authorities.[41]

3.5.2 Storage safety considerations

In addition to security measures, the studies initiated by NRC in October 2001 also addressed a number of issues directly related to the safety of pool storage:

- Thermal response of fuel to fully drained and partially drained pool conditions,
- Structural response of spent fuel pools,
- Spent fuel heat-up and coolability enhancement, and
- Confirmatory testing of analytical methods for calculating the thermal response of boiling water reactor (BWR) and pressurized water reactor (PWR) fuel assemblies.

The NRC issued orders in February 2002 based on the results of these initial studies.[42] These orders, which are designated as Safeguards Information and thus are not available to the public, imposed specific requirements that provided additional protection for fuel in pools. The new requirements addressed strategies to restore or maintain core cooling, containment, and spent fuel cooling under circumstances associated with the loss of large areas of the plant due to explosion or fire. Additional guidance specifically related to pools was issued to licensees in July 2004 and February 2005. The updated guidance was subsequently incorporated into guidance supporting the 2009 Power Reactor Security Requirements final rule (74 FR 13926).

In 2003, an independent study of safety issues associated with the storage of spent fuel in reactor pools conducted by Robert Alvarez *et al.*[43] raised concerns about the trend towards increasing amounts of fuel stored in high-density configuration in pools and the possibility that under certain conditions in which water is drained from a pool, the fuel could overheat and ignite the zirconium cladding, leading to large releases of radioactivity. (This possibility had already been identified by analyses performed for the NRC.)[44] The Alvarez report recommended that reactors in the U.S. reduce their fuel pool inventories and return to a more open fuel storage configuration by transferring relatively older fuel to dry casks, which are passively cooled. The Alvarez study made a number of other specific recommendations, among

[41] Staff Requirements Memorandum dated Aug. 26, 2010 (SECY-10-0014 Enclosure 1, found at http://wba.nrc.gov:8080/ves/view_contents.jsp).
[42] EA-02-026, "Order for Interim Safeguards and Security Compensatory Measures" (the ICM Order), February 25, 2002.
[43] Alvarez et. al., "Reducing the Hazards from Stored Spent Fuel Power-Reactor Fuel in the United States," *Science and Global Security* 11: 1-51, 2003.
[44] Spent Fuel Heatup Following Loss of Water During Storage by Allan S. Benjamin et al. (Sandia National Laboratory, NUREG/CR-0649, SAND77-1371, 1979),.

them installing emergency water sprays to cool the fuel pools in the event water levels are insufficient, and making preparations to repair holes in spent fuel pool walls on an emergency basis, if called for.[45]

In a response to this study, the NRC argued that currently permitted, more densely arrayed pool storage could be carried out both safely and securely.[46] This position has continued to be questioned by advocates of lower-density pool storage, especially since the accident at Fukushima Daiichi.

Prompted by conflicting public claims about the safety and security of commercial spent nuclear fuel storage at nuclear power plants,[47] the U.S. Congress in 2003 asked the National Academies to provide an independent scientific and technical assessment, specifically with respect to the following issues:

- Potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial nuclear reactor sites.
- Safety and security advantages, if any, of dry cask storage versus wet pool storage at these reactor sites.
- Potential safety and security advantages, if any, of dry cask storage using various single-, dual-, and multi-purpose cask designs,
- The risks of terrorist attacks on these materials and the risk these materials might be used to construct a radiological dispersal device.

The classified study was completed in July 2004 and an unclassified summary report (titled *Safety and Security of Commercial Spent Nuclear Fuel Storage*) was published in 2006.[48] BRC Commissioners and staff with appropriate clearances have reviewed the classified report and have met with NRC security personnel to discuss the NAS report findings, as well as subsequent developments that might be relevant to the BRC's deliberations.

The NAS study reached several summary conclusions concerning security considerations and risks for current modes of spent fuel storage:

- Spent fuel pools are necessary at all operating reactors to store recently discharged SNF.
- A successful attack on a fuel pool, though difficult, is possible.
- If an attack leads to a propagating zirconium cladding fire, it could result in large releases of radioactive material.
- Additional analyses are needed to understand more fully the vulnerabilities and consequences of events that could lead to a zirconium cladding fire.
- It appears to be feasible to reduce the likelihood of a zirconium cladding fire by rearranging spent fuel assemblies in the pool in a "checkerboard" pattern (such that newer, higher decay-heat fuel elements are surrounded by older, lower decay-heat elements) and making provision

[45] Alvarez at p. 21.
[46] USNRC. 2003a. Nuclear Regulatory Commission (NRC) review of "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States." Science and Global Security, Vol. 11, pp. 203–211.
[47] NAS, p. 5.
[48] National Research Council, Committee on the Safety and Security of Commercial Spent Nuclear Fuel in Storage, *Safety and Security of Commercial Spent Nuclear Fuel Storage*, 2006, accessible at http://www.nap.edu/catalog.php?record_id=11263) (National Research Council 1).

for water-spray systems that would be able to cool the fuel, even if the pool or overlying building were severely damaged.

- Dry cask storage has inherent security advantages over pool storage, but is only suitable for older SNF (fuel that has been removed from the reactor for about five years or more).
- There are no large security differences among different storage cask designs.
- It would be difficult for terrorists to steal enough spent fuel from a storage facility to use in a "dirty bomb."[49]

The NAS committee in 2004 recommended further engineering and cost-benefit studies be undertaken to determine whether additional security measures and precautions, such as accelerating the transfer of spent fuel from pool to dry cask storage, should be adopted.[50]

The NRC has since taken action to address the risks outlined in the NAS study. In February 2005, following completion of the classified version of the NAS study, NRC staff provided guidance for implementing the orders that had been issued in 2002, including best practices for mitigating losses of large areas of the plant and measures to mitigate fuel damage and minimize releases. The NRC subsequently conducted inspections at operating reactor sites to assure compliance with these orders. In December 2006, the Nuclear Energy Institute (NEI) issued a document that provides guidance for implementing a set of strategies intended to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities under the circumstances associated with the loss of a large area of the plant due to explosions or fire.[51] (The NRC endorsed this document as an acceptable means for developing and implementing the requirement for mitigation strategies.) The guidance related to pools includes adding make-up water to the pool and spraying water on the spent fuel. In addition to these measures, the industry has reportedly taken steps to implement the "checkerboarding" arrangement of hotter and cooler SNF assemblies in pools, as recommended by the NAS study.[52]

In 2006, a coalition of more than 150 national and local non-governmental organizations (NGOs) adopted a set of principles "based on the urgent need to protect the public from the threats posed by the current vulnerable storage of commercial irradiated fuel." These "Principles for Safeguarding Nuclear Waste at Reactors"[53] call for several steps to be taken at existing reactor sites:

- Implement a low-density, open-frame layout for fuel pools
- Establish hardened on-site storage (HOSS – see text box)
- Provide for greater protection of fuel pools

[49] As used in this discussion, "dirty bomb" is defined as a potential weapon using conventional explosives to disperse radioactive material, causing contamination in addition to the conventional explosive effects.
[50] National Research Council 1, at 3
[51] [NEI 06-12, Revision 2, "B.5.b Phase 2 & 3 Submittal Guideline.". This document was initially designated for Official Use Only – Security Related Information, and so is unavailable to the public. However, it was made publicly available on May 9, 2011 and can be found on NRC's ADAMS system at http://www.nrc.gov/reading-rm/adams.html with accession number ML070090060.
[52] See remarks by comments of Bill Borchardt, Executive Director for Operations of the Nuclear Regulatory Commission, and Anthony Pietrangelo, Senior Vice President and Chief Nuclear Officer of the Nuclear Energy Institute, in the transcript of the March 29, 2011 meeting of the Senate Committee on Energy and Natural Resources on the accident at the Fukushima Daiichi reactor complex, at http://dpwsa.powergenworldwide.com/index/display/wire-news-display/1389933775.html
[53] "Principles for Safeguarding Nuclear Waste at Reactors," submitted to the BRC by Michelle Boyd, May 11, 2010 (found at http://www.brc.gov/sites/default/files/comments/attachments/hoss_principles_3_23_2010x.pdf).

- Require periodic review of HOSS facilities and fuel pools
- Provide dedicated funding to local and state governments to independently monitor and protect sites
- Do not reprocess spent fuel

The key technical points in these coalition principles are (1) that fuel older than five years should be removed from the pools to reduce storage density in the pools and allow a more open storage layout, thereby reducing the risk of pool fires, and (2) the fuel that is removed should be placed into hardened storage at the reactor sites. In the Subcommittee's view, these are two distinct and separable issues that warrant separate consideration. A requirement for hardened on-site storage has been specifically recommended in a rulemaking petition (PRM-72-6); the NRC intends to address this petition as part of its future security rulemaking (described in Section 3.5.1 above). The Subcommittee has received many dozens of comments, and has received and heard testimony from several witnesses at meetings, urging the adoption of HOSS principles for spent fuel dry storage at current sites. The Subcommittee has considered these comments and supporting information carefully. At this time, we believe that the NRC's rulemaking process is the appropriate venue for considering and assessing the technical merits of the HOSS concept.

The Hardened On-Site Storage (HOSS) Concept

Hardened on-site storage (HOSS)[54] dry cask or vault systems have been proposed to enhance the safety and security of spent fuel storage. As described by proponents, these systems have generally included berms and reinforced concrete vaults and overstructures[55] with the intent of offering greater resistance to potential terrorist attacks using aircraft or conventional weapons. Proponents argue that several features of a HOSS system would make it safer and more secure than current storage arrangements. Fuel pools, they note, are more vulnerable to attack or damage if they are penetrated and lose the ability to hold water to cover and cool the fuel being stored there. Dry storage offers "passive" cooling using air vents, and casks hold smaller volumes of fuel spaced farther apart. HOSS advocates have also urged ongoing expert verification and oversight independent from both the nuclear industry and the NRC. They have also recommended that the results of such reviews be made available to the public and local and state governments (who they believe should be funded to independently monitor the sites). Proponents of HOSS have also advocated additional measures such as requiring a low-density, open-frame layout for fuel pools, providing additional protection for pools.

Utilities and the nuclear power industry have generally not supported the HOSS concept for a variety of reasons. Industry representatives have suggested that continued reliance on NRC requirements, which use a design-basis threat assessment methodology, will ensure that facilities remain safe and secure by requiring tiered security forces, active and passive response systems, and conservative, robust technology designs.[56] They argue that the HOSS approach could increase risk if the storage/vault system were to collapse under attack and then interfere with the cooling of the fuel. Some fuel experts have stated that the primary objectives of the HOSS proposal are effectively already being met.[57] NEI has stated that "the existing NRC Orders ensure that a consistent overall protective strategy is in place for all types of ISFSIs, given the current threat environment. Imposing significant additional generic requirements without consideration of facility and cask design features, as well as the current threat environment, does not appear to be consistent with a risk-informed and performance-based regulatory structure."[58]

The Subcommittee believes the existing regulatory process is adequate and appropriate for assessing the effectiveness and appropriateness of the HOSS proposals.

[54] The term "hardened on-site storage" is not currently defined in regulations, and is not commonly used by the industry.
[55] "Principles for Safeguarding Nuclear Waste at Reactors," submitted to the BRC by Michelle Boyd, May 11, 2010 (found at http://www.brc.gov/sites/default/files/comments/attachments/hoss_principles_3_23_2010x.pdf).
[56] "Storage and Transportation of Spent Fuel: Does Storage/Transport System Hardening Enhance Safety and Security," submitted to the BRC Transportation and Storage Subcommittee by Mr. Charles W. Pennington, Sept. 2010 (found at http://www.brc.gov/index.php?q=comment/re-general-comments-88). Mr. Pennington subsequently submitted a detailed critique of the HOSS proposal as presented by Mr. David Kraft at the subcommittee meeting in Chicago, Il on Nov. 2, 2010. Mr. Kraft's submittal can be found at http://www.brc.gov/index.php?q=meeting/open-meeting-3). Mr. Pennington's critique was submitted to the BRC on January 20, 2011 and is available at http://www.brc.gov/sites/default/files/comments/attachments/recapitulating_and_expanding_upon_safety_of_dry_storage_-_final.pdf.
[57] Ibid (Pennington critique cited above).
[58] Letter from Chris Earls, Security Director, NEI to Alex Thrower, BRC staff, dated Feb. 7, 2011 (available at http://www.brc.gov/index.php?q=comment/fw-independent-spent-fuel-storage-installation-facilities).

As noted above, the question of whether the amount of spent fuel currently stored in reactor pools should be reduced is distinct from the question of where and how it should be stored if that were done. The Subcommittee believes that the issue of pool storage and the potential for fires in pools that lose water through natural or man-made events must be carefully reexamined in light of the disaster at the Fukushima Daiichi plant. The Subcommittee believes the NRC and industry are working appropriately to identify and address potential issues, but is continuing to closely follow developments on this issue.

A week after the disaster, on March 18, 2011, the NRC issued Information Notice 2011-05, to provide a general discussion of the earthquake events at Fukushima and encourage plants in the U.S. to review and consider available information to avoid similar problems.[59] Even before issuance of the notice, the industry had launched its own investigation to verify and validate each plant's readiness to respond to extreme events. The Institute for Nuclear Power Operations (INPO) is leading this effort, which will be completed soon.[60] The NRC has established a task force to "review relevant NRC regulatory requirements, programs, and processes;" the Commission plans to have a final report prepared by July 19, 2011, with periodic updates on May 12 and June 16.[61] Longer-term analyses and lessons learned will, according to NRC, be conducted as appropriate.

It appears at this time that the longer term analyses will in fact be necessary, since much information about what actually happened in and to the spent fuels at the Fukushima Daiichi reactors is still lacking and may not be available until after the reactors have been fully stabilized and brought to cold shutdown. The Fukushima plant operator, TEPCO, has recently indicated that this could take until January 2012. Such analyses might indicate that moving fuel earlier than previously planned from pool storage to dry casks, either on-site or away from reactors, is a prudent safety measure. Such measures carry their own potentials costs and risks, however, and will need to be carefully considered. For these reasons, the Subcommittee recommends that the National Academies be engaged, once adequate information is available, to undertake an update of their earlier study of the safety and security of at-reactor storage (both pool and dry) to (1) evaluate what actions and studies were undertaken as a result of the previous study, (2) identify the lessons that can be learned from the experience at Fukushima Daiichi, and (3) identify and evaluate additional measures that might be appropriate for reducing any risks associated with current storage practices in the United States.

3.5.3 Transportation

With regard to transportation security, the NRC has security regulations and orders in place to provide adequate protection from potential threats in cases where spent fuel is shipped from one location to another.

The NRC is currently undertaking a separate rulemaking to codify transportation security requirements.[62] The proposed protective strategy for transportation includes several elements:

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[59] NRC ACRS Briefing at 10. The notice is available at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/2011/ML110760432.pdf

[60] NRC ACRS Briefing at 11.

[61] NRC ACRS Briefing at 13.

[62] In addition, the Departments of Homeland Security and Transportation adopted regulations in 2008 to enhance the safety and security of rail shipments of hazardous materials, including spent nuclear fuel (49 CFR 172, 179, 209, 1520, 1580). The rules designated 46 High Threat Urban Areas (HTUAs) that require a chain of custody and control procedures. They also require rail route evaluations using 27 risk factors, including proximity to densely populated areas, iconic targets, and places of congregation. These rules have not been applied to large-scale spent nuclear fuel shipping campaigns; in fact, a number of observers have noted that doing so on a nationwide basis could be problematic. See presentation of Robert Halstead to the

- Advance planning and coordination with states,
- Increased notifications and communications before and during shipment,
- Continuous and active shipment monitoring,
- Use of armed escorts over the entire shipment duration (previously, armed guards had been required only in highly populated areas), and
- Background investigations of personnel with access to Safeguards Information.

In 2006, the National Academies issued a report titled *Going the Distance: the Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States*.[63] The report concludes that there are "no fundamental technical barriers" to the safe transport of such materials, but it made a number of recommendations to improve safety, communicate risk, and conduct planning and other activities in preparation for a large-scale transport campaign for spent fuel. The NAS committee noted that "[m]alevolent acts against spent fuel and high-level waste are a major technical and societal concern," but it was unable to perform an in-depth analysis of transportation security due to informational constraints (primarily lack of access to classified materials).[64] Accordingly, the NAS committee recommended that experts with full access to all relevant information conduct an independent assessment of security risks before any large-scale campaign to ship materials to a disposal or consolidated interim storage facility is launched.

In subsequent discussions with the NRC's Office of Nuclear Security and Incident Response, BRC staff reviewed the additional analyses NRC has conducted following the release of the National Academies' reports and others developed since that time.[65] The NRC has taken actions to respond to vulnerabilities that have been identified. Subcommittee members who participated in these briefings found the NRC's actions in this area to be reasonable and believe the rulemaking process it is following will be sufficient to ensure that any needed future changes will be made appropriately.

DOE and NRC have also supported research at the national laboratories aimed at understanding how spent fuel performs when subjected to attack using high energy density devices. This research was undertaken in the early 1990s and was overseen by the International Working Group on Sabotage Concerns for Storage and Transportation Casks, a group of fuel experts from the United States, France, Germany, Great Britain and Japan.[66] Funding for this research was provided through the Yucca Mountain project, but that support was effectively halted in 2009.

3.6 Key Findings

- The institutional and technical capacity exists to provide safe and secure on-site interim storage of SNF at existing or new reactors, even for extended periods of time (100 years or more). However, the issue of pool storage and the potential for fires in pools that lose water through natural or man-

BRC Transportation and Storage Subcommittee, Sept. 23, 2010 (available at http://www.brc.gov/sites/default/files/meetings/presentations/d_halstead_final_sep23.pdf).

[63] National Research Council, Nuclear and Radiation Studies Board/Transportation Research Board, *Going the Distance: The Safe Transport of Spent Nuclear Fuel and High-Level Waste in the United States*, Aug. 2006 (National Research Council 2).

[64] *Id.* at 8.

[65] BRC staff met with NRC/NSIR staff on January 11, 2011, and reviewed the classified versions of the NAS reports, as well as NRC summaries of the actions it has taken to address the issue identified. NRC staff also briefed cleared staff and Commissioners on Feb. 3, 2011.

[66] SAND2007-0870, Molecke at al., *Spent Fuel Sabotage Test Program: Characterization of Aerosol Dispersal: Interim Final Report*, March 2008 (found at http://prod.sandia.gov/techlib/access-control.cgi/2007/078070.pdf).

made events must be carefully reexamined in light of the disaster at the Fukushima Daiichi plant. The Subcommittee believes the NRC and industry are working appropriately to identify and address potential issues; in addition, the Subcommittee is recommending that the NAS be engaged to conduct an independent investigation. Such analysis might indicate that moving fuel earlier than previously planned from reactor pool storage to dry casks, either on-site or away from reactors, is a prudent safety measure. Such measures carry their own potential costs and risks, however, and will need to be carefully considered.

- NRC, DOE, and industry (through EPRI) have been engaged in rigorous research and oversight for more than two decades to ensure that current methods of storage remain safe and secure. Thus far, they have performed effectively in this area, and have adapted to changes appropriately. These efforts must continue as ongoing vigilance and effective enforcement will be critical to assure a good track record of safety and security in the future.

- An important information gap that should be addressed as soon as possible concerns the storage environment and condition of spent fuel at existing dispersed sites. This information is not being collected at present because many storage systems lack the requisite monitoring instruments. Additionally, some of the spent fuel being placed in storage will have a higher burnup, different cladding, and/or be older than the spent fuel that has been evaluated to provide the technical basis for extended fuel storage. It is important to continue and potentially expand current activities by EPRI, DOE, NRC and others to explore fuel degradation mechanisms and other issues associated with long-term storage. Sustained research in this area will be necessary to ensure that the technical basis for extended storage remains sound. In addition to efforts at consolidated storage facilities to better understand the behavior of dry storage systems and their contents over time, it would be useful to explore the feasibility and utility of enhancing instrumentation in dry storage systems at existing dispersed sites to provide insights on the evolution of these systems as they age.

- It is possible that future research and field experience will identify unanticipated problems with extended fuel storage (e.g., unexpected corrosion rates or embrittlement). If so, such issues will not develop suddenly; they can be monitored and mitigated if they are detected. Sustained efforts to monitor the condition of spent fuel and its environment in dry storage systems are needed to develop a full understanding of potential degradation phenomena in stored fuel and to determine whether conditions that would require mitigation are developing.

- Current storage arrangements have evolved in an *ad hoc* fashion, based on individual utilities' decisions about what is optimum on a site-by-site basis and not as part of a broader, integrated strategy for managing SNF and high-level waste. An integrated national approach to storing spent fuel is needed as part of a long-term waste management program that ultimately leads to the safe and permanent disposition of radioactive materials through reuse or direct disposal. Standardizing casks used at utility sites may enable greater system efficiency and cost reduction.

- The NRC is reexamining its security requirements for spent fuel storage sites and transportation systems, and it is possible that enhanced security measures may be required in the future. A number of groups have called for the implementation of HOSS, which would involve converting present storage facilities and adopting some additional safeguards. The Subcommittee concludes that the advantages and disadvantages of the HOSS proposal and of other ideas for enhanced security should be evaluated through the established NRC process.

- While the transport of spent fuel following extended interim storage may present unknown challenges due to fuel condition (embrittlement or corrosion), past experience, including the shipment of highly damaged fuel from the Three Mile Island 2 reactor, has shown that degraded or even destroyed fuel assemblies can be safely loaded, transported, unloaded, and stored.

- If future modifications to existing storage configurations necessitate increased handling of spent fuel, the additional radiation exposure that could result must be taken into account.

- As the duration of storage is extended, the amount of penetrating radiation emitted that "self-protects" spent fuel against theft or diversion diminishes (in other words, unshielded exposure to the fuel becomes less immediately debilitating and hence creates less of a deterrent to handling by unauthorized persons). This means that over long time periods (perhaps a century or more, depending on burnup and the level of radiation that is deemed to provide adequate self-protection), the fuel could become more susceptible to possible theft or diversion. This in turn could change the security requirements. Extending interim storage to timeframes of more than a century could thus require increasingly demanding security protections at storage sites.

- The Subcommittee is confident that existing processes and agencies have the capacity and expertise to conduct these ongoing assessments. The NRC (and ultimately Congress) must ensure adequate resources and funding are available to maintain this capacity.

4. CONSOLIDATED INTERIM STORAGE

4.1 Importance of Interim Storage in an Integrated Waste Management System

Storage will play a pivotal role in any integrated strategy involving eventual disposal or new fuel cycle technologies. It is also the only component of a management strategy for the back end of the nuclear fuel cycle that is currently being deployed on an operational scale. The events at Japan's Fukushima Daiichi plant are already prompting—as they should—a vigorous re-assessment of risks and vulnerabilities associated with current modes of spent fuel storage at reactor sites, particularly as they involve wet (or pool) storage. These assessments may point to the need for further safety and security measures at existing sites. Overall, however, the Subcommittee is confident that the technical and institutional capacity exists in the United States to store spent fuel safely and securely for decades.

An important point to underscore at the outset is that storage should not be regarded as merely an unfortunate but necessary step in the nuclear fuel cycle. On the contrary, interim storage—that is, storage for a period of perhaps decades before final treatment or disposal—offers many potential benefits as one element of a comprehensive fuel cycle strategy, no matter where the storage takes place. Most importantly, it preserves options and enhances flexibility while other aspects of an integrated waste management strategy are developed. The United States may ultimately either dispose of spent fuel or perhaps recycle it if circumstances make recycling advantageous. Storage preserves the option of going in either direction. A period of interim storage also is advantageous for eventual disposal, if that is the ultimate disposition path that is chosen, since allowing the fuel to cool reduces the siting challenge for a disposal facility or increases the disposal capacity of a given facility.

The evolution of the fuel cycle will have implications for interim storage needs. Several new or proposed reactor designs, if successfully commercialized and deployed, would require different fuel types or configurations than those used by the current generation of light water reactors. Small modular reactors, for instance, may have more compact fuel cores, but higher fuel burnup. If advanced fuel cycles were developed that required fuel processing or transfers from one reactor to another—for instance from a light water reactor to a "fast" reactor—the resulting spent fuel may be considerably "hotter" than is currently typical of commercial spent fuel when it is being handled and loaded into dry storage (typically after five or more years of cooling in wet storage).

Given the variety of advanced fuel cycles that have been proposed, it is certainly possible that future technology developments could have some impact on the quantity and characteristics of spent fuel generated by commercial nuclear power reactors. However, it is difficult to predict in advance how specific storage requirements might change in response to these developments. For example, if reprocessing were to be adopted, it might be advantageous to store spent fuel in canister systems with bolted rather than the more common welded lids to allow storage casks to be opened and unloaded more easily, thereby facilitating later fuel retrieval. Fuel reprocessing or recycling could, depending on the technology used, reduce inventories of spent fuel in both and wet and dry forms of storage. These and other issues related to advanced fuel cycle and reactor technologies (i.e., proliferation risks) are being addressed by a separate subcommittee of the BRC. For purposes of this discussion the most salient point is that future fuel cycle developments will not affect the need for a well-integrated near-term storage program for spent fuel from light water reactors. Indeed, such a system would preserve the option to apply technology changes if they prove to be advantageous.

4.2 Importance of providing consolidated interim storage

The broad system benefits just described are independent of whether storage takes place at the site where the waste was generated or at a consolidated location. At present, with a few minor exceptions, all commercial spent fuel is being stored by default at the sites of the reactors where it was generated. *The fundamental policy issue facing the nation with respect to spent fuel storage is whether the federal government should proceed to develop one or more dedicated storage facilities to allow the start of an orderly transfer of the fuel to federal control pending its ultimate disposition through reuse or disposal.* Numerous past studies by different groups have concluded that the government *should* establish such facilities, particularly as the anticipated schedule for a permanent repository has continued to recede further and further into the future.

As discussed in Chapter 3, the current U.S. "system" for spent fuel management is an *ad hoc* affair that has evolved as the sum of decisions by individual utilities about how best to manage their own particular circumstances, while waiting for the federal government to begin meeting its obligation to accept the spent fuel and remove it from their sites. It was not designed for overall efficiency of operations at a system level or for flexibility to respond to unforeseen events or changes in management strategy, much less for indefinite storage at the reactor sites after the reactors themselves have been decommissioned. One or more purpose-built consolidated storage facilities would provide the needed system-level capabilities that are now lacking.

Given current uncertainty about the prospects for completing a permanent disposal facility or resolving questions about whether spent fuel might be reused within any set timeframe, *the Subcommittee concludes that there are compelling reasons to move forward with establishing one or more consolidated interim storage facilities on a regional or national basis while progress is made toward implementing final disposition.* This is the Subcommittee's central and most important recommendation—without it, the other recommendations advanced in this report are unlikely to be meaningful or successful.

4.2.1 Consolidated storage would limit and reduce the number of shutdown reactor sites at which "stranded" spent fuel is stored

Not by reasoned choice or intent, but by default, the United States has been backing its way into a system of dispersed storage of relatively small quantities of spent fuel at an increasing number of shutdown reactor sites throughout the country, where the only activity at the site is providing safety and security for dry storage casks. These are sites where all the spent fuel has been placed into dry storage and the reactor has been removed. (In these cases, the spent fuel is often referred to as "stranded fuel.") The continued presence of stranded fuel prevents those sites from being reclaimed for other uses that would benefit the surrounding communities, and makes those communities the unasked and unwilling hosts of long-term spent fuel storage facilities without any of the rights of participation or benefits that would be provided under the NWPA to the host of a federal storage facility.

There are currently nine such commercial reactor sites in the United States (see Table 1) plus the DOE-owned Ft. St. Vrain fuel storage facility in Colorado.

Table 1: Quantities of Stranded Spent Fuel in Storage at Shutdown Commercial U.S. Reactor Sites[67]

Table 1. Status of Decommissioned Commercial Nuclear Power Reactor Sites in the U.S.

Plant	State	MTHM Stored at Site	MTHM in Pool Storage	MTHM in Dry Storage	Number of Casks	DOE Estimated Casks	Total Casks (Actual Plus Estimated)	Average MTHM/Cask
Big Rock Point	Michigan	58	0	58	7	—	7	8.3
Haddam Neck	Connecticut	412	0	412	41	—	41	10.1
Humboldt Bay[a]	California	29	0	29	5	—	5	5.8
LaCrosse[b]	Wisconsin	38	38	0	5	—	5	7.6
Maine Yankee	Maine	542	0	542	60	—	60	9.0
Rancho Seco	California	228	0	228	21	—	21	10.9
Trojan	Oregon	359	0	359	34	—	34	10.6
Yankee Rowe	Massachusetts	127	0	127	15	—	15	8.5
Zion 1 & 2[c]	Illinois	1,019	1,019	0	—	106	106	9.6
TOTALS		2,813*	1,057	1,756*	188	106	294	—

NOTE: [a]Dry storage underway in 2008. Holtec canister has capacity of 80 assemblies (five canisters for the 390 assemblies).

[b]Dry storage contract entered with NAC for five NAC-MPC canisters. Dry storage schedule indicates target completion by the end of 2010.

[c]Decommissioning contract entered with EnergySolutions. Canisters estimated using FuelSolutions W21 capacity. Target schedule for completion is 2013.

DOE = U.S. Department of Energy; MPC = multipurpose canister; NAC = Nuclear Assurance Corporation.

*Totals might differ from sums of values due to rounding.

The number of shutdown reactor sites with stranded fuel will grow sharply when increasing numbers of reactors reach the end of their operating lives, starting around 2030. The potential for rapid growth in the number of shutdown sites starting around 2030 is shown in Figure 7. While there are only nine sites in the shutdown category today, that number could reach 30 by 2035 and 70 by 2050. While subsequent life extensions beyond 60 years would push this curve farther into the future, it is also possible that not all currently operating reactors will in fact have their lives extended to 60 years, in which case the number of shutdowns would increase more rapidly than shown.

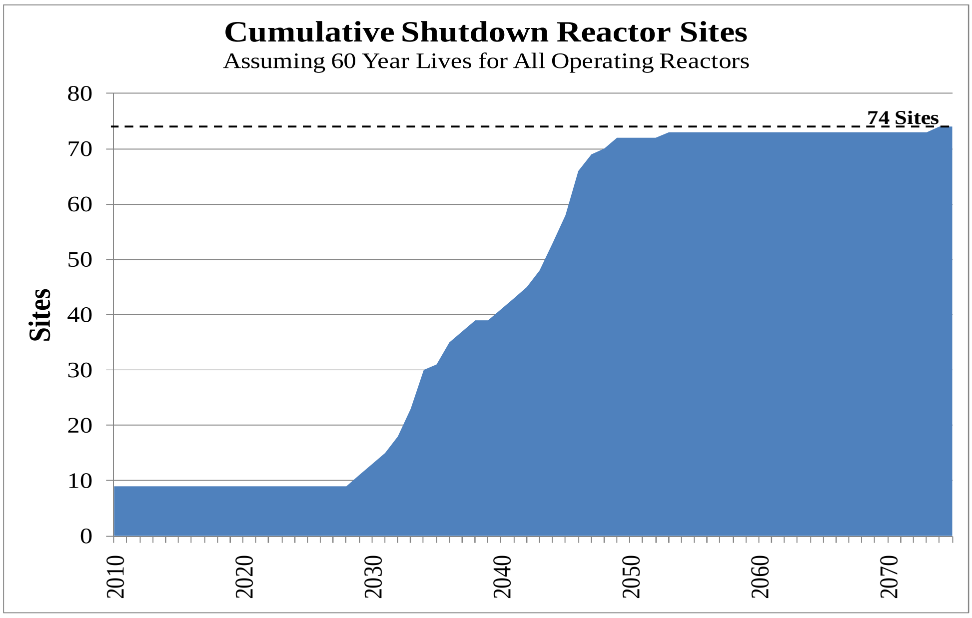

Figure 7. Projected Growth in Cumulative Shutdown Reactor Sites

67 U.S. Department of Energy, *Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites*, December 2008, DOE/RW-0596.

The current situation involves storage at reactor sites of almost all of the approximately 65,000 metric tons of spent fuel generated by U.S. reactors to date. Over two-thirds of this fuel is in pools that were originally designed to hold only a fraction of the amount they are now storing, with increasing amounts of stranded storage at shutdown sites, and with no foreseeable date for changing the situation. This situation was neither consciously intended nor anticipated when national nuclear waste management policy was established in 1982. While the Nuclear Waste Policy Act gave utilities responsibility for interim spent fuel storage until the fuel could be accepted by DOE for disposal in a repository, it was expected that that this period of interim storage would be relatively short. At the same time, even the strongest supporters of the repository program recognized the potential need for MRS facilities as a backup in the event that repository development were to be delayed beyond the time at which reactors began to be decommissioned.[68]

Nearly four decades later, circumstances and expectations have clearly changed. The termination of the second repository program and the narrowing of site investigations for the first repository to a single site at Yucca Mountain in the 1987 Nuclear Waste Policy Amendments Act eliminated the substantial redundancy built into the original repository development program, placing all of the government's "eggs" in a single basket and providing no backups if that site did not work out. Furthermore, the Amendments tied the development and operation of an MRS facility tightly to the repository. This meant that the MRS could not function as a form of backstop to allow federal waste acceptance to go forward in the event of major delays or failures in the repository program.

The Subcommittee believes that it is important to restore the original expectation that the utility responsibility for interim SNF storage is not an open-ended commitment. This means moving forward expeditiously to develop consolidated storage capacity so that it is possible to begin transferring spent fuel from utilities to federal custody pending future disposition.

We have heard many recommendations that whatever else is done, the fuel now stranded at the currently shutdown sites should be removed as a first step. Access to consolidated storage would make it possible for those sites, which are serving no useful purpose (other than storing spent fuel), to be completely decommissioned and returned to economically productive or otherwise beneficial uses. Among other benefits, this could mitigate the impact on the host communities' need to provide emergency response capabilities and of the loss of economic activity and income associated with the reactor.

Even limited storage capability at a central site would allow for a relatively rapid reduction in the total number of sites at which spent fuel is stored. For example, a facility with a capacity of not even 3,000 tons could handle all of the spent fuel now stored at the nine currently shutdown commercial reactors and could quickly lead to a net reduction of eight in the number of sites at which spent fuel is stored. Of course, a much larger facility or set of facilities would be needed by the early part of the next decade if

[68] The House Committee on Interior and Insular Affairs, which strongly supported proceeding to develop repositories rather than storage facilities, nonetheless saw MRS facilities as a back-up in the event of failure or serious delay in the repository program past the point at which reactors began to be decommissioned. House Report 97-491, Part 1, Report to Accompany H.R. 3809, April 27, 1982, p. 44. The early recognition of the importance of avoiding continued storage of fuel at reactor sites after the reactor ceases operation is reflected in the Standard Contract provision that allows DOE to give priority to acceptance of fuel from shut down reactors.

the aim is to transfer fuel from commercial reactors nearing the end of their operating lives and thereby avoid a proliferation of stranded fuel storage sites and the associated maintenance costs.[69]

While we believe that spent fuel can continue to be stored safely and securely at shutdown reactor sites, we also believe that safety and security can be enhanced (or maintained at the same level much more cost effectively) by moving the fuel to one or more consolidated facilities. The largest single cost factor favoring centralized storage is the avoided cost of providing continued maintenance at shutdown sites, where the entire cost of providing security and oversight is attributable solely to the continued presence of fuel on the site. *Even assuming no further change in security requirements at shutdown sites, the cost savings from consolidating spent fuel now being stored at those sites could be sufficient to pay for the cost of the centralized facility.*[70] If security or safety requirements increase for any reason in the future, the cost savings achievable through centralized storage would rise accordingly. Moreover, this cost advantage would tend to increase as the number of shutdown reactor sites with stranded fuel grows.

In summary, while the current situation at the shutdown reactors does not present immediate safety or security concerns, we believe that the U.S., with the oldest and largest nuclear power program in the world, can do better. The implication that any new reactor site will become a very long-term waste management site by default adds an unnecessary burden on new investments in nuclear power and constrains the nation's ability to rely on future nuclear plants as an option for the meeting energy needs. There are important equity issues involved as well. The growing number of communities hosting stranded fuel storage facilities were never asked about, and never contemplated or approved, the conversion of the reactor sites into indefinite long-term storage facilities. The nation should not ask these communities simply to wait patiently and have faith that, like Dickens' Mr. Micawber, sooner or later "something will turn up." It seems clear that if one or more sites for consolidated storage facilities can be found using the consent-based process we recommend, considerations of fairness alone argue strongly for moving spent fuel there from the shutdown sites.

4.2.2 Consolidated storage would enable the government to begin meeting waste acceptance obligations in a timely way.

The standard contract DOE signed with utilities pursuant to the NWPA of 1982 required DOE to begin accepting waste from the utilities by January 31, 1998, in exchange for their payment of a fee on nuclear generated electricity. Federal courts have found that DOE is now in partial default of that contractual requirement and are awarding damages to utilities to compensate for the cost of DOE's breach.

Moving spent fuel to an interim storage site would enable the federal government to begin fulfilling its legal obligations with respect to the disposition of spent fuel. This would provide a concrete demonstration of the federal government's commitment to meeting its obligations, which in turn could enhance rather than reduce confidence that the government will also meet its statutory obligations to develop a permanent repository.

As discussed in more detail in Section 6.2, the establishment of consolidated interim storage capacity would also limit a large and growing source of financial and legal liability to the federal government and ultimately U.S. taxpayers. (Taxpayers are already covering some of these costs because damages

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[69] Cliff W. Hamal et al., *Spent Nuclear Fuel Management: How centralized interim storage can expand options and reduce costs*, http://www.brc.gov/index.php?q=library/documents/commissioned-papers)

[70] Hamal, op. cit.. See also *The Future of the Nuclear Fuel Cycle*, An Interdisciplinary MIT Study, p. 50.

awarded by the courts to date are being paid from the federal Judgment Fund, not the Nuclear Waste Fund). DOE currently estimates that total damages could amount to $16.2 billion if DOE were to begin accepting spent fuel in 2020. This may be a best-case scenario: DOE has previously estimated that liabilities will increase by roughly $500 million annually if the schedule for starting spent fuel acceptance slips further beyond 2021.

It now appears that a storage facility could be the fastest and surest path for the federal government to begin performing under the contracts and ultimately achieve acceptance rates that can stop the further growth of taxpayer liability. There are no technical, regulatory or legislative obstacles to bringing a federal storage facility up to the point of construction, at which time legislative authorization to proceed—independent of the status of a permanent repository—would be required. Regulations for independent spent fuel storage facilities have been developed and used to approve several types of storage technologies.[71] For example, DOE has obtained NRC licenses for dry cask and dry vault spent fuel storage facilities at the Idaho National Laboratory, with licensing processes that required between 2.5 and 4.5 years. Furthermore, the MRS provisions of the NWPA as amended in 1987 already authorize the federal government to find a storage facility site, design a facility, and obtain a construction authorization.[72]

Apart from commercial spent fuel, the Federal government also is liable for the eventual disposition of waste from defense production facilities. Enforceable commitments to remove federally owned waste have been made in cleanup agreements with the host states of Washington, South Carolina, and Idaho. There appear to be no technical or safety-related reasons to move defense high-level waste and spent fuel from temporary storage at the DOE sites where these materials are now located, before final disposal capacity becomes available. Direct disposal of both defense high-level waste and the West Valley high-level waste at an appropriate site (without interim storage at another location) should be pursued, as it is highly unlikely this material will ever be reprocessed.

However, the Subcommittee does *not* believe that defense waste disposal should be deferred. To the contrary, the comparatively smaller volume of waste and its more homogeneous properties may make it easier to site and design a facility for disposal of these materials. The Subcommittee takes no position on whether separate repositories for defense-related and commercial waste are needed; however, if a defense waste repository becomes available on an accelerated basis, the demonstration experience gained may make siting and designing a repository (or expanding the defense-related one) for commercial SNF less difficult. And DOE would avoid the financial penalties for not meeting its site cleanup agreements, which could amount to millions of dollars per year.

Finally, although much of the Federally-owned high-level waste and spent fuel was generated to develop nuclear weapons, a smaller inventory of spent fuel exists and is being generated by the U.S. Navy's nuclear fleet. Continued Navy facility operations in Idaho depend upon the future availability of disposal capacity at a suitable repository site for naval spent fuel.

The key uncertainty affecting prospects for a consolidated storage facility is the availability of a site. The technical requirements for storage sites are far less demanding than for repositories, making it much easier to find sites that would have the necessary technical qualifications and an accepting host community. There have been some indications that willing host communities can be found; for

[71] Multiple types of dry cask technologies as well as dry vaults. While no ISFSIs using pools have been proposed, there is little doubt that pools – the storage technology for which there is most experience - would not raise any new technical issues.
[72] NWPA, sections 144-149.

example, when DOE began implementing the Global Nuclear Energy Partnership (GNEP) initiative under the Bush administration, some eleven communities expressed interest in hosting a recycling facility that would include capacity for interim spent fuel storage.[73] This suggests grounds for optimism that a new initiative to find one or more willing hosts for interim storage facilities can succeed.

4.2.3 Consolidated storage would provide flexibility to respond to lessons learned from Fukushima

Centralized storage facilities would provide flexibility to respond to changes that might result from reassessments of current practices in light of the events at Fukushima. The current *de facto* national spent fuel storage strategy involves maximizing the amount of spent fuel that can be stored in reactor pools through use of high-density storage racks, and then moving the older fuel into dry storage casks on site as needed to maintain enough free space in the pools for discharge of the full reactor core. [74] We believe that these storage arrangements are generally safe and robust. However, the fact that in the Fukushima accident the spent fuel in the reactors' pools appears to have played a significant role suggests that this *de facto* policy will be examined in the context of an overall assessment of the lessons to be learned from the accident. The nuclear industry and the NRC are currently reexamining and re-analyzing spent fuel inventories, storage configurations, equipment, and procedures to ensure that current storage methods remain safe, and to improve system performance in the event of an emergency. In addition, the BRC is recommending that the National Academies conduct an independent assessment of lessons learned from the Fukushima accident.

While no determination has been made that current storage arrangements are not adequately safe, results from these assessments may strengthen the case for developing consolidated storage capability. A consolidated storage facility could enhance overall safety since it could be located where there is a very low probability of extreme events—unlike reactors, for example, it need not be near a large source of water. It could also provide a wider range of storage options than is currently available. For example, if it were decided to reduce the inventories stored in reactor pools, as has been recommended by some,[75] it might be desirable to have one or more consolidated storage facilities that would have pool capacity to accept fuel younger than the nominal five years after discharge usually assumed for the transfer into dry storage.[76] This capability would allow a focus on reducing the heat load in reactor pools by preferentially removing the hotter fuel, should that be determined to be the best approach. After adequate additional cooling, the fuel could then be transferred into dry storage in a staged process. (Note that at the Fukushima facility, nearly 60 percent of the fuel discharged from the six reactors to date had already been transferred into a shared pool, leaving relatively small inventories

[73] In directing DOE to "develop a plan to take custody of spent fuel currently stored at decommissioned reactor sites to both reduce costs that are ultimately borne by the taxpayer and demonstrate that DOE can move forward in the near-term with at least some element of nuclear waste policy" in 2007, the House Appropriations Committee said the Department should engage these 11 sites as part of a competitive process to locate a site for a storage facility. http://www.brc.gov/index.php?q=document/nuclear-waste-there-need-federal-interim-storage-executive-summary-report-monitored-retriev

[74] This approach is consistent with the incentives for utilities to use the most cost-effective storage measures—expanding reactor pool capacity—before incurring the substantially higher costs of dry storage.

[75] Alvarez et al., "Reducing the Hazards from Stored Spent Fuel Power-Reactor Fuel in the United States," Science and Global Security 11: 1-51, 2003

[76] This would be consistent with common practice in Sweden and France, where fuel is removed from reactor pools within a year after discharge and moved to central pool storage pending later disposition. (In Sweden, the fuel is stored for disposal; in France it is stored for reprocessing.)

(compared to U.S. practice) in the reactor pools. This shared pool appears to have survived the combined effects of the earthquake and tsunami relatively unscathed.)

By allowing even relatively recently discharged and still hot fuel assemblies to be moved from a reactor pool using transportation-only casks and to be stored safely underwater pending later disposition, a consolidated federal storage facility that includes a pool would also provide a "quick response" capability to remove fuel from reactor pools on short notice and with minimum operational demands on the reactor operators. This could greatly simplify the management of a post-accident situation at a reactor. For example, it could reduce risks associated with the fuel in the pool if it has been affected by the accident, free pool space for other purposes (e.g. storage of radioactive debris), or simply take the fuel off the list of things requiring attention by the reactor's operators.[77] As Fukushima has shown, completely unexpected difficulties can arise suddenly. At present, the U.S. lacks any planned and prepared capability to receive spent fuel in emergency situations, even though the standard contracts do permit modification of the contractual receipt priority ranking to accommodate such situations.

4.2.4 Consolidated storage would support the repository program

The Subcommittee believes that siting and developing one or more consolidated storage sites would support a successful repository program both during the process of finding suitable repository sites, and during subsequent repository operations.

First, the process of establishing consolidated storage capability would provide technical and institutional experience that would benefit repository development and operation. However spent fuel is stored over the next decades, billions of dollars will be spent in the process. Myriad small-scale operations to transfer fuel from pools into dry casks at multiple reactor sites will provide little experience that could benefit the development and operation of a national system to provide for the transportation and disposition of spent fuel on a large and sustained scale. All of the issues associated with the ultimately unavoidable tasks of siting central facilities and moving the spent fuel there from reactor sites will be faced for the first time at the first repository, further complicating what is already sure to be a challenging task. In contrast, developing and operating one or more consolidated storage facilities would improve prospects for implementing a fully integrated waste management system. Much of the experience gained from siting, testing, licensing, and operating such a facility would be transferable to the development and operation of one or more permanent disposal facilities,[78] since all the activities (apart from waste emplacement for disposal) would be the same.

In addition, consolidated storage would provide flexibility to enable an adaptive, staged approach to repository development. The NWPA of 1982 tied the start of the federal government's contractual obligation to accept spent fuel to an ambitious target date for operation of the first repository, January 31, 1998, and did not authorize DOE to site and construct a storage facility as an alternative means to meet this obligation. This put great pressure on DOE to maintain the prescriptive repository siting schedule laid out in detail in the Act, since operation of the first repository was the only available way for DOE to meet its contractual obligations. While the 1987 Amendments authorized the construction

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[77] The MRS Review Commission concluded that "in view of the continuing delay in the building of a repository… it would be in the national interest to have available a safety net of storage capacity for emergency purposes, such as an accident at a nuclear power plant, which would make it advantageous to have the plant's spent fuel pool available for decontamination of affected parts of reactors and for storage of debris." The Commission recommended construction of a Federal Emergency Storage (FES) facility with a capacity limit of 2,000 metric tons.

[78] 1987 OCRWM Mission Plan Amendment, DOE/RW-0128, June 1987, p. 116.

of an MRS facility and established two parallel siting processes for it, they also linked this facility closely to the repository; it could not be constructed until construction of the repository was authorized. This did nothing to mitigate—on the contrary, it may have heightened— pressure on the schedule for developing Yucca Mountain after it became the only repository site under consideration.
As early as 1990 the National Academies' Board on Radioactive Waste Management recommended adopting a more flexible, adaptive approach to site investigation and repository development. This issue is being considered in the report of the BRC's Disposal Subcommittee. From the perspective of the Transportation and Storage Subcommittee, however, it is clear that by allowing federal acceptance of spent fuel to proceed at an adequate and steady rate, both before a disposal facility is available and when it is in operation, consolidated storage would provide the flexibility to proceed with an adaptive, staged approach to repository development, unencumbered by the imperatives of meeting contractual waste acceptance obligations.

This flexibility is particularly important during the most delicate and challenging phase of repository development: finding a technically and institutionally workable site or sites. Once a disposal facility is open, consolidated storage would provide a buffer, allowing utilities to continue to ship spent fuel away from reactor sites as scheduled while construction and loading of the repository could proceed in a staged, adaptive process tailored to the particular circumstances of the repository.

The likelihood of a successful repository program thus is enhanced by provision of federal interim storage. But, as discussed further below, the continued commitment to a robust repository development program is necessary to provide confidence that interim storage facilities do not become *de facto* permanent disposal facilities.

Even after a repository is operating at full scale, availability of a separate consolidated storage facility could facilitate the smooth operation of the waste management system. Separate storage capacity would provide valuable redundancy in the waste management system so the government could continue accepting fuel even if a repository had to slow or cease operation for a period of time for any reason. It would add surge capacity to facilitate the flow of spent fuel to the repository, and even allow the rate of receipt of fuel to be increased beyond the receipt capacity of the repository for an extended period if that proved desirable.

Finally, consolidated storage offers opportunities to simplify repository operations. For example, by accumulating a substantial inventory of spent fuel in one place, the storage facility could take over some of the thermal management activities that might be required for efficient repository operation (e.g. blending hot and cool fuel assemblies to create a uniform thermal load for waste packages). A consolidated storage facility would even offer the option of packaging the waste for disposal before it is shipped to the repository, greatly simplifying operations at the repository site, which could be limited to receiving waste packages in transportation overpacks, removing them, and emplacing them underground. (In Sweden, for example, the decision has been made to construct the disposal packaging facility at the site of their interim storage facility rather than at the repository site.)

4.2.5 Consolidated storage offers technical opportunities for the waste management system

Once a site with spent fuel receipt, handling and storage capabilities is available, it can allow other valuable activities that would benefit the waste management system.

Consolidated storage would provide a capability for long-term monitoring and testing of dry storage

and work on improved storage methods. We have discussed in section 3.6 the importance of ongoing monitoring and research to explore fuel degradation mechanisms and other issues associated with long-term dry storage. While some of this work can be done in laboratories, key aspects require the ability to handle and open loaded spent fuel storage containers under dry conditions and remove the fuel for inspection.[79] A consolidated storage facility with laboratory and hot cell facilities and a substantial quantity and variety of spent fuel in dry storage systems would provide an excellent platform and focal point for an ongoing R&D program to better understand how the storage systems currently in use at both commercial and DOE sites perform over time.

Such a national center for ongoing research on all aspects of the storage of spent fuel could be a significant ancillary benefit for a community willing to host a storage facility. For example, Spain's effort to find a volunteer host for a storage facility for spent fuel and a small amount of high-level waste included a technological research laboratory to deal with waste processing, waste forms, disposal of HLW as well as spent fuel, etc. as an integral part of the facility.[80] Eight volunteer communities for the integrated storage/research facility were identified and selection of a final site in Spain is expected soon.

Consolidated storage would provide options for increased flexibility and efficiency in storage and future waste handling functions. Section 3.4 discussed the proliferation of dry cask storage types and sizes, and the importance of achieving greater standardization of these systems to simplify the operation of the waste management system. Shipping spent fuel from operating reactors before it is placed in dry storage at reactor sites would facilitate the standardization of storage and transportation systems and could make it possible to use more cost-effective storage systems at a central facility.[81]

In addition, consolidated storage would provide a flexible, safe, and cost-effective means for waste handling operations that might become necessary. Consolidated storage facilities at one or more locations could more safely and efficiently provide services such as repackaging/sorting of fuel for final disposal (thereby avoiding the need for extensive handling at many reactor sites). For example, performing management activities at consolidated storage facilities instead of at multiple reactor sites can be expected to reduce total worker doses because of the greater ability to use remote operations and remote handling facilities.[82] This could be particularly important if changes that occurred in the spent fuel as a result of extended storage made it necessary to open storage containers and repackage

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[79] These aspects include the following elements of the research program recommended by the Nuclear Waste Technical Review Board in its recent report on the technical basis for extended dry spent fuel storage:

- Inspection and monitoring of fuel and dry-storage systems to verify the actual conditions and degradation behavior over time, including techniques for ensuring the presence of helium cover gas
- Verification of the predicted mechanical performance of fuel after extended dry storage during cask and container handling, normal transportation operations, fuel removal from casks and containers, off-normal occurrences, and accident events
- Design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage

U.S. Nuclear Waste Technical Review Board, Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel, December 2010.

[80] *ATC: The Centralised Storage Facility for the Spanish Spent Nuclear Fuel and High Level Radioactive Waste*, Pablo Zuloaga, ENRESA, http://www.brc.gov/index.php?q=meeting/open-meeting-1).

[81] "If standardization is not mandated by the Federal government, then an MRS facility that accepts waste early could promote standardization by reducing the variety of spent fuel forms and packages to be handled and limiting the number of reactors providing storage for other than intact, unpackaged spent fuel." MRS Review Commission, p. 97.

[82] The MRS Review Commission evaluated occupational doses for the no-MRS, linked MRS, and unlinked MRS systems and concluded that the unlinked MRS system would have the lowest doses because of "greater reliance on remote operations and remote handling facilities" at the MRS. *Is There a Need for Interim Storage?*, 1989, p. 13.

fuel before it could be moved elsewhere for disposition.[83] Storage facilities at shutdown reactors do not have any of the fuel handling and recovery capabilities that would be provided in a consolidated facility. Once the reactor pools have been decommissioned and removed, there is no capability to do anything other than load the sealed storage containers into transportation overpacks. In effect, these facilities are simply guarded parking lots for storage casks. A new fuel handling facility would have to be constructed if repackaging were necessary, at considerable cost.

Considering the uncertainties in this area, it is prudent to enable a planned, deliberate, and reliable process for moving spent fuel from reactor sites to a central facility before any such issues arise and where they can be dealt with much more easily and cost effectively than at multiple shutdown sites. The importance of consolidating the storage of spent fuel before there might be a need to reopen dry storage containers increases as the period of interim storage being contemplated approaches a century or even longer.[84]

4.3 Principal objections to consolidated storage

The Subcommittee has also heard and considered arguments *against* proceeding with consolidated interim storage. The principal arguments are discussed below.

4.3.1 Adverse impacts on the development of a repository

Perhaps the most longstanding and persistent concern that has been expressed about providing a centralized storage facility is that it could become a *de facto* disposal facility and inhibit progress toward the development of one or more permanent repositories. This concern is reflected in the provision in the 1987 Nuclear Waste Policy Amendments Act (NWPAA) that explicitly prohibits the construction of an MRS facility before a construction authorization for the first repository has been issued by NRC, and limits the capacity of the facility to a maximum of 15,000 MTHM.

In recommending expeditious development of consolidated storage capacity, we recognize that the broader challenge will be to establish appropriate linkages between interim storage and permanent disposal in which both objectives are seen as essential and complementary components of a comprehensive strategy for managing all aspects of the back end of the nuclear fuel cycle. In the NWPA, Congress recognized that both temporary storage and ultimate disposal are necessary, but the Subcommittee believes that the linkages between the two that are now in the law need to be relaxed in light of current realities.

Instead of one or more consolidated storage facilities, temporary storage is now being implemented at dozens of operating and shutdown reactors, and throughout the DOE complex. The repository program, meanwhile, has stalled with prospects of near-term progress uncertain at best. Meanwhile, litigation by the utilities, and now by several states that are hosting inventories of DOE-owned waste, has been ongoing for over 10 years. In light of the current situation and the experience of the last two decades,

[83] The MRS Review Commission explicitly evaluated the argument that a system using dual-purpose storage/transportation casks for storage at reactors would provide as much flexibility as a system including a centralized MRS facility and concluded that it would not because they could not be certain "that a dual-purpose cask could be developed that could be used for prolonged storage and then transported without having to be returned to a spent fuel pool or opened." Ibid., p. 95.
[84] The recent MIT fuel cycle study refers to storage on the order of a century. NRC is evaluating the implications of storage for a period of up to 300 years.

the Subcommittee believes it necessary to reexamine how consolidated interim storage and permanent disposal might be linked in ways that actually enhance prospects for system success, instead of increasing the likelihood of failure.

Linkages can be useful, but they can also have unintended consequences and must be constructed very carefully. The way the 1987 amendments to the NWPA linked the construction and operation of a storage facility to the licensing of a repository, for example, proved counterproductive and should be revisited. As the MRS Review Commission concluded in a 1989 report to Congress on the need for a consolidated federal MRS facility: "Because of delays already experienced in the repository schedule and continued uncertainty surrounding the repository's location and date of operation, the value of the MRS would be greatly diminished if its construction were tied to the schedule of the repository."[85] More than 20 years later, this conclusion remains valid.

Certainly, efforts to develop consolidated storage must not hamper efforts to move forward with the development of permanent disposal capacity. In testimony and other information provided to the Subcommittee, commenters emphasized that decisions about spent fuel storage, disposal, and potential reprocessing or recycling are all interrelated, and should be addressed comprehensively as part of an integrated strategy. An effective integrated national waste management plan must provide for the siting and development of one or more permanent disposal facilities. But it is clear that such facilities will be delayed far longer than was expected either in 1982 or 1987, and that it is now time to provide federal consolidated storage capacity to begin the orderly transfer of spent fuel from reactor sites to federal facilities independent of the uncertainties about when a repository will be available for that purpose.

The Subcommittee believes it is essential that success in siting and developing one or more consolidated storage sites support, not distract from, prospects for a successful disposal program. Development of consolidated storage facilities should be coordinated closely with the development of a permanent repository. Pursuing both objectives simultaneously, as part of an integrated waste management program, will allow the two programs to reinforce rather than undermine each other.

By taking a first tangible step toward meeting its longstanding commitment to manage spent fuel and high-level waste, through development and operation of consolidated storage, the federal government would address a major source of political pressure, and legal and financial liability, which will otherwise complicate efforts to move beyond the current impasse in the nation's nuclear waste management program. As noted above, success in siting, developing and operating a storage facility could also provide experience that would contribute to a repository development effort, and would facilitate flexibility in the repository program.

Just as progress on consolidated storage is important for progress on permanent disposal, the reverse is also true: efforts to site one or more consolidated storage facilities will succeed only in the context of a corollary disposal program that is effective, focused, and sustains the trust and confidence of key stakeholders and the public. A firm commitment to a robust repository siting program could increase confidence that at least one suitable site will be identified in a reasonable timeframe. This in turn should allow states and communities that might be interested in hosting storage facilities to move

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[85] Nuclear Waste: Is There a Need for Federal Interim Storage?, Report of the Monitored Retrievable Storage Review Commission, November 1, 1989, p. xvi (found at http://www.brc.gov/index.php?q=document/nuclear-waste-there-need-federal-interim-storage-report-monitored-retrievable-storage-revie).

forward with less concern about their becoming *de facto* hosts of a permanent repository.

In any case, assurance that storage facilities do not become permanent repositories by default requires changes to the current system for financing waste management activities to ensure that storage and disposal development programs do not have to compete for limited funding. As discussed at length in the next chapter, and in the report of the Disposal Subcommittee, we also recommend another key step that should minimize any adverse impact on the repository effort from a program to develop storage facilities in the meantime: allowing the funding mechanism established by the NWPA to work as intended. This would help address the concern that competition for limited financial and management resources would delay work on a repository if emphasis were placed on pursuing storage facilities. While the funding mechanism set up by the NWPA was intended to avoid resource constraints that would cause such competition, this mechanism has not worked as intended and funding limitations have been a significant problem. For that reason one of our strong recommendations is that the waste management organization should have full access to the funds that have been and are being provided by utilities (and collected from ratepayers) to cover the full costs of the program for managing and disposing of spent nuclear fuel.

4.3.2 Handling fuel twice

The Subcommittee has heard concerns about the possibility that handling and moving used/spent fuel at least twice—once from the plant site to centralized storage, and then again from centralized storage to a disposal facility—would increase the risk of accidents and the potential for workers to be exposed to radiation during handling and transport operations. It has been suggested that fuel from operating and even shutdown plants should remain where it is until it can be moved to a permanent disposal facility.

The MRS Review Commission performed a thorough analysis of risks and doses—to workers and the public—under three scenarios: no MRS facility, an MRS facility linked to the repository as required in the law, and an MRS facility unlinked to the repository. They concluded that storage at an unlinked MRS facility instead of at multiple reactor sites or at a linked MRS facility can be expected to lead to lower total worker doses because of the greater ability to use remote operations and remote handling facilities at a consolidated site. This particular benefit also increases the longer the repository is delayed. The MRS Review Commission also concluded that all of the options are safe, the total system risks are small, and these risks should not drive decisions about whether there should be an MRS facility.[86]

It should be noted that this analysis considered only normal storage operations—the analysis did not consider the additional impacts (including worker doses) that might result if storage casks had to be reopened and the fuel repackaged before transportation from at-reactor storage. Any incremental risks associated with an additional transportation and handling step involved in moving fuel to consolidated facilities sooner rather than later must be balanced against the uncertainties about whether the fuel can be moved and handled after extended storage without returning to a pool or hot cell. In the latter case, the costs (and perhaps worker doses) could be substantial if this had to be done at shutdown reactor

[86] "From a technical perspective, both the No-MRS and MRS options are safe. Although neither option is completely without risk, the risks are expected to be small and within regulatory limits, and the degree of difference in risks between the No-MRS and MRS options is so small that the magnitude of difference should not affect the decision whether there should be an MRS. "

sites. The Subcommittee believes that it would be far better to have spent fuel already located at a central facility with dedicated remote fuel handling capabilities if any such issues arise. Consequently, a plan for early initiation of deliberate movement of spent fuel to a central facility is prudent in light of uncertainties about long term storage. The additional handling and transportation involved in such a process would occur when the fuel is still relatively young – when one has the greatest confidence that there will not be issues that might require reopening casks before the fuel is moved.

4.3.3 Increased waste management cost

The Subcommittee has heard concerns about the potential for increased costs involved in siting and developing storage facilities and then moving fuel twice, first from the reactor site to the consolidated storage site and then again from consolidated storage to a geologic repository or other final disposition facility (e.g. a reprocessing plant). However, analyses of the costs of storage options examined by the subcommittee indicate that these additional costs could be more than offset by the ability to avoid growing storage costs at shutdown reactor sites.

The cost attributable to storing spent fuel reactor sites increases dramatically once the reactor is shut down. Since the cost of loading fuel into dry storage casks has generally already been incurred at this point, continued storage involves little activity other than site security and monitoring. At an operating nuclear plant, security is already in place and only incremental effort is required to include the Independent Spent Fuel Storage Installation (ISFSI) within the plant's security umbrella. The same is true for the personnel needed to monitor the status of the fuel and perform any routine maintenance. When the rest of the site is shut down, however, these structures, systems, equipment and people are still needed to tend the spent fuel, and the cost is substantial. Recent studies of storage costs use estimates of operations and management (O&M) costs ranging from $4.5 million/year to $8.0 million/year attributable directly to storage at shutdown sites, compared to $1 million/year or less when the reactors are still in operation. Absent the ability to accept spent fuel at a consolidated storage facility or repository, the added security and monitoring expenses associated with keeping stranded spent fuel at as many as 70 different decommissioned reactor sites could be in the area of $350 to $550 million per year at today's costs, using this range of estimates cited. These costs would ultimately be paid by taxpayers rather than utilities through payments from the federal Judgment Fund as damages for failure to meet the contractual obligations to accept the fuel.

Figure 8 shows the growth in O&M costs for stranded fuel storage, depending on when facilities for disposition elsewhere become available. Figure 8 is based on the most conservative estimate of annual O&M costs mentioned above ($4.5 million/year), and assumes that priority is given to acceptance of fuel from shutdown reactors. The figure shows that annual and cumulative storage costs at these sites are significant even if a disposal facility begins operation in 2030; they will rise substantially with further delays. Even if there are no delays in building offsite disposition capacity, costs will rise because waste from plants shutting down will accumulate faster than the offsite facility can accept it (assuming the rate of transfer that has long been the basis for planning). This suggests that to reduce the cumulative costs of stranded fuel storage, it will be necessary to begin moving spent fuel away from reactors that are nearing the end of their operating life, before they are permanently shut down.

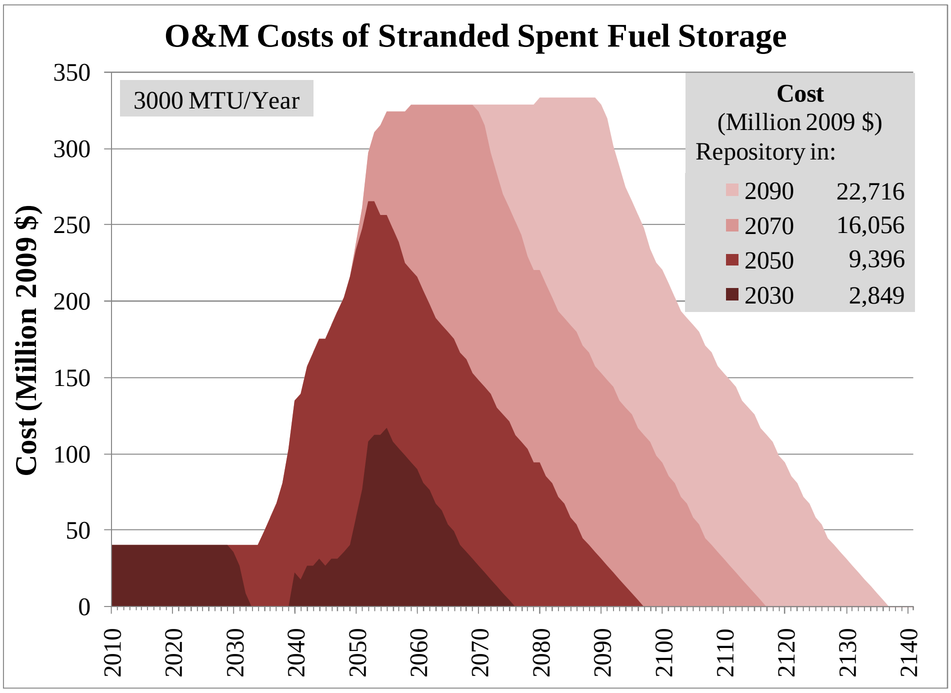

Figure 8. Operation and Maintenance Costs of Stranded Spent Fuel Storage

Moving stranded spent fuel from shutdown sites to consolidated facilities would save all but a small fraction of current monitoring and security costs because of the economies of scale achievable in a consolidated facility. Economic analysis performed for the BRC indicates that expected savings in O&M costs alone could be more than sufficient to offset the cost of consolidated storage for the stranded fuel, including the extra transportation costs incurred in moving the fuel first to the storage site and then to a permanent disposal or reprocessing facility. [87] In fact, a recent MIT analysis concluded that avoiding the costs of continued storage at just three of the currently shutdown sites could be sufficient to offset the costs of a central storage facility for their fuel.[88]

It should be emphasized that development of one or more storage facilities does not require, or even imply, an irreversible commitment to the costs of any particular long-term plan for movement of fuel there or for a specific set of activities to be performed at the site. All of the capabilities that would ultimately be desirable do not have to be developed at once, particularly since it is not clear at this time exactly what features will be needed over the many decades such a facility would be in operation. A storage facility or system of facilities can be developed in a stepwise manner, as the need for expansion of capacity and capability becomes clearer. Furthermore, the initial cost to site, design, and license a storage facility is relatively low (less than $100 million),[89] so that the money put "at risk" in giving future decision makers the option to proceed with construction and operation of a storage facility is small compared to the potential benefits from having that option available. Siting, licensing,

[87] Hamal, op. cit. The fact that avoiding the cost of stranded fuel storage significantly offsets the cost of including consolidated storage in the waste management system has long been known. In 1989, the MRS Commission concluded "[t]he major cost account increasing the cost of No-MRS cases is the increase attributable to the delay in removing spent fuel from shutdown reactors."

[88] Kadak and Yost, at p. 57.

[89] Staged development of a centralized storage facility is discussed in Hamal, op. cit., pp. 48-50.

construction and operation of a storage facility with even with limited initial capabilities would substantially resolve uncertainties about the costs and time required for these activities and provide a firmer basis for decisions concerning whether future expansion is desirable.

4.4 Near-Term Steps toward Implementing Consolidated Interim Storage

In this report, the Subcommittee makes three recommendations with respect to interim storage.

1. The federal government should proceed expeditiously to develop one or more consolidated interim storage facilities for commercial spent fuel as an integral part of a waste management system that also includes a permanent repository. Further, the federal government should begin operating these facilities and accepting spent fuel from shutdown reactors as soon as possible.

2. A site or sites for such facilities should be found using a consent-based process (discussed further in Section 6).

3. The federal government should work with utilities to develop an approach to standardize dry storage of spent fuel at reactor sites until the fuel can be accepted at a federal facility.

The Subcommittee concurs with the recommendations of the BRC's Disposal Subcommittee concerning the need for a new waste management organization to carry out federal responsibilities for the storage, transportation, and disposal of spent fuel and high level waste. There appear to be fundamental problems with the current organizational structure that are major obstacles to successful performance of these responsibilities, and the Subcommittee agrees that an organizational change offers the best chance of removing these obstacles.

At the same time, the Subcommittee also believes that initial progress on the above recommendations need not and should not be deferred until the necessary legislation to create such an organization can be adopted and a new organization has been established. Each year of delay in the federal government's acceptance of spent fuel further erodes the credibility of the federal commitment and creates additional liabilities for American taxpayers, placing a significant premium on avoiding unnecessary delays in providing the capability for performance under the contracts.

Sufficient authority already exists under the NWPA to lay the groundwork for implementing the Subcommittee's recommendations.[90] Moreover, until new legislation has been adopted, responsibility for meeting the obligations established by the NWPA remains with DOE. Even after a new organization is established, the existing contractual liabilities may remain with DOE for an extended period.[91] In that event, DOE would retain an interest in and responsibility for doing what it can to promote the timely and cost-effective development and operation of the waste management system that would enable the performance under contracts for which DOE remains liable. Furthermore, DOE would be responsible for

[90] For example, under the monitored retrievable storage provisions of the NWPA as amended, DOE is authorized to go as far as to identify a site for a storage facility, negotiate a consultation and cooperation agreement and/or benefits agreement with a host state or tribe, design a facility, and obtain an NRC license for it. Under the existing linkage requirements, construction could not begin until a construction authorization for a repository is granted by NRC.

[91] For example, the Upton/Voinovich bill to establish a fuel cycle corporation leaves the liability for contracts and settlements with DOE until 10 years after termination of a reactor's license.

any contractual renegotiations needed to accomplish recommended actions like reprioritizing the waste acceptance queue to promote more efficient transportation or removal of fuel from shutdown sites.

For these reasons, the Subcommittee recommends that DOE begin implementation of a number of steps to get the process moving. In addition, Congress should support these actions by making funding available from the Nuclear Waste Fund. Moving ahead with the initial steps now, rather than waiting for the creation of a new waste management organization, could allay concerns that a new strategy and approach will only produce further delay, and could accelerate by several years a concrete demonstration of the determination of the federal government to at last begin meeting its obligations under the Nuclear Waste Policy Act.

Specifically, DOE should proceed to:

1. Perform the systems analysis and design studies needed to define the required capabilities (e.g., receipt rates and storage capacity) of, and develop a conceptual design for, a highly flexible initial federal interim spent fuel storage facility. An initial conceptual design will be needed to provide a basis for discussions with potential host states/tribes/communities; it will also accelerate the eventual development of a design of sufficient detail for inclusion in a license application. DOE understands the spent fuel inventory that must be received and has an extensive knowledge and experience base related to storage system design issues and approaches on which to build.

   For maximum flexibility, the initial consolidated storage facility would have several key features:

   - It would be capable of accepting spent fuel in all types, delivered by truck or rail.
   - It would have a pool with substantial capacity to allow the acceptance of relatively young (e.g., one year from the reactor) fuel if there is an emergency situation at a reactor or if there is a policy to begin reducing the amount of fuel currently stored in reactor pools.
   - It would include a flexible R&D facility for a long-term research program on spent fuel storage (including hot cell capacity to allow storage casks to be reopened and the contents to be removed for inspection and testing purposes).
   - It would be incrementally expandable in receipt rate, total storage capacity, and fuel handling and management capabilities. The front end costs and time required to begin operations at a level sufficient to provide emergency storage capability and to remove spent fuel from existing shutdown reactor sites should be kept as low as possible, while building in the capability to expand capacity as warranted by future developments (e.g., better specification of the likely time of availability of a repository or recycling facilities).[92] Since we are recommending a consent-based siting process, this implies that strong preference would be given to potential host communities willing to accept the possibility of future expansions of capacity and function.

2. Begin laying the informational groundwork for a siting process by collecting and evaluating the information and experience gained from past efforts to develop an integrated monitored retrievable storage (MRS) facility. For example, DOE could review the preliminary siting requirements for an

[92] For example, the site must have sufficient area to accommodate expansion of its storage capacity or to site to add facilities for large-scale repackaging of fuel from dry storage systems should subsequent developments require it.

MRS facility to determine what changes might be required to reflect the type of flexible facility described above.[93] DOE could also evaluate lessons learned from the Global Nuclear Energy Partnership (GNEP) initiative under the Bush administration, which involved a preliminary siting process through which some eleven communities expressed willingness to host an advanced fuel cycle facility that would include capacity for interim spent fuel storage.

The Subcommittee also recommends that DOE be prepared to provide relevant information to any state, tribal or local government that expresses an interest in potentially hosting a storage facility, should such interest be expressed before a new waste management organization is operational.

3. Work cooperatively with nuclear utilities, the nuclear industry, and other stakeholders to (a) define the operational requirements for a standardized system for dry storage at reactor sites that will enhance the compatibility of at-reactor storage with the rest of the waste management system, and (b) address any contractual issues that would arise in implementing the use of such a system.[94] The need for greater standardization of dry storage systems has become increasingly apparent as more spent fuel is transferred to dry storage each year and as growing numbers of reactors approach the end their projected 60-year operating lives (assuming all receive life extensions). The importance of moving quickly on this issue has been heightened by the possibility that efforts to remove spent fuel currently being stored in pools will accelerate in the wake of the Fukushima accident, either because of a policy decision to reduce the amount of fuel stored in reactor pools or because some plants may close earlier than currently expected.

4.5 Key Findings

In light of the delays that have occurred in the nation's repository program, an extended period of interim storage is inevitable for a large portion of the nation's spent fuel inventory. This time can be used productively to determine how best to manage all aspects of the back end of the nuclear fuel cycle in a safe, integrated, and cost-effective manner.

1. All segments of the nuclear fuel cycle—including the siting and construction of new plants, the operation of existing plants (with or without license extensions), and the interim storage of waste—require appropriate confidence that waste will eventually be safely treated and disposed of. That said, it is not necessary to resolve every technical or scientific issue related to disposal before activities in other parts of the fuel cycle can be allowed to continue or expand. However, involved entities and the public need to have reasonable assurance that actual progress on treatment and disposal is being made. Rulemakings and legislation on the waste confidence issue can only partially address this need for assurance; they cannot substitute for tangible progress toward developing disposal capacity.

2. Storage of nuclear materials at sites where these materials have been generated, including at commercial power plants and federal defense production sites, will continue for many years. Storage will play a pivotal role in any integrated strategy involving eventual disposal or new fuel cycle technologies. It is also the only component of a management strategy for

[93]U.S. Department of Energy, Preliminary Site Requirements and Considerations for a Monitored Retrievable Storage Facility, DOE/RW-0315P, August 1991

[94]As noted above, DOE may well retain the liability for the contracts, in which case it would remain responsible for any such contractual negotiations.

the back end of the nuclear fuel cycle that is currently being deployed on an operational scale in the U.S.

Interim storage of spent nuclear fuel can provide a number of important benefits as part of a comprehensive approach to the safe and secure management of the back end of the fuel cycle. Storage is comparatively inexpensive and preserves options, particularly if future research and development allows for large-scale and economically viable re-use of this material. Storage allows the fuel to cool and thereby reduces the siting challenge for a disposal facility and/or increases the capacity of the disposal site.

3. There are compelling reasons to move forward with establishing one or more consolidated interim storage facilities, as several previous studies have also recommended. Such storage would be best utilized if it precedes the availability of disposal capacity. Interim storage would allow the government to finally begin meeting its obligations under the NWPA and would mitigate damages resulting from DOE's inability to meet its contractual commitments to the utilities. A consolidated storage facility could also serve as a national research center with greatly improved capability for undertaking long-term monitoring and testing of dry storage and work on improved storage methods. If there were changes to current industry fuel management practices that would require more rapid removal of fuel from pools, interim storage could be brought on-line quickly.

4. The case for consolidated storage is especially strong for spent fuel that is currently being stored at decommissioned reactor sites. The number of such sites is expected to increase substantially in the future. The avoided costs of storage at shutdown reactor sites may be sufficient to offset the additional costs of developing a central storage facility and moving fuel to it. Actual performance under existing utility contracts could foster a climate where needed changes in those contracts would be possible and would be more attractive to all parties than continuing costly and unproductive litigation.

5. Current storage arrangements have evolved in an *ad hoc* fashion, and not as part of a broader, integrated strategy for managing SNF and HLW. Better integration would support increased standardization of the dry storage systems in use at reactors, and facilitate efforts to optimize the order in which waste is shipped to a repository.

6. If there were substantial confidence that a disposal site would be available in the near term (within a decade or two), there would be relatively little need for consolidated storage to begin meeting acceptance obligations (although the other benefits of an integrated storage facility would still apply). However, if a repository cannot realistically be opened in the near term, then consolidated storage would take on much greater importance given the large amount of spent fuel that may be located at shutdown nuclear power plant sites by mid-century. In that case, however, it could also be much more difficult to site a consolidated storage facility due to concerns that it would become a de facto permanent facility. Thus, a longer timeframe (more than several decades) for repository development simultaneously strengthens the rationale for proceeding with consolidated storage, and increases the difficulty of siting such a facility.

7. Recommendations being made by the BRC's Disposal Subcommittee regarding the need for (a) a new waste management organization to take responsibility for consolidated interim

storage and final disposition of SNF and HLW and related transportation requirements; (b) Congressional and administrative action to ensure that the Nuclear Waste Fund and fees are available for the purposes for which they are intended; and (c) a new approach to the siting of critical waste management facilities. Recognizing that it will take some time to implement these recommendations, however, it is important to begin laying the groundwork for rapid progress on consolidated interim storage capacity without further delay. There are several concrete activities DOE can and should undertake to that end in the near term, including (a) performing the systems analysis and design studies needed to define the required capabilities of, and develop a conceptual design for, a highly flexible initial federal interim spent fuel storage facility; (b) begin laying the informational groundwork for a successful siting process; and (c) work cooperatively with nuclear utilities, the nuclear industry, and other stakeholders to define the operational requirements for standardized dry storage systems at reactor sites that would be compatible with the rest of the waste management system.

5. MANAGEMENT AND FINANCING CONSIDERATIONS

5.1 Restoring the Nuclear Waste Fund to its Intended Purpose

The federal government is responsible for accepting commercial spent fuel under existing contracts with utilities, whether the fuel is removed to a final disposal facility or to another location for treatment and/or storage. Whatever entity or entities ultimately site, build, and operate storage and disposal facilities, they must be able to demonstrate performance and accountability over a long period of time. This requires a stable and predictable source of funds.

At the heart of the NWPA's strategy for dealing with high level waste and spent fuel is a unique mechanism intended to provide such a funding source. Under the Act, utilities have signed contracts with DOE and pay a fee every year in exchange for the federal commitment to begin accepting spent fuel for disposal by January 31, 1998. (The fee is currently one mill—or one-tenth of a cent—per kilowatt-hour and must be adjusted as needed to recover the full costs of disposing of the waste.) This mechanism was designed to ensure that commercial nuclear generators (and their ratepayers), not taxpayers, would provide, up front, the tens of billions of dollars needed to construct and operate storage and disposal facilities over a period of a century or more. Before passage of the NWPA, a history of constrained and erratic funding for the nation's waste program had demonstrated the need for a source of assured funding to meet the Act's commitment—to commercial nuclear generators and to the American people—to deal with the waste in a timely manner.[95]

For the mechanism to work as intended by Congress, the funds paid by commercial nuclear generators were to be used by the waste program as needed to implement the law. However, actions by previous administrations and Congresses have undermined that intent: the waste program has been effectively walled off from the source of funds intended to implement the Act. This lack of access to funds has effectively returned the program to the same dependence on constrained funding that the fee-for-service mechanism was meant to end. Thus, despite the existence of a dedicated user-financed Nuclear Waste Fund, the DOE waste program remains entangled in a set of budget rules that force it to compete with other programs for limited discretionary funding through the regular year-to-year Congressional appropriations process. This has resulted in inconsistent and sometimes inadequate funding of the nation's nuclear waste program, which in turn has played a major role in DOE's failure to carry out its responsibilities under the NWPA.[96] The funding situation has also raised concerns that development of a storage facility might slow progress on a disposal facility because of competition for the limited resources available to the program. In its 1996 report, *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance*, the NWTRB highlighted this concern in light of the way the Nuclear Waste Fund was (and still is) treated in the budget process.[97]

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[95] 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.

[96] For example, the FY 1996 appropriation was 40% below the 1995 funding level. OCRWM had to abandon a new program approach that it had developed in 1994 to respond to previous budget pressures, and develop a new one that required deferral of work on (and slippage of the schedule for) a license application and abandonment of implementation of the multi-purpose canister system. U.S. Department of Energy, *Draft Civilian Radioactive Waste Management Program Plan Revision 1*, May 1996, DOE/RW-0458, Revision 1.

[97] "The costs for disposing of commercial spent fuel are paid from the Nuclear Waste Fund. But, because the disposal program must compete for funding against other energy programs both inside the DOE and before Congress, competition for funding has been and will continue to be intense. This already constrained financial situation could be squeezed even more severely by

The Subcommittee concludes that the ability to access the Nuclear Waste Fund will be essential in allowing a new waste management organization to demonstrate accountability, meet commitments, and restore credibility. Unless the funding mechanism established by the NWPA is allowed to work as intended, the credibility of commitments to implement a multi-billion-dollar, multi-decade waste management program cannot be achieved. The Subcommittee therefore recommends that the Administration and Congress act to provide full access to the Fund for the purposes for which it was intended in a way that is broadly acceptable to the utilities and ratepayers who pay the fees.[98] As with the cross-cutting issue of establishing a new entity, the BRC's Disposal Subcommittee is addressing the question of funding more generally, and is developing recommendations concerning changes to the use of Nuclear Waste Fund for full BRC consideration.

The Subcommittee also recognizes that the NWPA authorizes use of the Fund to implement consolidated storage incidental to final disposal. Any legislation to implement storage and disposal should treat both components as integral to overall waste management objectives, and should ensure that these two key components avoid having to compete for limited funds. While geologic disposal capacity is being developed, consolidated storage undoubtedly would allow the government to begin meeting its contractual obligations to remove waste from commercial reactor sites.[99]

5.2 Dealing with Ongoing Litigation

For a variety of reasons, DOE was unable to begin accepting commercial SNF by January 1998, as required under the Standard Contract. DOE and utilities have been engaged in protracted litigation since then over the Department's failure to perform its obligations, as shown in Table 2. Some 74 lawsuits have been filed, dozens of lawsuits have yet to be tried, some utilities have reached settlements with the government, and courts have reached judgments in other cases that find DOE in "partial breach" of its contracts. This means the U.S. government must pay damages incurred by utilities as a result of DOE's failure to accept fuel, even as it remains obligated to accept this fuel in the future.

DOE currently estimates that total damage awards to utilities could amount to $16.2 billion if the federal government were to begin accepting spent fuel in 2020. DOE has previously estimated that liabilities will increase by roughly $500 million annually if the schedule for starting acceptance slips further beyond 2020. DOE and the Department of Justice note, however, that one significant development in the litigation in 2008 could substantially affect damage estimates going forward. Specifically, the Court of Appeals for the Federal Circuit has ruled in one case that DOE was obligated to accept spent fuel at higher rates than were used in the settlements on which these damage estimates are based.[100] Further,

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the possible diversion of funds from the disposal program to develop and operate a centralized storage facility." U.S. Nuclear Waste Technical Review Board, *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance,* March 1996, p.26.

[98] The National Association of Regulatory Utility Commissioners (NARUC) and the Nuclear Energy Institute (NEI) recently filed suit against the DOE to halt continued collection of these fees.

[99] The new acceptance rate to be used for assessing federal liabilities described above was based on DOE's plan to use a Monitored Retrievable Storage facility to begin federal waste acceptance by 1998, some years ahead of operation of the repository. In the 1987 Mission Plan Amendment, DOE stated "The strategy preferred by the DOE to meet the terms of the contract is based on a waste-management system that includes an integral MRS facility. This strategy would achieve the goal of improved operating efficiency for the system as well as allow waste acceptance to begin by 1998." (U.S. Department of Energy, OCRWM Mission Plan Amendment, June 1987, DOE/RW-0128,) p. 11. DOE proposed development of an integral MRS facility funded through the Waste Fund to Congress in 1987 (U.S. Department of Energy, *Monitored Retrievable Storage Submission to Congress*, DOE/RW-0035/1, Rev. 1, three volumes, March 1987) and Congress subsequently authorized construction of an MRS facility in the 1987 amendments to the NWPA, making the facility eligible for funding from the Waste Fund under section 302(d)(1) of the NWPA.

[100] Yankee Atomic Electric Co. v. United States, 536 F.3d 1268 (Fed. Cir. 2008); Pacific Gas & Electric Co. v. United States, 536

the Court of Appeals directed the trial court to apply these higher rates in determining damages. If this acceptance rate is applied to settlements and decisions going forward, it could substantially increase federal liabilities.

Table 2. Status of DOE-Utility Standard Contract Litigation (as of January 2011) [101]

Standard contracts	76
Reactors covered by contracts	118
Cases filed through 2010 • Second-round	74 (6)
Claims	$6.4 billion
Voluntarily withdrawn	7
Settled	12
Separate settlement agreements	8
Reactors covered by settlements	47
Final judgments • Unappealable • On appeal	28 (6) (22)
Pending before the trial court	27
DOJ trials through 2010	27
Litigation costs through 2010 (Experts and support; no DOJ or DOE staff)	$168 million
DOJ trials expected 2011 through 2012	12
Awards (including still on appeal)	$2.2 billion
Damage payments through 2010	$956 million
Estimated total damages (if acceptance starts in 2020)	$16.2 billion
Estimated increase for each year slippage	$500 million

To date, damages in the amount of $956 million have been paid from the taxpayer-funded Judgment Fund, which is overseen by the Department of Justice. The Judgment Fund is being used because a federal court ruled in *Alabama Power Co. v. United States Department of Energy*, 307 F.3d 1300 (11th Cir. 2002), that the government could not use the Nuclear Waste Fund to pay for any of the damages incurred by utilities as a result of DOE's delay. In addition, the Department of Justice has spent $168 million in litigation costs; it has participated in 27 trials through 2010 and more are expected in the future. Because DOE is only in "partial breach" of the contracts, utilities can only file for actual damages incurred as of the date of filing, not for damages projected to be incurred later. As a result, utilities must re-file periodically—at least every 6 years, because of the statute of limitations—to recover additional damages incurred after the previous claim was filed. For this reason, a steady stream of lawsuits can be anticipated until either DOE has accepted enough waste under the contracts to "catch

F.3d 1282 (Fed. Cir. 2008); Sacramento Municipal Utility District v. United States, Nos. 2007-5052, -5097, 2008 WL 3539880 (Fed. Cir. Aug. 7, 2008).

[101] 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.

up" with the amount it should have accepted on the schedule determined by the courts, or until DOE has negotiated settlements with all the contract holders that would allow damages to be paid without further litigation.

The current litigation over the federal government's failure to meet a 1998 deadline for accepting spent fuel from commercial reactors has been expensive, time-consuming, not conducive to resolving the current impasse in the nation's nuclear waste management program, and detrimental to the full and open communication among parties needed for integrated planning concerning spent fuel management. Because most of the major recurring issues have been resolved in litigation and the outcomes are now more predictable, in July 2010 the Department of Justice suggested moving toward a simplified claims process for the purpose of settling existing lawsuits,[102] but little progress has been made to date. Settling current and pending lawsuits expeditiously would reduce unnecessary litigation costs, make it possible to assess the cost impacts of changing current spent-fuel acceptance priorities more reliably, and facilitate more open communication and coordination between the waste management organization and contract holders. The Subcommittee therefore urges all parties to work to conclude these proceedings expeditiously, either through settlement agreements or through another process, such as mediation or arbitration, consistent with the precedents set by past court decisions.

5.3 The Case for a New Approach to Prioritizing the Transfer of Spent Fuel from U.S. Commercial Reactor Sites

Under DOE's Standard Contract with utilities, priority for the acceptance of spent fuel is allocated to utilities according to the "oldest fuel first" or "OFF" principle. This does not mean that utilities would necessarily choose to ship their oldest fuel first, since they would have a contractual right to decide each year (subject to DOE's approval) which fuel to ship from which reactor (with the overall amount being determined by the OFF allocation). The current approach, however, has a number of shortcomings, particularly from the standpoint of maximizing the value of at-reactor storage as one tool in an integrated management system.

First, the current approach may limit the ability to use at-reactor storage as part of an integrated thermal management strategy for a permanent disposal facility. Assuming that a geologic repository begins operation while existing nuclear power plants are still operating, the heat output from waste packages may be an important consideration for both repository design and emplacement operations, and the ability to select which spent fuel is delivered for disposal each year may avoid the need for additional storage at the repository site to hold fuel that is too hot for immediate emplacement. However, since utilities can choose which fuel to deliver, they may prefer to send the hottest eligible fuel in their pools, assuming that the plants are still operating when waste acceptance begins. This may require more complex thermal management activities at the repository.

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[102] "Because the claims of a substantial number of utilities are not substantially affected by issues that require resolution at the appellate level, it may be possible to implement an administrative claims process with these utilities that is less expensive and more efficient than litigation and that achieves largely the same results." "Budget Implications of Closing Yucca Mountain, " Testimony of Michael F. Hertz, Deputy Assistant Attorney General, Civil Division, before the Committee on the Budget, U.S. House of Representatives, July 27, 2010.

Second, the current system can add complexity and reduce efficiency in planning for shipments of spent fuel to a consolidated facility. For example, an analysis performed for the BRC[103] showed that accepting fuel based on the OFF priority ranking could result in a situation where spent fuel is being shipped from an average of 58 to 63 nuclear power plant sites each year. In contrast, a system that gives priority to accepting spent fuel from shutdown reactor sites could mean that shipments are coming from an average of 12 to 19 nuclear power plant sites in a given year (assuming that a consolidated spent fuel management facility is available by 2030 or shortly thereafter). However, if a consolidated spent fuel management facility is not available for several decades (more than half of currently operating plants will reach the end of their extended licenses by 2040), the advantage of granting acceptance priority to shutdown plants will diminish, since many plants will have permanently ceased operation.

In both cases, of course, a robust transportation management system would need to be in place to ensure that transportation route planning, emergency response planning, and transportation campaign planning are carried out in a safe and efficient manner (see further discussion in Section 7). However, the planning challenge for transporting spent fuel from an average of 58 to 63 sites annually would be considerably more complex than in a scenario where shipments are coming from one-third as many sites or even fewer.

While a transport system based on OFF priority ranking appears to be less efficient than one based on giving priority to shutdown reactor sites, it should be recognized that nuclear operating companies can utilize their OFF acceptance rights to ship SNF from any of their nuclear power plant sites. In order to ship spent fuel from nuclear power plant sites more efficiently and minimize the impact on their own plant operations, it is reasonable to expect that a nuclear operating company would utilize its spent fuel acceptance rights to ship larger quantities of spent fuel in campaigns from selected nuclear power plant sites, rather than shipping small quantities from each site annually. Whether priority for transport is based on OFF or some other methodology, it is clear that there would be system efficiencies if SNF is transported from plant sites in according to a schedule that allows resources for route planning and emergency response training to be deployed in an efficient manner.

Assuming that a consolidated storage facility could be operational by 2030 or shortly thereafter, maximizing the costs savings that could be achieved through consolidated storage will require that priority be given to accepting spent fuel from shutdown reactor sites before accepting fuel from still-operating plants. Figure 10 (below) assumes that a disposal or consolidated storage facility begins operating in 2030, and shows how cumulative O&M costs differ if priority is given to fuel at shutdown sites versus sticking to the OFF priority ranking that is currently codified in DOE's contracts with nuclear utilities.

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[103] Eileen M. Supko and Michael H. Schwartz, *Overview of High-Level Nuclear Waste Materials Transportation: Processes, Regulations, Experience and Outlook in the U.S.,* Energy Resources International, Inc., ERI-2030-1001, January 25, 2010 , p. 74., available at http://www.brc.gov/sites/default/files/documents/012511_final_report_transportation_of_nuclear_waste_material.pdf.

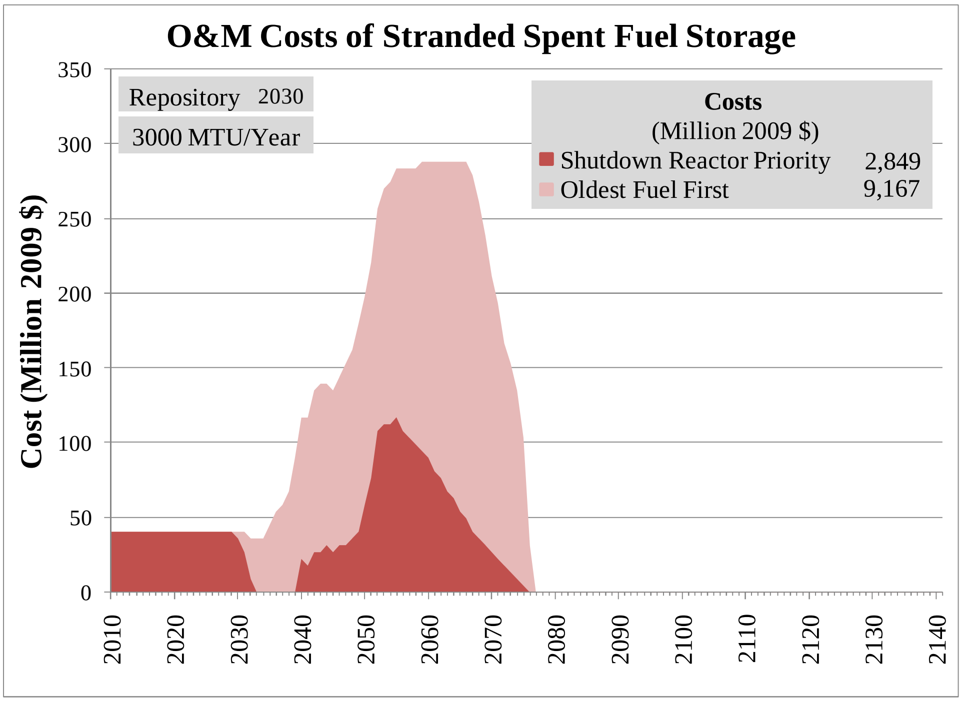

Figure 10. Operation and Maintenance Costs of Stranded Spent Fuel Storage[104]

While the Standard Contract allows DOE to give priority to fuel at shutdown sites, the Department has declined to consider this option in the past because of concerns about equity impacts on contract holders.[105]

Nevertheless, the magnitude of the cost savings that could be achieved by giving priority to shutdown sites appears to be large enough (i.e., in the billions of dollars) to warrant DOE exercising its right to move this fuel first. Although this action would disrupt the queue specified in the Standard Contract, as utilities continue to merge and a growing number of reactors reach the end of their operating licenses, every utility (or nearly every utility) will have one or more shutdown plants. In that context, giving priority to moving fuel from decommissioned sites is likely to be seen by all parties involved as being in everyone's best interest.

In sum, the Subcommittee takes the view that a new, independent waste management organization should be directed (as part of enabling legislation) to take the lead in working on a cooperative basis with nuclear plant operators to identify measures that could reduce the overall costs and impacts of an integrated spent fuel management system. As part of this effort, the new organization should seek to renegotiate contracts as necessary to implement cost-saving and risk-reducing measures, while also recognizing the contractual rights of current waste owners as originally established under existing statutes, and as subsequently interpreted by the courts.

[104] This chart uses GAO's estimate of $4.5 million/year M&O costs for stranded fuel at a shutdown site.
[105] U.S. Department of Energy, *Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites*, Dec. 2008, DOE/RW-0596, p. 3.

5.4 Key Findings

- A new institutional system is needed to make progress on addressing the nation's spent fuel and high-level waste management challenges. The BRC's Disposal Subcommittee is exploring options to recommend to the full Commission for the formation and governance of a new waste management organization. In the interests of pursuing an integrated strategy, it makes sense to consolidate responsibility for consolidated storage, permanent disposal, and associated transportation needs in a single new organization.
- Consistent access to adequate resources will be critical to the success of a new waste management organization. However, a web of budget rules now isolates the waste program from the source of funds intended to implement the Act, forcing it to compete with other programs for limited discretionary funding and obstructing the development of an integrated system by creating internal competition for scarce resources between storage and disposal activities. This must change. The nuclear waste fee and Nuclear Waste Fund mechanism must be allowed to work as originally intended: that is, to provide the full funding needed to implement the nation's integrated waste management policy and program.
- Consistent with priorities of safety, significant cost savings could be achieved by re-prioritizing the current "queue" of federal commitments to accept commercial spent fuel from nuclear plant owners and operators. DOE should exercise its rights to remove spent fuel from decommissioned reactor sites, where the cost savings are greatest. It should also seek flexibility to develop the most efficient sequencing of waste shipments from different locations. To that end, DOE or a new waste management organization should initiate negotiations with current contract holders.
- Taxpayer money is currently being wasted in unnecessary and non-productive litigation related to DOE's failure to perform under the standard spent fuel contracts. All parties should work together to settle existing or pending lawsuits and claims as expeditiously as possible. Mediation or arbitration, consistent with the precedents set by previous court rulings, should significantly reduce litigation costs and should be considered if settlements cannot be achieved.

6. ESTABLISHING POTENTIAL INTERIM STORAGE SITES: PROCESS ISSUES

6.1 Background and Discussion

Past efforts to develop consolidated storage facilities have run into significant difficulties at the siting stage of the process, just as in the case of the repository program. The original NWPA of 1982 called for DOE to develop a proposal for a MRS facility to receive SNF and high-level waste prior to its being prepared and shipped to a permanent disposal site. DOE's initial selection of Oak Ridge, Tennessee for this purpose, however, provoked strong opposition at the state level although it was acceptable, with specified conditions, to the local community.

The 1987 NWPAA effectively rescinded the recommendation of Oak Ridge and focused efforts to develop a permanent repository on a single site at Yucca Mountain in Nevada. At the same time, the 1987 amendments authorized an MRS facility and established a new DOE MRS siting and development process that linked the MRS closely to the repository. It included provisions that would allow states to receive up to $20 million per year for hosting a repository and up to $10 million per year for hosting a consolidated interim storage facility.

Finally, the amendments established a new, independent federal entity—the Office of the United States Nuclear Waste Negotiator—for the express purpose of identifying and negotiating with communities and states or Indian tribes that might be interested in hosting a consolidated storage or permanent disposal management facility on a voluntary basis. The creation of a wholly separate federal office was intended to create distance from DOE, whose relationship with many states and communities was considered tainted by the Department's past record of managing nuclear facilities and waste management efforts.

The negotiator, who was to be appointed by the President, was authorized to reach agreements under any "reasonable and appropriate terms"—there were no pre-set limits on the incentives that could be offered, in other words, though any agreement reached would need to be enacted into law by Congress.

At the time, a negotiated, voluntary agreement seemed the best hope for siting a MRS facility that would enable DOE to meet its obligation to begin accepting waste from commercial reactors by 1998.[106] The hope was that a voluntary process that offered economic incentives might succeed where other siting efforts had failed.

The Office of the Nuclear Waste Negotiator closed in 1995, after just a few years in operation: the first head of the agency, David Leroy, had not been appointed by President George H.W. Bush until 1990. And neither he nor his successor, Richard Stallings (who was appointed by President Clinton in 1993), succeeded in reaching an agreement, although at one point in 1992, seven communities, including five Indian tribes, had formally notified the government of their interest in being considered.[107] Each of

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[106] By 1989, DOE was relying on the Negotiator to find an MRS site, with linkages to the repository removed. "Schedule for the MRS facility. As indicated in Figure 1, the reference schedule for the MRS facility assumes that (1) a site will be obtained through the efforts of the Nuclear Waste Negotiator and (2) the statutory linkages specified in the Nuclear Waste Policy Amendments Act between the MRS facility and the repository (see Section 4) are modified." Department of Energy, *Reassessment Of The Civilian Radioactive Waste Management Program: Report to the Congress by the Secretary of Energy*, November 29, 1989, DOE-RW-0247.

[107] http://www.nytimes.com/1992/01/09/us/grants-open-doors-for-nuclear-waste.html?scp=2&sq=Office+of+the+nuclear+waste+negotiator&st=cse&pagewanted=print

these communities was entitled to receive $100,000 in DOE grants, while those that agreed to participate in a second phase of study could potentially have been eligible for several million in grants.

Nevertheless, it is clear from news accounts at the time that even where community leaders were interested in participating, state leaders (including governors and attorneys general) and some citizens groups remained adamantly opposed. State-level opposition may have been less of an issue for Indian tribes, which are accorded "dependent" sovereignty under the Constitution and can act independently from a state, but tribal councils that put themselves forward also encountered opposition—in some cases from members of the tribe who organized within the community as well as from outside advocacy organizations. Throughout, the government's voluntary siting effort was subject to charges of environmental racism and concerns it was taking unfair advantage of rural communities facing economic hardship. This is a recurrent issue that will need to be addressed in future voluntary siting efforts.

A December 2010 report by MIT on storage issues summarizes the reasons offered by Mr. Stallings (in an interview after he left office) for the failure of the independent negotiator process:

- "It was a very hard sell";
- Public fear of nuclear waste despite the safety of storage;
- Political realities—governors and other elected state leaders could not be seen as supporting proposals that would bring nuclear waste into their state; and
- Congressional belief that if the MRS was built, pressure would be taken off the Yucca Mountain disposal site project.

The report cited a conversation in which David Leroy expressed the view that "the volunteer siting process can work provided that the negotiator is given the resources and time to negotiate the terms of an interim storage facility and benefit package," although "the lack of a proposed repository makes the process more difficult."[108]

Some years after the Office of the United States Nuclear Waste Negotiator was dissolved, a utility-sponsored private corporation attempted to site a MRS facility, the Private Fuel Storage (PFS) project, on the sparsely populated Skull Valley Goshute Indian reservation in Utah. Details about offered compensation to the tribe have not been disclosed, but reportedly included millions of dollars in promised payments to the host tribe. The effort generated bitter controversy within the tribe, however, and was strongly opposed by the state of Utah and a majority of Utah citizens, according to media reports.[109] The project was halted when the Department of the Interior's Bureau of Indian affairs did not approve the tribe's lease of land for the storage facility (citing the risk that it would become a permanent repository by default) and the Bureau of Land Management denied needed railroad rights of way over federal land. These decisions were recently found by a federal court[110] to be arbitrary and

[108] Kadak and Yost, pp. 27-28.
[109] See MSNBC, "Store Nuclear Waste on Reservation? Tribe Split," June 26, 2006 (http://www.msnbc.msn.com/id/13458867/).
[110] Skull Valley Band of Goshute Indians v. Davis, 728 F. Supp. 2d 1287 (D. Utah, 2010).

capricious and were remanded for reconsideration, leaving the future of the facility "uncertain," according to a recent (2010) article that appeared in the Environmental Law and Policy Review.[111]

Negotiations in the MRS Siting Process

In 1985, a joint task force of the City of Oak Ridge and Roane County, TN, reviewed DOE's proposal to site an MRS facility in their area, using part of a $1.4 million DOE grant to the state for independent evaluation of the proposal. The task force concluded that the MRS could be safely built and operated, but that it would not generally be perceived as safe unless a number of specific recommendations were implemented in the MRS authorizing legislation. The specific concerns of the task force and some of the mitigation measures they recommended included:

- "Without diligent adherence to rules, regulations, and safety procedures, the MRS could adversely impact the surrounding population and the local environment." To mitigate this concern, the task force proposed a citizen MRS Environment, Safety, and Health Review Board to oversee operations and even be able to suspend operations in the event of releases at the MRS above agreed-to levels. Other proposed measures included specifying highway routes and standards for rail lines.

- "The proposed facility could delay construction of the geologic repository and become a de facto site for permanent spent fuel storage." To mitigate this concern, the task force recommended that authorizing legislation: 1) limit receipt to 300 metric tons until the repository received a construction authorization, 2) limit receipt to 10,000 metric tons until out-shipments to the permanent repository begin, 3) require that any expansion above 15,000 metric tons be subject to the same review and notice of disapproval procedures that applied to the initial authorization, and 4) provide for a significant "overdue-removal penalty" for any spent fuel stored at the MRS longer than 15 years.

- "The MRS facility could hinder the communities' efforts to diversify and expand their commercial/industrial base." To address this concern, the task force recommended a range of measures including payments-equivalent-to-taxes, relocation of the management of the MRS and transportation for the entire civilian radioactive waste management system to Oak Ridge, use of private facilities for MRS activities to the greatest extent possible, proximity to Oak Ridge as a major factor in procurements related to the MRS, and commitment by MRS contractors to diversification of the communities' economic base by bringing non-DOE business into the communities.

- "Public trust in DOE has seriously eroded." Citing historical experiences that "leave many skeptical that DOE's assurances regarding the MRS will be fulfilled," the task force specified measures enhancing local authority, such as: 1) consultation and cooperation agreements directly between DOE and units of local government as well as between DOE and the State; 2) preferred status for local governments in interactions with the State, DOE, and NRC regarding the MRS; and 3) a legislative requirement that DOE comply with the task forces' recommendations. They also recommended that DOE implement a procedure to guarantee private property values surrounding the MRS site and along the railroad spur serving the MRS facility.

- "The MRS may be perceived as a 'nuclear waste dump'." While the task force recognized that "the 'waste dump' label already given to the proposed MRS by many throughout the State can be proven erroneous," they specified mitigation measures including a significant DOE-funded pre-operational public education program, exhibits in the local Museum of Science explaining the MRS and its role in the waste management system, and a visitor center at the facility.[1]

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[111] "See Richard B. Stewart, "Solving the US Nuclear Waste Dilemma," Forthcoming, Environmental Law and Policy Review, 2010, http://www.brc.gov/index.php?q=meeting/open-meeting-0.

As is clear from even this very short account of past efforts to site consolidated interim storage facilities for SNF, it has proved difficult to locate a site that has enough community and state support to succeed. Clearly, process issues are extremely important, just as they have proved to be in the context of siting a permanent disposal facility.

Communities in other countries that host storage and disposal facilities have entered into agreements with utilities and their national governments to provide funding and other resources that enable those communities to be involved in siting and licensing activities, to develop and conduct independent evaluations of safety, and to develop response capabilities. In the case of Sweden, two municipalities—Oskarshamn and Osthammar—entered into an agreement with Swedish utilities and government corporations known as the "Surplus Value Agreement." Parties to the agreement (most notably SKB AB, the Swedish Nuclear Fuel and Waste Management Company) have committed up to 2 billion kronor—over $310 million—to support a number of activities, including:

- A visitors' center at the repository,
- Infrastructure and industrial development,
- Education and in-service training for residents,
- Further development of SKB's laboratories in Oskarshamn,
- Head office functions (SKB will relocate its head office from Stockholm),
- A waste encapsulation facility, and
- Investments in local energy production and other energy-related development[112].

Oskarshamn hosts the spent fuel storage facility; the final repository will be located in Osthammar.

In France, the repository program is managed by ANDRA, the National Agency for the Management of Nuclear Waste. The enabling legislation (passed in 1991 and 2006) provides for specific impact assistance to the eventual host community and to towns in the region. The assistance is overseen by a "public interest group" consisting of local and regional officials and representatives of industry. Financial support is provided by a dedicated tax on waste generators.[113] Annually, about 40 million euro, or about $5.9 million, is made available for infrastructure and other investments.[114]

Drawing from Sweden's successful interim storage facility siting effort (see Figure 11) and from experiences in siting controversial facilities in the United States, the Transportation and Storage Subcommittee has concluded that any siting process—to succeed—must be viewed as fair, credible, transparent, and consent-based. It must not only invite, but actively support, the engagement of all involved parties, including especially state, tribal, and local governments. And finally, it must be flexible enough not to force a narrow and prescriptive outcome, but be fully prepared to take advantage of siting opportunities when they arise.

[112] Electronic mail message from Urban Strandberg, University of Gothenburg, to Mary Woolen, BRC staff, March 3, 2011.
[113] ANDRA, "Radioactive Waste Repositories and Host Regions: Envisaging the Future Together," April 2009 (found at http://www.oecd-nea.org/rwm/fsc/documents/FSC_Workshop_France_2009_Proceedings_En_000.pdf).
[114] Ibid at p 12.

Figure 11. The Clab Interim Spent Fuel Storage Facility at Oskarshamn, Sweden.

Notwithstanding the difficulties encountered in past siting efforts, the Commission has heard testimony indicating that willing and supportive host communities, states and tribes could be identified in the context of an open process that engages affected constituencies from the outset and gives them actual bargaining power. Unanimous consent by all involved parties is not a prerequisite (and may be achievable only rarely, if ever), but a broad degree of acceptance appears to be. To achieve this acceptance, it would have to be clear that hosting a consolidated storage facility would offer local and regional benefits. Besides financial incentives, local benefits could include hosting co-located research and demonstration facilities or other activities that would generate new employment opportunities and make a positive contribution to the local and regional economy.

A workable process for siting any facility will take time. It will be further complicated by the timelines for needed system elements discussed elsewhere in this report, such as transportation planning. The process must be flexible enough to permit each element of the system to "ramp up" when needed. If an integrated approach is needlessly saddled with rigid milestones, each of which must be fully completed before moving to the next, the effort is unlikely to succeed.

6.2 Key Findings

- Interim storage of spent fuel has been a contentious issue and attempts to site new away-from-reactor facilities for consolidating spent fuel have been, to date, largely unsuccessful. A new approach to siting is needed.

- The BRC's Disposal Subcommittee is developing specific recommendations for an improved and more successful approach to siting for consideration by the full Commission. Many of the same recommendations would apply to the siting process for consolidated interim storage facilities.

Meanwhile, the experience of other countries that have successfully sited interim storage and permanent disposal facilities (i.e., Sweden) and from initial consultations for facility siting as part of the Global Nuclear Energy Partnership (GNEP) process should be examined for any positive lessons they may offer for future siting efforts in the United States.

- State, tribal and local elected and appointed officials have primary responsibility for public safety and protection of the environment. These officials should be fully involved in the development of storage and transportation solutions and should be the primary interface with their communities. Their cooperation and involvement in past and ongoing projects has been a critical element of success.

There may be advantages to co-locating storage facilities with other components of the back-end fuel management system, such as a research and development center focused on long-term spent fuel storage and transportation, reprocessing/recycling facilities (if pursued), or possibly geologic disposal. Co-location could reduce the total number of shipments needed; it could also increase the overall level of activity at a site and generate more long-term employment opportunities for skilled nuclear workers than a storage facility alone would require. The economic benefits of these other activities might make siting of a combined storage/disposal site more attractive. Finally, this approach would provide additional flexibility in terms of the rate at which materials must be placed in the repository. Any co-location proposal would necessarily require strong support from the host community.

DOE can undertake immediate steps to lay the groundwork for siting and licensing one or more consolidated storage facilities using existing authorities established under the NWPA. This would include performing systems and design studies; engaging in discussions with potential voluntary state/tribal/community hosts (should they wish to do so); and working with industry and the NRC to standardize dry cask storage systems. Compelling arguments exist for moving forward on consolidated interim storage without waiting for the formation of a new waste management organization.

7. TRANSPORTATION ISSUES

7.1 Background and Discussion

As the National Academies' *Going the Distance* report concluded in 2006, there appear to be no fundamental technical barriers to the safe transport of spent fuel and high-level radioactive waste in the United States. This finding, however, is contingent on continued strict compliance with the stringent regulations that are in place for the transport of radioactive materials, and on the ability of shippers and carriers to address the complex institutional and public acceptance challenges that would arise in the context of a large-scale shipping campaign. The NAS report made a number of recommendations concerning the transportation of radioactive materials that have been adopted, at least in part, by federal agencies such as the NRC, DOE, and the U.S. Department of Transportation (DOT).[115] The Subcommittee believes that other NAS recommendations that have not yet been implemented, for whatever reason, should be revisited and addressed as appropriate.

The NAS *Going the Distance* study recommended that DOE initiate transport "through a pilot program involving relatively short, logistically simple movements of older fuel from closed reactors to demonstrate its ability to carry out its responsibilities in a safe and operationally effective manner."[116] As discussed earlier, the Subcommittee recommends that one or more consolidated storage facilities be established, initially to accept stranded spent fuel from shutdown reactor sites.

The current system of standards and regulations governing the transport of spent fuel and other nuclear materials appears to be functioning well, and the safety record for past shipments of these types of materials is excellent. More details on the transport system and its record of performance are described in a commissioned paper by Energy Resources International, which is available on the BRC website. However, past performance does not guarantee that future transport operations will match the record to date, particularly as the logistics involved expand to accommodate a much larger number of shipments. In addition, spent fuel that has been stored for extended periods may be degraded and may require additional handling and preparation before it can be transported.

Even if only the 2,800 metric tons of spent fuel currently being stored at shutdown reactors are slated for initial transfer to a consolidated facility, extensive planning and preparation for transport arrangements will be required. The Subcommittee has heard testimony indicating that between 5 and 9 years could be required to plan and coordinate a transport strategy and to establish the institutional and physical infrastructure to conduct a large-scale shipping operation.[117]

As is the case with the earlier discussion on facility siting, state, tribal and local officials need to be extensively involved in transportation planning and be provided the resources necessary to conduct their vital functions in this arena. To that end, DOE or another organization should complete the development of procedures and regulations for providing technical assistance and funds for training local and tribal officials in areas traversed by spent fuel shipments, pursuant to Section 180(c) of the NWPA. Although the final destination of the material to be shipped (whether for storage, recycling or disposal) is not known, every origin site is known. DOE has a well-established practice of working with

[115] Presentation of Earl Easton, NRC Office of Spent Fuel Storage and Transportation, to the BRC Subcommittee on Storage and Transportation, Nov. 2, 2010 (materials accessible at http://www.brc.gov/index.php?q=meeting/open-meeting-3) .
[116] *Going the Distance*, p. 20.
[117] Presentation of Lisa Janairo, Midwest Council of State Governments, to the BRC Transportation and Storage Subcommittee, Nov. 2, 2010 (found at http://www.brc.gov/index.php?q=meeting/open-meeting-3).

state regional groups and other organizations to coordinate and provide technical assistance for transportation. Future programs should build upon these proven approaches.

The WIPP Transportation System
A Decade of Safe, Secure Shipments of Radioactive Waste

In March 1999, the Waste Isolation Pilot Plant (WIPP) in New Mexico received its first shipment of transuranic (TRU) radioactive waste. The experience of the WIPP transportation system provides compelling evidence that nuclear waste can be confidently transported across the nation safely and securely. The Department of Energy designed and operates the WIPP transportation system, a comprehensive structure of coordinated elements working to assure safe secure transport. Key elements of the WIPP transportation system include:

The Transport Container--All waste is transported in packages approved for use by the NRC. Several different types of shipping containers have been developed to enable shipment of both contact-handled and remote-handled waste. All packages meet NRC and U.S. Department of Transportation radiation limits.

The Drivers and Carriers--the U.S. Department of Transportation sets standards for drivers of trucks that carry hazardous cargo. DOE agreed to go beyond these requirements for its WIPP drivers and carriers. WIPP drivers must meet or exceed experience, licensing and training qualifications, and maintain good driving records. Once hired, drivers are also instructed in defensive, adverse weather, road hazards, and mountain driving, in addition to extensive WIPP relevant training, and are subject to stringent penalties if they deviate from specific procedures. Drivers work in pairs to ensure that the truck and payload are attended at all times and that drivers are rested while driving. WIPP drivers must stop and check their trucks and payload every 150 miles or 3 hours en route.

The Shipping Network and The Emergency Preparedness and Response Systems--DOT regulations require radioactive materials to be shipped on the interstate highway system unless states designate other routes. WIPP shipment protocols and routes were developed through cooperative efforts between states, tribal governments and DOE. Prior to departing a TRU waste site, state police inspect WIPP trucks to Commercial Vehicle Safety Alliance Level VI standards, the most rigorous in the commercial trucking industry. WIPP drivers notify state officials two hours before entering each state and WIPP trucks are subject to inspections at each state port of entry. The states and DOE have agreed on procedures to monitor weather and road conditions so that shipments can avoid hazards. Shipments will not depart DOE facilities if they are likely to encounter severe weather along the route. If unexpected bad weather or road conditions are encountered, procedures for the selection and use of safe parking areas have been developed. Designated federal, state and tribal officials can also monitor the shipments. While designed to prevent accidents from occurring, the WIPP transportation system also has extensive measures to address emergency response in the unlikely event a shipment is involved in a serious accident. Plans and procedures specifically designed to deal with transportation incidents involving the WIPP shipments are in place throughout the routes of the transportation system to address notification, incident command, and response procedures. WIPP has trained more than 26,000 emergency response professionals along the routes to respond effectively in the event of a WIPP-related accident. In coordination with DOE, the states have developed a WIPP-specific training regimen for emergency first responders, which are incorporated directly into hazardous materials training programs for fire fighters, police and emergency medical staff along the routes

In 1994, the National Academy of Sciences projected that WIPP's planned shipping program would be 'safer than that employed for any other hazardous material in the US.' The evidence suggests the NAS was correct in its assessment.

Finally, numerous parties have suggested that expanded full-scale testing of transportation casks (in addition to computer modeling) could be useful in enhancing public confidence in transport safety. Full-scale testing is part of the testing methodology used by the NRC in its integrated evaluation program. The NAS *Going the Distance* study endorsed the current approach and recommended that full-scale cask testing, as well as other accepted approaches, should continue to be used for technical reasons:

> *Full-scale package testing should continue to be used as part of integrated analytical, computer simulation, scale-model, and testing programs to validate package performance. Deliberate full-scale testing of packages to destruction should not be required as part of this integrated analysis or for compliance demonstrations. [p.15]*

Naval SNF Transportation

Since 1957, the Naval Nuclear Propulsion Program (NNPP) has made over 800 rail shipments of spent nuclear fuel to the Naval Reactors Facility (NRF) at the Idaho National Laboratory (INL). These shipments have been completed safely with no release of radioactivity and no injury to workers or the public.

Naval spent nuclear fuel is shipped in robust 14-inch thick solid stainless steel containers that meet or exceed all NNPP, NRC, and DOT requirements. Radiation levels measured outside the shipping container have been low, typically about 100 times less than DOT safety limits. Naval spent fuel is extremely rugged, and is designed to withstand battle shock-forces much greater than would be expected to occur in a transportation accident.

The following practices are used for naval spent fuel shipments:

- Shipments are escorted by specially trained and armed Navy couriers
- Shipments are dry—no water in the shipping container during shipment
- Shipment location and status are constantly monitored
- Government-owned railcars are strictly inspected and regularly maintained
- Shipments are coordinated in advance with railroad police and operations personnel.

The NNPP has an extensive outreach program to educate and train emergency services personnel, including periodic accident exercises near its major facilities and along typical shipping routes. These exercises provide an opportunity for civilian emergency services personnel and interested officials to learn about naval spent fuel shipments, to interact with the Navy shipment escorts, and to train and practice emergency actions for a potential response. The key lesson learned from these exercises is that a coordinated, collaborative relationship between the shipper (NNPP), rail carrier, and civilian authorities (state, tribe, local) is crucial.

In 2005, the NRC approved a staff proposal for the full-scale testing of a rail cask—of the kind expected to be used in transporting spent fuel to a high-level waste repository—in a scenario involving a collision with a locomotive traveling at high speed followed by a hydrocarbon fire. DOE supported the proposed Package Performance Study and suggested combining it with an emergency response exercise to maximize the benefits of the study. Plans to provide NRC with needed funding in 2009 did not materialize because of budget constraints (the estimated cost of the study was approximately $15 million) and uncertainties about the Yucca Mountain project. The Subcommittee recommends that if the proposed test has independent value, funding should be provided from the Nuclear Waste Fund for NRC to update these plans, and to proceed with those tests the NRC determines to be most useful.

Figure 12. SNF Cask with Personnel Barrier Loaded on a Rail Car

Figure 13. Rail Transport of DOE-Owned Spent Nuclear Fuel to the Idaho National Laboratory

Figure 14. NAC Legal Weight Truck Cask

7.2 Key Findings

- There appear to be no fundamental technical barriers to the safe transport of spent fuel and high-level radioactive waste in the United States. This finding, however, is contingent upon continued strict compliance with applicable regulations and a continued commitment to updating applicable safety requirements and protective measures.

- The safety record for past spent fuel shipments is excellent. This record itself and the reasons for it—which include extensive efforts to engage states, tribes, and local governments in logistics coordination and emergency response planning—need to be more widely understood and vigorously maintained in the future.

- To be effective, 5 to 9 years of transportation planning may be needed before large-scale shipments commence. Thus, such planning needs to take place at the very beginning of any proposed project.

- Early completion of the policies and procedures for providing funding and technical assistance to states for transportation planning purposes as required by Section 180(c) of the NWPA is an important near-term step that is required before shipments under the NWPA can begin.

- The Package Performance Study proposed by the NRC, which includes full-scale confirmatory testing of a cask, should be reassessed without regard to the status of the Yucca Mountain project. If the proposal has independent value, resources from the Nuclear Waste Fund should be used to support this project.

8. SUMMARY OF FINDINGS AND RECOMMENDATIONS

<u>Principal Findings on Consolidated Interim Storage:</u>

- Storage of nuclear materials at sites where these materials have been generated, including at commercial power plants and federal defense production sites, will continue for many years. Storage will play a pivotal role in any integrated strategy involving eventual disposal or new fuel cycle technologies. It is also the only component of a management strategy for the back end of the nuclear fuel cycle that is currently being deployed on an operational scale in the United States.

  Interim storage of spent nuclear fuel can provide a number of important benefits as part of a comprehensive approach to the safe and secure management of the back end of the fuel cycle. Storage is comparatively inexpensive and preserves options, particularly if future research and development allows for large-scale and economically viable re-use of this material. Storage allows the fuel to cool and thereby reduces the siting challenge for a disposal facility and/or increases the capacity of the disposal site.

- There are compelling reasons to move forward with establishing one or more consolidated interim storage facilities, as several previous studies have also recommended. Such storage would be best utilized if it precedes the availability of disposal capacity. Interim storage would allow the government to finally begin meeting its obligations under the NWPA and would mitigate damages resulting from DOE's inability to meet its contractual commitments to the utilities. A consolidated storage facility could also serve as a national research center with greatly improved capability for undertaking long-term monitoring and testing of dry storage and work on improved storage methods. If there were changes to current industry fuel management practices that would require more rapid removal of fuel from pools, interim storage could be brought on-line quickly.

- The case for consolidated storage is especially strong for spent fuel that is currently being stored at decommissioned reactor sites. The number of such sites is expected to increase substantially in the future. The avoided costs of storage at shutdown reactor sites may be sufficient to offset the additional costs of developing a central storage facility and moving fuel to it. Actual performance under existing utility contracts could foster a climate where needed changes in those contracts would be possible and would be more attractive to all parties than continuing costly and unproductive litigation.

- Current storage arrangements have evolved in an *ad hoc* fashion, based on individual utilities' decisions about what is optimum on a site-by-site basis and not as part of a broader, integrated strategy for managing SNF and high-level waste. An integrated national approach to storing spent fuel is needed as part of a long-term waste management program that ultimately leads to the safe and permanent disposition of radioactive materials through reuse or direct disposal. Better integration would support increased standardization of the dry storage systems in use at reactors, and facilitate efforts to optimize the order in which waste is shipped to a repository.

- Recommendations being made by the BRC's Disposal Subcommittee regarding the need for (a) a new waste management organization to take responsibility for consolidated interim storage and final disposition of SNF and HLW and related transportation requirements; (b) Congressional and administrative action to ensure that the Nuclear Waste Fund and fees are available for the purposes for which they are intended; and (c) a new approach to the siting of critical waste management facilities. Recognizing that it will take some time to implement these recommendations, however, it is important to begin laying the groundwork for rapid progress on consolidated interim storage capacity without further delay. There are several concrete activities DOE can and should undertake to that end in the near term, including (a) performing the systems analysis and design studies needed to define the required capabilities of, and develop a conceptual design for, a highly flexible initial federal interim spent fuel storage facility; (b) begin laying the informational groundwork for a successful siting process; and (c) work cooperatively with nuclear utilities, the nuclear industry, and other stakeholders to define the operational requirements for standardized dry storage systems at reactor sites that would be compatible with the rest of the waste management system.

Recommendation #1*: The United States should proceed expeditiously to establish one or more consolidated interim storage facilities as part of an integrated, comprehensive plan for managing the back end of the nuclear fuel cycle. An effective integrated plan must also provide for the siting and development of one or more permanent disposal facilities.*

Principal Findings on Research Needs to Support Long-Term Storage:

- The institutional and technical capacity exists to provide safe and secure on-site interim storage of SNF at existing or new reactors, even for extended periods of time (100 years or more). However, the issue of pool storage and the potential for fires in pools that lose water through natural or man-made events must be carefully reexamined in light of the disaster at the Fukushima Daiichi plant. The Subcommittee believes the NRC and industry are working appropriately to identify and address potential issues; in addition, the Subcommittee is recommending that the NAS be engaged to conduct an independent investigation. Such analysis might indicate that moving fuel earlier than previously planned from reactor pool storage to dry casks, either on-site or away from reactors, is a prudent safety measure. Such measures carry their own potential costs and risks, however, and will need to be carefully considered.

- NRC, DOE, and industry (through EPRI) have been engaged in rigorous research and oversight for more than two decades to ensure that current methods of storage remain safe and secure. Thus far, they have performed effectively in this area, and have adapted to changes appropriately. These efforts must continue as ongoing vigilance and effective enforcement will be critical to assure a good track record of safety and security in the future.

- The NRC is reexamining its security requirements for spent fuel storage sites and transportation systems, and it is possible that enhanced security measures may be required in the future. A number of groups have called for the implementation of HOSS, which would involve converting present storage facilities and adopting some additional safeguards. The Subcommittee concludes that the advantages and disadvantages of the HOSS proposal and of other ideas for enhanced security should be evaluated through the established NRC process.

- An important information gap that should be addressed as soon as possible concerns the storage environment and condition of spent fuel at existing dispersed sites. This information is not being collected at present because many storage systems lack the requisite monitoring instruments. Additionally, some of the spent fuel being placed in storage will have a higher burnup, different cladding, and/or be older than the spent fuel that has been evaluated to provide the technical basis for extended fuel storage. It is important to continue and potentially expand current activities by EPRI, DOE, NRC and others to explore fuel degradation mechanisms and other issues associated with long-term storage. Sustained research in this area will be necessary to ensure that the technical basis for extended storage remains sound. In addition to efforts at consolidated storage facilities to better understand the behavior of dry storage systems and their contents over time, it would be useful to explore the feasibility and utility of enhancing instrumentation in dry storage systems at existing dispersed sites to provide insights on the evolution of these systems as they age.

- It is possible that future research and field experience will identify unanticipated problems with extended fuel storage (e.g., unexpected corrosion rates or embrittlement). If so, such issues will not develop suddenly; they can be monitored and mitigated if they are detected. Sustained efforts to monitor the condition of spent fuel and its environment in dry storage systems are needed to develop a full understanding of potential degradation phenomena in stored fuel and to determine whether conditions that would require mitigation are developing.

- If future modifications to existing storage configurations necessitate increased handling of spent fuel, the additional radiation exposure that could result must be taken into account.

- As the duration of storage is extended, the amount of penetrating radiation emitted that "self-protects" spent fuel against theft or diversion diminishes (in other words, unshielded exposure to the fuel becomes less immediately debilitating and hence creates less of a deterrent to handling by unauthorized persons). This means that over long time periods (perhaps a century or more, depending on burnup and the level of radiation that is deemed to provide adequate self-protection), the fuel could become more susceptible to possible theft or diversion. This in turn could change the security requirements. Extending interim storage to timeframes of more than a century could thus require increasingly demanding security protections at storage sites.

- The Subcommittee is confident that existing processes and agencies have the capacity and expertise to conduct these ongoing assessments. The NRC (and ultimately Congress) must ensure adequate resources and funding are available to maintain this capacity.

Recommendation #2: ***Recognizing the substantial lead-times that may be required in opening one or more consolidated storage facilities, dispersed interim storage of substantial quantities of spent fuel at existing reactor sites can be expected to continue for some time. The Subcommittee has concluded that there do not appear to be unmanageable safety or security risks associated with current methods of storage (dry or wet) at existing sites. However, to ensure that all near-term forms of storage meet high standards of safety and security for the multi-decade-long time periods that they are likely to be in use, active research should continue on issues such as degradation phenomena, vulnerability to sabotage and terrorism, full-scale cask testing, and other matters.***

Principal Findings on Priorities for Fuel Acceptance:

- All segments of the nuclear fuel cycle—including the siting and construction of new plants, the operation of existing plants (with or without license extensions), and the interim storage of waste—require appropriate confidence that waste will eventually be safely treated and disposed of. That said, it is not necessary to resolve every technical or scientific issue related to disposal before activities in other parts of the fuel cycle can be allowed to continue or expand. However, involved entities and the public need to have reasonable assurance that actual progress on treatment and disposal is being made. Rulemakings and legislation on the waste confidence issue can only partially address this need for assurance; they cannot substitute for tangible progress toward developing disposal capacity.

- If there were substantial confidence that a disposal site would be available in the near term (within a decade or two), there would be relatively little need for consolidated storage to begin meeting acceptance obligations (although the other benefits of an integrated storage facility would still apply). However, if a repository cannot realistically be opened in the near term, then consolidated storage would take on much greater importance given the large amount of spent fuel that may be located at shutdown nuclear power plant sites by mid-century. In that case, however, it could also be much more difficult to site a consolidated storage facility due to concerns that it would become a de facto permanent facility. Thus, a longer timeframe (more than several decades) for repository development simultaneously strengthens the rationale for proceeding with consolidated storage, and increases the difficulty of siting such a facility.

Recommendation #3: ***Spent fuel currently being stored at decommissioned reactor sites should be "first in line" for transfer to a consolidated interim storage facility as soon as such a facility is available.***

Principal Findings on the Waste Management System:

- A new institutional system is needed to make progress on addressing the nation's spent fuel and high-level waste management challenges. The BRC's Disposal Subcommittee is exploring options to recommend to the full Commission for the formation and governance of a new waste management organization. In the interests of pursuing an integrated strategy, it makes sense to consolidate responsibility for consolidated storage, permanent disposal, and associated transportation needs in a single new organization.

Recommendation #4: ***A new integrated national approach is needed to revitalize the nation's nuclear waste program. A new organization charged with developing one or more permanent disposal facilities should also lead the development of consolidated storage and transportation capabilities.***

Principal Findings on Siting Processes and Related Issues:

- Interim storage of spent fuel has been a contentious issue and attempts to site new away-from-reactor facilities for consolidating spent fuel have been, to date, largely unsuccessful. A new approach to siting is needed.

- The BRC's Disposal Subcommittee is developing specific recommendations for an improved and more successful approach to siting for consideration by the full Commission. Many of the same recommendations would apply to the siting process for consolidated interim storage facilities.

Meanwhile, the experience of other countries that have successfully sited interim storage and permanent disposal facilities (i.e., Sweden) and from initial consultations for facility siting as part of the Global Nuclear Energy Partnership (GNEP) process should be examined for any positive lessons they may offer for future siting efforts in the United States.

- State, tribal and local elected and appointed officials have primary responsibility for public safety and protection of the environment. These officials should be fully involved in the development of storage and transportation solutions and should be the primary interface with their communities. Their cooperation and involvement in past and ongoing projects has been a critical element of success.

- There may be advantages to co-locating storage facilities with other components of the back-end fuel management system, such as a research and development center focused on long-term spent fuel storage and transportation, reprocessing/recycling facilities (if pursued), or possibly geologic disposal. Co-location could reduce the total number of shipments needed; it could also increase the overall level of activity at a site and generate more long-term employment opportunities for skilled nuclear workers than a storage facility alone would require. The economic benefits of these other activities might make siting of a combined storage/disposal site more attractive. Finally, this approach would provide additional flexibility in terms of the rate at which materials must be placed in the repository. Any co-location proposal would necessarily require strong support from the host community.

- DOE can undertake immediate steps to lay the groundwork for siting and licensing one or more consolidated storage facilities using existing authorities established under the NWPA. This would include performing systems and design studies; engaging in discussions with potential voluntary state/tribal/community hosts (should they wish to do so); and working with industry and the NRC to standardize dry cask storage systems. Compelling arguments exist for moving forward on consolidated interim storage without waiting for the formation of a new waste management organization.

<u>Recommendation #</u>**5:** ***Although the regulatory standards may differ, the general principles that the BRC recommends for the siting and development of permanent disposal facilities should apply to the siting and development of interim storage facilities, and to planning for transportation needs. Processes used to develop and implement all aspects of the spent fuel and waste management system should be science-based, consent-based, transparent, phased, and adaptive. They should also include a properly designed and substantial incentive program.***

<u>Principal Findings on Transportation:</u>

- There appear to be no fundamental technical barriers to the safe transport of spent fuel and high-level radioactive waste in the United States. This finding, however, is contingent upon continued strict compliance with applicable regulations and a continued commitment to updating applicable safety requirements and protective measures.

- The safety record for past spent fuel shipments is excellent. This record itself and the reasons for it—which include extensive efforts to engage states, tribes, and local governments in logistics coordination and emergency response planning—need to be more widely understood and vigorously maintained in the future.

- While the transport of spent fuel following extended interim storage may present unknown challenges due to fuel condition (embrittlement or corrosion), past experience, including the shipment of highly damaged fuel from the Three Mile Island 2 reactor, has shown that degraded or even destroyed fuel assemblies can be safely loaded, transported, unloaded, and stored.

- To be effective, 5 to 9 years of transportation planning may be needed before large-scale shipments commence. Thus, such planning needs to take place at the very beginning of any proposed project.

- Early completion of the policies and procedures for providing funding and technical assistance to states for transportation planning purposes as required by Section 180(c) of the NWPA is an important near-term step that is required before shipments under the NWPA can begin.

- The Package Performance Study proposed by the NRC, which includes full-scale confirmatory testing of a cask, should be reassessed without regard to the status of the Yucca Mountain project. If the proposal has independent value, resources from the Nuclear Waste Fund should be used to support this project.

Recommendation #6: ***The current system of standards and regulations governing the transport of spent fuel and other nuclear materials appears to be functioning well, and the safety record for past shipments of these types of materials is excellent. However, planning and coordination for the transport of spent fuel and high-level waste is complex, and should commence at the very start of a project to develop consolidated storage capacity.***

Principal Findings on Financing:

- Consistent access to adequate resources will be critical to the success of a new waste management organization. However, a web of budget rules now isolates the waste program from the source of funds intended to implement the Act, forcing it to compete with other programs for limited discretionary funding and obstructing the development of an integrated system by creating internal competition for scarce resources between storage and disposal activities. This must change. The nuclear waste fee and Nuclear Waste Fund mechanism must be allowed to work as originally intended: that is, to provide the full funding needed to implement the nation's integrated waste management policy and program.

- Consistent with priorities of safety, significant cost savings could be achieved by re-prioritizing the current "queue" of federal commitments to accept commercial spent fuel from nuclear plant owners and operators. DOE should exercise its rights to remove spent fuel from decommissioned reactor sites, where the cost savings are greatest. It should also seek flexibility to develop the most efficient sequencing of waste shipments from different locations. To that end, DOE or a new waste management organization should initiate negotiations with current contract holders.

- Taxpayer money is currently being wasted in unnecessary and non-productive litigation related to DOE's failure to perform under the standard spent fuel contracts. All parties should work together to settle existing or pending lawsuits and claims as expeditiously as possible. Mediation or arbitration, consistent with the precedents set by previous court rulings, should significantly reduce litigation costs and should be considered if settlements cannot be achieved.

***<u>Recommendation #7</u>*: To successfully implement a new strategy for managing the back end of the fuel cycle, a new organization will need reliable access to financial resources. The Subcommittee recommends that the Administration and Congress take action to provide full access to the Nuclear Waste Fund for the purposes for which it was intended, including funding consolidated interim storage and transportation as an integral part of broader waste management efforts. Ongoing litigation between DOE and the utilities regarding fuel acceptance should be resolved expeditiously.**