Consolidated Interim Storage of Commercial Spent Nuclear Fuel

A Technical and Programmatic Assessment

APS physics

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PANEL ON PUBLIC AFFAIRS

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Executive Summary

Approximately 54,000 tons of spent nuclear fuel are stored at operating nuclear power plants and several decommissioned power plants throughout the country. Spent fuel storage at these sites was never intended to be permanent. The current Federal plan is to place the fuel in a repository for permanent disposal in Nevada at Yucca Mountain.

Recently, appropriations committees in Congress suggested building one or more Federal sites for consolidated interim storage of spent fuel. Several reasons were identified. The schedule for opening Yucca Mountain continues to slip. Further, the Federal government faces substantial and growing liability costs the longer the spent fuel stays at reactor sites. Finally, there is a concern that the buildup of spent fuel at reactor sites and lack of progress on final disposition could be serious constraints on the growth of the domestic nuclear power industry by discouraging investment in new nuclear power plants and enhancing the difficulty of siting new nuclear power plants.

We focus on the issues associated with proposals to establish one or more sites for the consolidated storage of spent nuclear power reactor fuel as an interim measure before final disposition. In reviewing numerous reports and research articles, we find that:

- There are no substantive safety or security reasons for establishing consolidated interim storage.
- There are no compelling cost savings to the Federal government associated with consolidated interim storage, so long as Yucca Mountain is not delayed well beyond its currently planned opening.
- There is sufficient space at all operating nuclear reactors to store all spent nuclear fuel in pools and in existing or additional dry casks that will be discharged even with plant license extensions. Although, some states may limit the amount of dry storage at a reactor site.

Nevertheless, we also find that:

- Consolidated storage could facilitate the decommissioning of sites with reactors that have been shut down.
- Consolidated interim storage would establish a process for taking Federal title to commercial spent fuel and decouple private sector nuclear power plant operators from the long-term spent-fuel management problem, thereby removing a potential obstacle to siting new nuclear power plants and to continued operation of existing plants.

Such a decoupling could arguably also be accomplished if the Federal government took title to the spent fuel at the reactor sites.

A permanent repository is the cornerstone of the nation's waste management strategy. Consequently, if the Federal government were to proceed with interim storage, it should be done in a manner consistent with Federal strategies for long-term management. Further, any development of consolidated interim storage must be sensitive to the significant hurdles to siting which would make it difficult to open a consolidated storage site in less than a decade. If Congress chooses to direct the development of consolidated storage facilities, the exploration of strategies to improve their economic and social attractiveness to potential host communities should receive careful consideration.

I. BACKGROUND

Interim storage of spent nuclear fuel is ongoing in the United States. Approximately 54,000 tons of spent fuel is in interim storage at operating nuclear power plants and several shut down and decommissioned power plants throughout the country.[1]

Utilities employ two interim storage methods for spent nuclear fuel: pools and dry casks. Fuel pools are stainless-steel-lined reinforced-concrete basins of water in which the spent nuclear fuel is stored for cooling after it has been discharged from the reactor. A typical pool stores hundreds of tons of spent fuel that amounts to up to two decades of a typical reactor's operation. Pools are currently being used by all 103 operating commercial nuclear reactors in the United States.

After spending roughly five years cooling in a pool, the fuel can be transferred into dry storage casks.[2] Casks are typically constructed of one or more shells of steel, cast iron, and/or reinforced concrete to provide leak containment and radiation shielding; they typically have a capacity of roughly 10 tons of spent fuel.[3] Currently, dry cask storage is licensed at 35 nuclear plant sites in 24 states. There are a total of 65 sites with operating reactors in the United States.[4]

Although interim storage is ongoing at reactor sites, it is not a means of permanent disposition of spent fuel. Indeed, spent fuel was never intended to be stored permanently at these sites. The Federal plan is to place the fuel in a repository for permanent disposal in Nevada at Yucca Mountain. The Federal government was required by law to begin removing the spent nuclear fuel from the nuclear plants starting in January 1998, but the Yucca Mountain project has suffered numerous delays and the spent fuel remains at the reactor sites. Yucca Mountain is currently scheduled to open at the earliest in 2017.[5]

The nuclear utilities have been pressing Congress to force the Department of Energy to begin removing spent fuel from their reactor sites. Appropriations committees in Congress recently responded by suggesting building one or more sites for the consolidated storage of spent nuclear fuel.[6] Several reasons were identified. There have

[1] Department of Energy, http://www.ocrwm.doe.gov/about/pm/programbrief/briefing.htm. "Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States", National Academy Press (2006).

[2] Decay heat and radiation decrease steadily after spent fuel is removed from the reactor. After about three years, heat and radiation have decreased sufficiently to allow the fuel to be "passively" cooled. At this point the fuel can be moved into dry casks. However, most dry cask storage systems currently in use in the United States are licensed for fuel that has been cooled for at least five years.

[3] The capacity of a dry cask depends not only on its size but also on the burnup and age of the spent fuel that it will contain. The largest dry casks licensed for use in the United States can hold up to 40 PWR spent fuel assemblies or 68 BWR spent fuel assemblies. The Transportation, Aging and Disposal (TAD) Canister System proposed by DOE (DOE, 2006) can hold up to 21 PWR or 44 BWR spent fuel assemblies.

[4] "Safety & Security of Commercial Spent Nuclear Fuel Storage: Public Report" National Academies Press (2006).

[5] Statement of Edward Sproat III, Director, Office of Civilian Radioactive Waste Management, Dept of Energy to the Subcommittee on Energy and Air Quality of the House Committee on Energy & Commerce, 13 September 2006: http://www.ocrwm.doe.gov/info_library/newsroom/documents/CtrSchedule.pdf

[6] House Report accompanying "Energy and Water Development Appropriations, 2007", p 103. Senate Report accompanying "Energy and Water Development Appropriations, 2007", p. 126.

been repeated slips in the schedule for licensing and constructing Yucca Mountain. Further, the Federal government faces substantial and growing liability costs the longer the spent fuel stays at reactor sites. Finally, there is a concern that the buildup of spent fuel at reactor sites and the lack of progress on final disposition could be a constraint on the growth of the domestic nuclear power industry by increasing the difficulty of siting new plants.[7]

Consolidated interim storage of spent fuel is not a new concept. The Congressionally-chartered Monitored Retrievable Storage (MRS) Commission in 1989 recommended a 2,000 ton Federal Emergency Storage facility and a 5,000 ton User-Funded Interim Storage Facility.[8] The MRS Commission's recommendations were not pursued.

It would take several years to license and construct a consolidated interim storage facility. Private Fuel Storage, a private facility in Utah, took nine years to obtain an NRC license.[9] But even with its NRC license, it still faces substantial obstacles to opening.[10] Based on that experience, the Nuclear Regulatory Commission estimates that licensing another such site, even if uncontested, would take, at minimum, three years.[11] Additional time would be required for construction.

Whether or not to develop one or more consolidated sites for interim spent fuel storage will depend on several issues. Among them are technical and programmatic issues including safety, security, cost, impact on the future of domestic nuclear power, and siting incentives. This report examines these issues and is divided into two distinct sections: technical considerations and programmatic considerations. Three additional issues - spent fuel repackaging, reprocessing of spent fuel, and cost estimates - bear on consolidated storage and are discussed in appendices.

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[7] "Moving Forward With Nuclear Power: Issues and Key Factors," Secretary of Energy Advisory Board, January 10, 2005: http://www.seab.energy.gov/publications/NETF_Final_Draft_0105.pdf

[8] Monitored Retrievable Storage Commission, "Nuclear Waste: Is There a Need for Federal Interim Storage?" Washington DC, US Government Printing Office, 1989.

[9] http://attygen.state.ut.us/HPI/A Nine Year Insight into the PFS Licensing Proceeding Before the Nuclear Regulatory Commission.pdf

[10] The Bureau of Indian Affairs issued a decision to "disapprove the proposed lease" for PFS. The Bureau of Land Management denied PFS a right-of-way to transfer and transport nuclear waste to the Skull Valley Goshute reservation: http://bennett.senate.gov/press/record.cfm?id=262652

[11] Martin Virgilio, US Nuclear Regulatory Commission staff, Presentation to the Nuclear Energy Study Group, August 8, 2006.

II. TECHNICAL CONSIDERATIONS

This section considers two technical questions that bear on the decision whether to develop one or more consolidated interim storage facilities. How would a consolidated storage facility affect overall safety and security risks of spent fuel management? Is there sufficient space at operating nuclear reactors to accommodate on-site interim storage of spent fuel for the duration of the plant operating licenses? Safety risks refer to accidents and human errors. Security risks refer to sabotage or attack.

RISK ASSESSMENT

Storage Safety & Security Risks

The U.S. Nuclear Regulatory Commission (NRC) is the Federal agency responsible for regulating the safety and security of commercial spent fuel storage and has promulgated several sets of regulations for this purpose.[12] The Department of Homeland Security is responsible for ensuring a coordinated response external to a nuclear facility in the case of a severe accident or terrorist attack and is working with the NRC, other Federal agencies, and state and local law enforcement to carry out this mission.

The NRC has concluded that spent fuel storage in pools and casks is safe and secure.[13] As evidence, among other things, they point to the three decades of pool and cask storage in the United States without a significant release of radioactive material to the environment.

Despite the very strong safety record, no storage method can provide absolute protection. There are scenarios in which a terrorist attack on a storage site could result in the release of radioactive material. The National Academies published a detailed examination of terrorist attack scenarios on spent fuel pools and dry casks in 2006. It concluded that an attack that partially or completely drained a spent fuel pool could lead to a propagating zirconium cladding fire and the release of large quantities of radioactive materials to the environment. It also concluded that there were readily implementable measures that could reduce the likelihood and the consequences of such cladding fires. The report also concluded that dry cask storage has inherent advantages over pool storage. These advantages increase the difficulty of successful attacks and reduce their potential consequences. The report also notes, however, that dry cask storage does not eliminate the need for pool storage at operating reactors.[14]

Experience and analysis strongly suggest that interim dry-cask storage facilities can be maintained with a high level of confidence for at least 50 years and likely much longer.[15] Replacing the casks could further extend their lifetimes. Consequently, there are no technical barriers to the safe and secure interim storage of spent fuel as long as adequate resources and attention are devoted to maintaining the storage facilities.

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[12] See: 10 CFR 50: Domestic Licensing of Production and Utilization Facilities; also 10 CFR 71, 72 and 73.

[13] http://appropriations.house.gov/_files/NilsDiazTestimony.pdf

[14] "Safety & Security of Commercial Spent Nuclear Fuel Storage: Public Report" National Academies Press (2006).

[15] "Interim Storage of Spent Nuclear Fuel", M. Bunn et. al., Harvard University & University of Tokyo (2001); IAEA, http://www.iaea.org/OurWork/ST/NE/NEFW/nfcms_spentfuel_conf2003_res.html

Safety & Security Risks in Transport

Spent fuel transportation is an important element of all interim storage and permanent disposal strategies. Ultimately, any strategy will require the shipment of spent fuel from the 65 nuclear plant sites where it is now stored either to a final geological repository or to one or more consolidated sites. Spent fuel will be transported across the nation's roadways and railways. The safety and security of spent fuel transportation is often mentioned by those concerned about plans to develop consolidated interim storage and permanent disposal facilities.

Spent nuclear fuel has been transported safely in the United States and many other countries for several decades. In the United States, since 1964, there have been more than 2800 highway shipments and 500 rail shipments of roughly 3,500 tons of spent fuel.[16] Worldwide, over that time, more than 100,000 tons of spent fuel has been transported by rail, road and ship.[17]

There have been no reported large-scale releases of radioactive materials from spent fuel casks in transport in the United States or any other western country. There have been, however, a few small releases of radioactive materials, but those leaks were from casks transporting spent fuel in water that are no longer licensed for use. Also, incidents have been reported of contamination above regulatory limits on the external surfaces of transportation casks but the contamination resulted from insufficient decontamination of casks after loading with spent fuel.

Several reports and studies have been issued that examine the safety and security of spent fuel transportation. A recent National Academies report provides a comprehensive discussion of transportation safety risks.[18] The report concluded that "transport by highway (for tens of tons) and rail (for hundreds to thousands of tons of spent fuel) is, from a technical viewpoint, a low-radiological risk activity with manageable safety, health, and environmental consequences when conducted in strict adherence to existing regulations."[19] The overwhelming consensus from this NAS report and numerous independent quantitative analyses and real-world tests of transportation casks is that there are no technical barriers to the safe transportation of spent fuel.

Studies on the security of spent fuel transport have been carried out in the United States since the 1970s.[20] Since the terrorist attacks on September 11, 2001, classified studies sponsored by the Nuclear Regulatory Commission have examined the behavior of spent fuel transport casks if subjected to various potential terrorist attacks. This panel has not

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[16] "Going the Distance?" National Academy Press (2006), Table 3.2.

[17] Ibid, Table 3.5.

[18] Ibid, Chapters 2 and 3.

[19] Ibid, p. 7. This report identified concerns about long-duration fires that might engulf a transportation cask. This potential scenario is being addressed by the NRC and the Association of American Railroads.

[20] There are several reports that were prepared for Sandia National Laboratories: Transport of Radionuclides in Urban Environs: Working Draft Assessment. DuCharme, A.R. et al. 1978, SAND77-1927; Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment, Finley, N.C. et al. 1980, NUREG/CR-0743 (SAND79-0369); An Assessment of the Safety of Spent Fuel Transportation in Urban Environs, Volume II, Sandoval, R.P. 1987. Appendix A: High-Energy Device Evaluation Tests: Test Data. SAND82-2365; An Assessment of the Safety of Spent Fuel Transportation in Urban Environs, Sandoval, R.P. et al. 1983, SAND82-2365.

had the opportunity to review these classified studies. In one public study, an examination of the results of various terrorist attacks - by planes, submachine guns, antitank grenades or sniper rifles - determined that any resulting radiation leakage due to breach in the casks would be highly localized and therefore manageable.[21]

Some state officials, non-government organizations, and members of the public have raised transportation security as a significant concern and have called for more sharing of security-related information. Federal restrictions on the public release of U.S. transportation security information have impeded the response to these requests.

Although there is insufficient publicly available information for the panel to conclude whether or not transportation security risks are significant, it has not had the opportunity to examine the extensive classified literature on this topic. The recent National Academies study on transportation wrote, "Malevolent acts against spent fuel and high-level waste shipments are a major technical and societal concern, but the committee was unable to perform an in-depth examination of transportation security because of information constraints. The committee recommends that an independent examination of the security of spent fuel and high-level waste transportation be carried out prior to the commencement of large-quantity shipments to a Federal repository or to interim storage."[22] While recognizing the protections required for classified studies, we endorse this recommendation but note that to be useful any such study must have an unclassified report with the classified details in an appendix.

Overall Risk Assessment Associated With Consolidated Interim Storage

The panel concludes that the safety and security risks associated with storage of spent fuel are not appreciably different whether the fuel is stored at plant sites or in one or more consolidated facilities. The same storage technologies are employed in both cases and the operational, maintenance, and security requirements are identical. Consequently, we conclude that safety and security considerations alone should serve neither as drivers nor inhibitors in determining whether to develop consolidated interim storage. There may be a small difference in overall risk, depending on where the sites are located but at all sites the risks are small and manageable. A breach in a cask could have more serious consequences for a site near a populated area than for a site in an isolated area. Modest net changes in risk could arise when the associated transportation risks or new waste configurations are considered.

With respect to transportation risks, an interim consolidated site would require spent fuel to be moved twice rather than once. The fuel would be moved from operating reactors to the consolidated site, and then from the consolidated site to the permanent repository. The additional transport adds risk. However, the transportation safety risks (as distinct from security risks) are so low that the overall risk increase is likely to be insubstantial as long as transportation programs operate with care and in adherence to applicable regulations. Similarly, as security risk information becomes publicly available, it is likely that it will not add substantially to the overall risks. Consequently, consolidating

[21] "Estimation of terrorist attack resistibility of dual-purpose cask", Alekseev et al., Russian Federal Nuclear Center, www.ans.org/meetings/docs/2006/ihlrwm06-official.pdf

[22] "Going the Distance," *op cit.*, p. 3.

the waste from operating nuclear reactors would likely not significantly change the overall risks associated with the storage of spent fuel.

ON-SITE CAPACITY OF OPERATING COMMERCIAL REACTORS

Most commercial nuclear plants in the United States were constructed with limited pool storage.[23] The pools were designed to store spent fuel until it was shipped offsite for reprocessing and to accommodate the fuel from the reactor core during refueling or emergency operations. Because of national policies created and adopted by the Ford and Carter administrations, a commercial reprocessing industry never developed in the United States.[24] Consequently, spent fuel generated by commercial nuclear plants has been stored onsite for much longer than originally anticipated.

By the 1970s, pool storage space at some plants was beginning to approach capacity. To increase pool storage capacities, plant operators began to replace the existing storage racks with high-density storage racks. This increased the storage capacities in some pools by up to about a factor of five.[25] By the early 1980s, plant operators were developing plans to move older spent fuel out of pools and into dry casks for storage at plant sites.

TABLE 1. US commercial spent fuel quantities & storage locations in 2005.[26]

Material	Approximate Quantity (metric tons)	Number of sites
Total commercial spent fuel storage	54,000	65 nuclear plant sites with 103 operating reactors 9 nuclear plant sites with no operating reactors 1 commercial interim storage site (Morris in Illinois) 2 DOE sites (Ft. St. Vrain in Colorado and Idaho National Laboratory)[a]
Pool storage	47,000	65 operating sites 1 centralized site (Morris in Illinois) 9 nuclear plant sites with no operating reactors
Cask storage	7,000	35 at nuclear plant sites 2 DOE sites (Ft. St. Vrain in Colorado and Idaho National Laboratory)[a]

[a] Fuel is owned and managed by DOE.

[23] Some of the last commercial plants licensed (e.g., Palo Verde in Arizona) were designed with larger pools.
[24] By the time the Reagan administration changed those policies, reprocessing was seen as uneconomic and no industry developed in the US.
[25] Emit, R., R. Riggs, W. Milstead, J. Pittman, and H. Vendermolen. 2003. A prioritization of generic safety issues. NUREG-0933. Washington, DC: Office of Nuclear Regulatory Research.
[26] "Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States", National Academy Press (2006).

At present, cask storage facilities are established at 35 reactor sites. There are projections that by 2017, the current scheduled opening date for Yucca Mountain, roughly 64 of the 65 reactor sites will have cask storage.[27] DOE estimates that 59 sites will have about 26,000 tons of spent fuel in casks by 2017.[28] There are 12 permanently decommissioned nuclear power plants in the US that still have spent fuel onsite.[29] On 9 of these sites there are no operating reactors and the sites contain about 2,800 tons of spent nuclear fuel mostly stored in dry casks.[30] An additional 2,000 tons of spent fuel from decommissioned reactors is stored at sites with other operating reactors.

Under current Yucca Mountain planning, it will take decades to move spent nuclear fuel off of existing plant sites in large quantities. For example, if Yucca opens on schedule in 2017, and if Yucca's statutory limit of 70,000 tons were increased, and if roughly 3,000 metric tons of spent nuclear fuel (SNF) and high-level waste (HLW) are transported there each year,[31] then shipments from existing plants would continue until 2054.[32] Consequently, regardless of whether Yucca Mountain opens on schedule or is delayed, interim storage of spent nuclear fuel either at reactors or at one or more consolidated sites will be necessary for at least the next 40 years. Moreover, it is important to note that no consolidated storage facility can eliminate the need for pool storage at reactor sites.[33]

From a technical standpoint, there is no reason that a new nuclear plant could not be designed with sufficient pool and cask storage to handle all of the spent fuel generated during its operating life. And, according to the Nuclear Energy Institute there is sufficient space at all nuclear reactors to accommodate all spent nuclear fuel for the duration of the plant licenses.[34] However, some States may limit the amount of on-site dry storage and all States have licensing requirements governing expansion of on-site dry storage. As one example, in Wisconsin there is a requirement that a permanent repository be opened before new nuclear power facilities can be built, but the requirement is under review.[35] These political factors are beyond the scope of this study.

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[27] "Safety & Security of Commercial Spent Nuclear Fuel Storage: Public Report" National Academies Press (2006). There is some uncertainty in predicting the storage situation. For example, the LaCrosse site is in a decommissioned status and had planned to use the Private Fuel Storage facility, but is now considering constructing onsite storage.

[28] Christopher A. Kouts, Director, Waste Management Office, Office of Civilian Radioactive Waste Management, US Department of Energy, Presentation to the NESG, "Used Fuel Storage." August 8, 2006.

[29] "Going the Distance?", National Academy Press (2006), Table 5.2.

[30] "Going the Distance?", National Academy Press (2006), Table 5.2.

[31] DOE reports that Yucca Mountain currently will have a "maximum annual acceptance rate of 3,000 metric tons per year": DOE. 2004. Acceptance Priority Ranking & Annual Capacity Report. Washington, D.C.: Office of Civilian Radioactive Waste Management.

[32] Based on the current and projected amounts of spent fuel generated from now until 2054.

[33] Spent fuel generates so much heat after removal from the reactor that several years in pool storage are always required before the fuel can be passively cooled in dry casks.

[34] Communication from Steven Kraft, Senior Director, Used Fuel Management, NEI, 16 November 2006.

[35] 1983 Wisconsin Act 403: "The [public service] commission may not certify....any nuclear power plant ...unless the commission finds that (a) A federally licensed facility or a facility outside of the United States which the commission determines...with adequate capacity to dispose of high level nuclear waste from all nuclear power plants operating in this state will be available...." In 2006 the Special Committee on Nuclear Power was directed to study the role of nuclear power in Wisconsin's energy future and to develop legislation to implement the recommended role, including, as appropriate, any modifications in the state's nuclear moratorium. Reference: Wisconsin Briefs, from the Legislative Reference Bureau (Brief 06-7 May 2006.)

Summary of Technical Findings

Technology Assessment:

- There are no technical barriers to long-term safe and secure interim storage of spent nuclear fuel either at nuclear plant sites or at one or more consolidated sites.

Risk Assessment:

- Consolidating the spent fuel from operating nuclear reactors would not significantly change the overall safety and security risks associated with its storage.

Storage Capacity Assessment:

- Regardless of whether Yucca Mountain opens on schedule or is delayed, interim storage of spent nuclear fuel either at reactors or at one or more consolidated sites will be necessary for at least the next 40 years, even if no new nuclear power plants are constructed in the U.S.

- One or more consolidated storage facilities would not eliminate the need for pool storage at operating reactor sites.

- There is sufficient space at all operating nuclear reactors to accommodate all spent nuclear fuel for the duration of the plant licenses.

III. PROGRAMMATIC CONSIDERATIONS

This section considers several programmatic questions that bear on the decision whether or not to develop one ore more consolidated interim storage facilities. Are there economic benefits to consolidated interim storage of spent nuclear fuel? Would consolidated storage facilitate the growth of domestic nuclear power? If consolidated interim storage were to proceed, are there steps that ease siting challenges? Are there steps to assure that Yucca Mountain and consolidated interim storage could be advanced in a complementary fashion?

Cost

The Department of Energy recently announced that Yucca Mountain could be open for delivery of spent fuel in 2017 at the earliest.[36] The schedule is based on several assumptions: adequate funding, submittal by DOE of a technically sound license application, timely review and actions from the NRC, and absence of litigation-related delays.

The Federal government is liable for the costs of extended at-plant storage by plant operators for its failure to take title of the spent fuel starting in January 1998 as required by Federal statute. Consequently, whether or not there would be an economic benefit to developing one or more consolidated interim storage sites depends in part on the timetable for opening Yucca Mountain.

DOE estimates that every year of delay in opening Yucca Mountain beyond the year 2017 will cost the Federal government an additional $0.5 billion per year in settlements with the utilities.[37] The Nuclear Energy Institute recently issued a press release asserting that the "potential cost to the industry for the storage of used nuclear fuel as a result of the Federal government's failure to meet its obligation has been estimated at more than $56 billion."[38] Appendix III explains the basis for this estimate, the bulk of which is return with interest of all payments into the nuclear waste fund.

A Federal consolidated interim storage facility is not subject to the long-term health and safety licensing requirements for Yucca Mountain, a permanent repository. However, it would face some of the same licensing challenges as Yucca Mountain including

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[36] Schedule: license application submittal in 2008, construction authorization from NRC in 2012, waste receipt in 2017. Statement of Edward Sproat III, Director, Office of Civilian Radioactive Waste Management, Dept of Energy to the Subcommittee on Energy and Air Quality of the House Committee on Energy and Commerce, 13 September 2006.
http://www.ocrwm.doe.gov/info_library/newsroom/documents/CtrSchedule.pdf

[37] U.S. House of Representatives Appropriations Committee, *Report on the Energy and Water Development Appropriations Bill, 20006,* Report 109-86, May 18, 2005, p. 125. The panel asked the Department of Energy for the basis for this estimate but was refused because the estimate relates to on-going litigation. Sometimes this estimate is incorrectly cited as $1 billion per year because the DOE adds to it an estimated cost of $0.5 billion year for storing vitrified high-level radioactive wastes from the production of U.S. weapons plutonium, spent naval-reactor fuel, and other government-owned fuels that are also to be disposed of in the Yucca Mountain repository: http://web.em.doe.gov/integrat/National_Report_05-02-03_1.pdf

[38] "Federal Claims Court Awards Damages to Three Companies For Government's Failure To Dispose of Used Nuclear Fuel," Nuclear Energy Institute Press Release, October 13, 2006. The $56 billion cost estimate is the same, however, as was attributed in 1998 to an NEI-funded study done by Eileen Supko of Energy Resources International in Margaret Kriz, "DOE fights Nevada nuke waste battle," May 11, 1998.

litigation-related delays. Further, as evidenced by Private Fuel Storage and decades of prior failures to open consolidated facilities, there are political challenges associated with opening any new spent fuel storage facility. All of these factors together could significantly extend the time it takes to open a new consolidated storage facility to well over a decade. Thus, by the time consolidated storage could be established almost all U.S. reactor sites will have installed dry storage systems. Under the current timetable, by 2011 51 of the 65 sites are expected to have dry storage, 57 by 2013, and 64 by 2017. Six additional sites with shut down reactors already have dry storage facilities.[39]

Balancing all these factors against each other, if Yucca Mountain opens approximately on schedule then we have seen no analysis that demonstrates a compelling economic benefit to the Federal government from the interim consolidation of spent fuel storage.[40] Because the dominant costs of storage either at the reactor sites or at a consolidated site are due to the capital costs of the dry casks, which are comparable no matter where the casks are located, we believe that the cost difference is likely to be small (see Appendix III). Moreover, the panel is aware of no rigorous cost estimates showing whether or when consolidated interim storage might become an economically attractive option in the face of significant delays in opening the repository.

It is reasonable to expect that the economies of scale associated with consolidation might offset some Federal government's liability costs for continued storage of the spent fuel at plant sites. However, the government would likely incur additional costs for establishing consolidated facilities. These would include the costs of land acquisition; construction of facilities for cask receiving and handling, especially if they are designed to handle bare fuel; and construction of rail and highway spurs to the facility and improvements to existing transportation infrastructure. These are all one-time costs, but could be considerable depending on the number, design, and location of the consolidated facilities.

Perhaps because of ongoing litigation, this panel has been unable to obtain detailed documentation for the costs to the government that might be avoided with one or more consolidated facilities. Our own estimate of direct costs (Appendix III) shows that the $0.5 billion per year total cost is reasonable. To accurately inform cost estimates on interim storage, Congress would need to request an independent review.

The Future of Nuclear Power

Several factors are contributing to the possible resurgence in nuclear power. Climate change, and a growing expectation that carbon dioxide emissions will be priced relatively soon, are principal motivations for nuclear power growth. The price volatility of natural gas is another motivator.

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[39] "Safety & Security of Commercial Spent Nuclear Fuel Storage: Public Report" National Academies Press (2006). pp 22-24.

[40] PFS in Utah could, in principle, yield economic benefits. However, if the costs of interim consolidated storage are comparable to the costs of leaving spent fuel at the individual reactor sites then these benefits would be modest at best. Furthermore, the costs to the Federal government would not be very different, because the liability costs would be the same whether the material is moved to PFS or left where it is.

A large expansion of nuclear power would require an examination of spent fuel management strategies well beyond that authorized for Yucca Mountain. For example, an expansion may require raising Yucca's authorized legislative capacity of 70,000 tons.

Under this expanded nuclear energy scenario, there could be two principal benefits to consolidated interim storage of spent fuel. First, and most important, consolidation of spent fuel in dry cask storage at one or more Federal sites, with the spent fuel moved from reactor locations sometime after its discharge from the reactor, serves to decouple the private sector nuclear power plant operator from the uncertainties inherent in any massive, long term, first-of-a-kind government program. The assurance that spent fuel can be removed from a reactor to a storage site may reduce the difficulty in siting new plants. The statutory requirements of Federal ownership and long term stewardship of spent fuel, with nuclear plant operators paying a yearly fee, is in effect aimed at such a decoupling. Consolidated interim storage as described is a logical extension of the policy that already has established this public-private relationship. (Such a decoupling could arguably also be accomplished if the Federal government took title to the spent fuel at the reactor sites where it is currently being stored.) Second, such an approach adds considerably to system flexibility for adjusting to new technical or societal developments.

It has been suggested that interim storage may allow for a smoother transition for a possible move to advanced reprocessing fuel cycles, such as is envisioned in the recent DOE GNEP initiative.[41] However, even under optimistic assumptions, it will take a minimum of several decades for commercial deployment of the GNEP envisioned facilities. Therefore GNEP is not relevant to interim storage decisions at this time. (The relationship of consolidated interim storage to reprocessing is reviewed in Appendix II.)

Siting Challenges for Waste Storage and the Role of Incentives

Experience with siting repositories and other radioactive waste sites, both in the United States and abroad, suggests that future efforts to site consolidated spent fuel storage facilities will be extremely difficult. As evidenced by PFS, obtaining a license to construct and operate a consolidated storage site is not sufficient to ensure that it will ever be opened. Even if the chosen site is on Federal lands, opposition from political leaders and non-governmental organizations can greatly delay and even block approval. Attempts to develop multiple new storage sites likely will compound these challenges.

Nevertheless, experience also suggests that these siting challenges can be overcome by making such facilities more economically and socially attractive to potential host communities. Several strategies merit consideration in this regard: for example, requiring that responsible federal agencies work cooperatively with states, tribes, and localities to identify potential host sites; providing host communities with an appropriate measure of control over facility location, design, and operations; and providing host communities with appropriate economic incentives, including infrastructure improvements to offset the impacts of site operations, and reliable revenue streams from site operations (e.g., through the imposition of user fees as is done for other types of non-nuclear facilities). Should Congress choose to direct the development of such facilities, the exploration of such strategies should receive careful consideration.

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[41] "Global Nuclear Energy Partnership", Department of Energy, http://www.gnep.energy.gov

Yucca Mountain & Interim Storage: A Complementary Strategy

The Nuclear Waste Policy Act (NWPA), as amended, established permanent disposal as the nation's strategy for managing commercial spent fuel. The cornerstone of that strategy, a repository at Yucca Mountain, Nevada, was approved by the President of the United States, with congressional concurrence, in 2003.

The NWPA recognized that consolidated interim storage (referred to in the Act as *monitored retrievable storage*) could become an "integral part of the system for the disposal of spent nuclear fuel and high-level radioactive waste established under this Act."[42] The Act anticipated that the establishment of such storage facilities could make it more difficult to site and license a permanent repository. To address this difficulty, it established a deliberative process and schedule for siting such storage facilities; specifically prohibited the construction of such facilities until a repository construction license was issued; and provided for impact assistance and possible additional benefits for states and tribes on whose lands such facilities were to be located. The Act also contains a congressional finding that "disposal of high-level radioactive waste and spent nuclear fuel in a repository developed under this Act should proceed regardless of any construction of a monitored retrievable storage facility pursuant to this section."[43]

Yucca Mountain and consolidated interim storage are not necessarily incompatible concepts, and steps would need to be taken to ensure that they are complementary. The establishment of one or more Federal consolidated interim storage sites could divert funding and attention away from the Yucca Mountain licensing effort, making it substantially more difficult to open the repository on its current schedule. Absent a continuing Federal commitment to - and clear progress toward - licensing Yucca Mountain, Federal interim storage could be viewed as a permanent alternative to disposal, making it substantially more difficult to gain the public confidence necessary to site and construct such storage facilities.

If Congress decides to establish consolidated interim storage facilities, it should take steps, consistent with the intent of the NWPA, to ensure that progress toward opening a permanent repository is not jeopardized or unnecessarily delayed. Such steps could also help to promote public confidence that consolidated interim storage would not become the de facto permanent solution for managing the nation's growing inventories of commercial spent fuel. In fact, consolidated interim storage could enhance the operational flexibility of Yucca Mountain. As detailed in Appendix I, should fuel repackaging of existing dry storage casks be necessary before disposal, the consolidated interim storage site can offer efficient and cost-effective fuel handling and repackaging. In addition, the consolidated site could carry out the necessary thermal mixing of fuels before disposal, thus reducing the size of buffer storage needed at the Yucca Mountain surface facility.

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[42] Nuclear Waste Policy Act, Section 145 (a)

[43] Nuclear Waste Policy Act, Section 141 (a)(5). Monitored retrievable storage as envisaged by the NWPA was never developed.

SUMMARY OF PROGRAMMATIC FINDINGS

Cost Assessment:

- If the Yucca Mountain repository opens roughly on schedule, then we have identified no clear economic benefit to the Federal Government to interim consolidation of spent fuel.

- To determine whether or when consolidated interim storage might become an economically attractive option to the Federal Government in the event that the repository faces significant delays, Congress would need to request an independent review of the basis of DOE's liability cost estimates and of the cost of interim storage.

The Future of Nuclear Power:

- Consolidated interim storage could relieve impediments to the growth of nuclear power by establishing a process and program for taking Federal title to spent fuel and decoupling the private-sector nuclear power plant operators from uncertainties inherent in the Federal long-term spent fuel management program. It could alleviate one of the difficulties in siting new power plants.

Implementation Considerations:

- A permanent repository is the cornerstone of the nation's waste management strategy. Consequently, if the Federal government were to proceed with consolidated interim storage, it should be done in a manner consistent with the current Federal strategies for long-term management.

- If Congress chooses to direct the development of one or more consolidated storage facilities, the exploration of strategies to improve their economic and social attractiveness to potential host communities should receive careful consideration.

- Steps should be considered that would insure progress toward opening the permanent repository and provide public confidence that a consolidated interim site would not become a permanent site.

APPENDIX I: Spent Fuel Repackaging

Two types of dry cask designs are used to store spent fuel: bare-fuel casks in which spent fuel is loaded directly into a basket that is integrated into the storage cask itself and the cask is then bolted and sealed; and canister-based casks in which spent fuel is loaded into baskets in a thin-walled steel canister. The thin-walled canister is sealed with a welded lid, then placed within another storage/transportation package, then closed with a bolted lid.[i] The canisters can, in principle, be used for storage, transportation, and disposal; however the current dry storage casks are for storage, or dual use (storage and transportation) only.

Recently the Department of Energy proposed a Transport, Aging and Disposal (TAD) canistered system approach. The TAD canisters are standardized welded canisters that contain bare fuels and can be used inside dry-storage casks, and transportation casks, and disposal packages. Under DOE's current plan, spent fuel from the pools will be loaded directly into the TAD canisters for storage, transport to, and disposal in the repository. Without the TAD system, operations at the Yucca Mountain surface would involve removing bare fuels from canisters and placing them into disposal packages.

DOE currently plans to include only the TAD canister system for commercial spent nuclear fuel in the License Application for Yucca Mountain. Since TAD is a new concept, DOE first needs to determine its performance specifications, TAD then needs to be certified by the NRC, and finally manufactured. The timing of the availability of TAD has been estimated to be at least 5-6 years.[ii] An important uncertainty arises for the fate of existing dry storage casks. DOE plans to amend the License Application in the future to include the existing dual-purpose canisters without repackaging into TAD. However, in the event the existing dual-purpose canisters cannot be licensed for disposal, a significant number of existing dry casks would need to be repackaged into TAD.

If consolidated interim storage becomes available and should repackaging of existing dry casks become necessary then existing casks could, in principle, be repackaged at the consolidated sites instead of at the reactor sites. There are advantages to repackaging away from the reactor sites. First, there are no facilities at decommissioned sites for opening and transferring spent fuel from existing storage casks. A consolidated site can offer consolidated, efficient fuel handling, eliminating the need for a facility at each closed site. Second, the Yucca Mountain repository plan includes a buffer storage area to allow the operator to select the proper mix of spent fuels to meet heat load requirements in the disposal area. A consolidated interim site could serve the function of fuel mixing and might eliminate the need for large buffer storage at Yucca Mountain itself.[iii] Consequently, even if Yucca opens on schedule, it may be desirable to have a facility to carry out the necessary thermal mix and match and allow for the transfer of fuel to TADs.

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[i] Currently there are 114 bare-fuel casks and 504 dual-purpose casks at dry-storage pads at 38 reactor sites (http://www.osti.gov/bridge/servlets/purl/828189-iDmb9b/webviewable/828189.pdf). According to information provided by cask vendors, nuclear power plant operators are currently purchasing mostly dual-purpose casks. Most U.S. licensed package designs consist of shells of steel or reinforced concrete (for structural strength), concrete, lead, or depleted uranium and polyethylene or water jackets (for neutron moderation).

[ii] Letter from Nuclear Waste Technical Review Board to DOE, June 14, 2006.

[iii] Buffer storage would still be needed for operational purposes. And, if DOE did not own the consolidated interim storage facility, negotiations would be required with private owners to facilitate this benefit.

APPENDIX II: Reprocessing & Consolidated Interim Storage

Domestic recycling of the plutonium and other transuranic elements in spent nuclear fuel was included as part of the Department of Energy's 2006 Global Nuclear Energy Partnership (GNEP) proposal.[i] Under the GNEP proposal these elements would be recycled in a new generation of fast-neutron reactors to reduce the overall amount and type of nuclear waste that would need to be disposed of. According to the Department of Energy, with recycling of the actinides and surface storage of the 30-year half-life fission products strontium-90 and cesium-137, the planned geologic repository site at Yucca Mountain would have the capability to accommodate the residual reprocessing waste for thirty times or more spent fuel.

GNEP requires advanced technologies. As a result, no firm decision has been made to proceed with reprocessing and the timeline for the deployment of advanced reprocessing facilities is quite uncertain. Even under optimistic assumptions, it will take decades for commercial deployment of the GNEP envisioned facilities. Indeed, a previous report by this panel concluded that "there is no urgent need in the United States to initiate reprocessing."[ii] Therefore GNEP is not relevant to interim storage technical discussions at this time unless a political linkage is made between siting of a reprocessing plant and accepting consolidated storage at the same site.

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[i] Department of Energy, http://www.gnep.energy.gov

[ii] POPA Nuclear Energy Study Group, "Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risk", http://www.aps.org/policy/reports/popa-reports/proliferation-resistance/upload/proliferation.pdf

Appendix III: Cost Estimates of On-Site Storage

This Appendix describes our Study Group's attempts to obtain or derive estimates for the costs of on-site dry-cask storage, both at sites with an operating reactor and at sites where no reactor is now operating. As this Appendix discusses below, our attempts have been only partially successful, in that our estimates have a good deal of uncertainty.

U.S. nuclear utilities are incurring additional on-site spent-fuel storage costs as a result of the Department of Energy's failure to fulfill its commitment to begin taking possession of their older spent fuel starting in 1998. They are suing DOE to recoup these costs. Two estimates have been floated for DOE's liability: $0.5 billion/year by DOE[i] and a total cost of $56 billion by the Nuclear Energy Institute (NEI), the nuclear industry policy institute.[ii]

We requested information about the basis of both these estimates. The Department of Energy responded that it could not provide this information because the U.S. Justice Department is litigating lawsuits in which the nuclear utilities are suing to recover their costs. The NEI explained that 65-70 percent of its estimate of liability (i.e. $36-39 billion) was due to the assumption that the DOE would repay the utilities the $8.5 billion they had paid into the Nuclear Waste Fund as of January 31, 1998 at a 7-14 percent rate of interest.[iii] The remaining $17-20 billion was the NEI estimate of the undiscounted cost to the utilities of storing the spent fuel from 1998 until approximately 2030.[iv] Dividing this amount by 32 years gives an average annual cost of $530-620 million per year – not very different from the DOE annual cost estimate.

In the absence of detailed information on the basis of either estimate, our APS Study Group has made its own rough estimate, based on the small amount of publicly available cost data that we could find. We thank Pierre Saverot, an industry consultant, for making the availability of this information known to us. We also thank Frank von Hippel, a physicist at Princeton University, for helping us to obtain and analyze this information

Costs at an operating-reactor site: The most complete capital cost data on a dry-cask storage project at an operating reactor that we were able to obtain is from the certificate of need, filed January 18, 2005, by Xcel Energy with the Minnesota Public Utility Commission for a dry cask storage facility with 30 spent-fuel canisters near the reactor building of the Monticello reactor. Each canister is designed to hold 61 BWR spent fuel assemblies containing about 11 metric tons of uranium.[v]

The capital cost at Monticello is $55 million, of which about $20 million represents fixed one-time costs that are roughly independent of the number of casks on the site, and the remainder works out to about $110,000 per ton of spent fuel. If additional spent-fuel dry casks were to be added later, only the incremental capital cost of about $110,000 per ton would be incurred.

For a dry-cask storage facility at an operating nuclear plant, the incremental annual security and maintenance costs are modest, since a guard force and maintenance personnel are already available. Pierre Saverot estimates the incremental operating cost at about $1 million per year.[vi]

Operating costs at a site where the reactor has been shut down: For costs at a shut-down facility, we have data provided by the Maine Yankee nuclear power plant in its license termination plan for storage of 543 tons of spent fuel.[vii] Here the estimated annual operating costs (for staffing, security, insurance, various state and NRC fees, etc.) come to slightly under $5 million/year.

Summary

Cost category	**basis**	**Estimated cost**
Capital costs	based on Monticello	about $20 million one-time fixed cost, plus about $110,000 per ton of spent fuel stored:
Operating costs at a site where a reactor is still operating	based on Saverot estimate	about $1 million per year
Operating costs at a site where the reactor has been shut down	based on Maine Yankee	about $5 million per year

A word of warning is needed about the accuracy of these estimates. The above numbers are based on very slim data. Because we expect there to be important variations from site to site, we would not be surprised if the results of a more thorough and comprehensive cost estimate (when averaged over the entire US spent-fuel-dry-cast-storage enterprise,) were different by ± 50 %.

Comparison of total costs with the DOE and NEI estimates: Nationally, as of the end of 2005, 28 of the 65 U.S. operating power plants had licensed dry-cask storage facilities.[viii] The industry has projected that, by 2017, virtually all will have installed them.[ix] After 2017, the relevant costs would be incremental. Assuming that U.S. nuclear reactors continue to discharge about 2000 tons of spent fuel per year, and using the Monticello numbers, the incremental capital cost for storing one year's output would be $220 million per year at operating reactors. The annual operating costs at the 65 sites (at $1M/year) add about another $65M, and the costs at the 7 sites without reactors, at about $5M/year, add about another $35M. This adds up to an incremental annual cost after 2017 of about $320 million nationwide.

If we were to add in the infrastructure costs for three new sites per year prior to 2017, this cost would increase to the range of about $400 million/year until all of the 65 sites have been "built out".

This figure is sufficiently close to the DOE estimate cited above (about $500M/year) that, for all practical purposes, these numbers are well within the range of the uncertainties.

If the Congress wants a more accurate cost estimate made independently from the DOE and the NEI on which to base policy decisions, it could commission a study by an organization such as the Government Accountability Office which would have better access to the basis of the payments that have been made to the utilities thus far and to the extensive additional information that is relevant to assessing the costs.

[i] "DOE has estimated that every year of delay in opening the Yucca Mountain repository will cost the Federal government an additional $1 billion per year, with a conservative estimate of $500 million in legal liability for failure to take title to commercial spent fuel, and another $500 million to monitor and guard defense spent fuel and high level radioactive waste at DOE sites," *Report on the Energy and Water Development Appropriations Bill, 2006,* U.S. House of Representatives Appropriations Committee, Report 109-86, May 18, 2005, p. 125.

[ii] "The potential cost to the industry for the storage of used nuclear fuel as a result of the Federal government's failure to meet its obligation has been estimated at $56 billion" in "Federal Claims Court Awards Damages to Three Companies for Government's Failure to Dispose of Used Nuclear Fuel," Nuclear Energy Institute Press Release, October 13, 2006. After our enquiry, this sentence was removed from the press release. However, a search of the NEI website found many other cites of the $56 billion dollar damage estimate, starting with a January 30, 1998 press release, "DOE To Breach 16-Year Legal Obligation To Manage Used Nuclear Fuel; U.S. Taxpayers Face $56 Billion in Liabilities."

[iii] Steven P. Kraft, NEI Director of Used Fuel Management, e-mail to Frank von Hippel, November 14, 2006.

[iv] Steven P. Kraft e-mail to Frank von Hippel, November 21, 2006.

[v] Based on the average weight of BWR fuel assemblies stored at reactor sites, "Spent Nuclear Fuel," US Energy Information Agency, October 1, 2004, http://www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnfdata.html.

[vi] Pierre Saverot, memo, November 1, 2006.

[vii] *Going the Distance?* (National Academy Press, 2006), Table 5.2.

[viii] *Information Digest, 2006-7,* U.S. Nuclear Regulatory Commission, 2006, Appendix I.

[ix] *Review of NRC's Dry Cask Storage Program,* Office of the Inspector General, U.S. Nuclear Regulatory Commission, OIG-01-A-11, June 20, 2001, shows, based on industry projections, that all but one U.S. nuclear power plant will have installed dry storage by 2017.

Appendix IV: Presentations to the Study Group

Lake Barrett
Barrett Consulting, LLC
"Consolidated Interim Storage: Assessing Need, Cost & Impact." August 8, 2006.

David Blee
Executive Director, US Transport Council
"Interim Storage & Spent Fuel Transportation Safety & Security." August 8, 2006.

Klaus Janberg
Former CEO of GNS-GNB
"International Perspectives on Interim Storage. " August 8, 2006.

Christopher Kouts
Director, Waste Management Office, Department of Energy
"Used Fuel Storage." August 8, 2006.

Steven P. Kraft
Director, Spent Fuel Management, Nuclear Energy Institute
"The Risks/Benefits of Consolidation." August 8, 2006.

David Lochbaum
Director, Nuclear Safety Project, Union of Concerned Scientists
"Interim Storage of Power Reactor Spent Fuel." August 8, 2006.

Martin J. Virgilio
Deputy Executive Director, Nuclear Regulatory Commission
"Overview of Spent Fuel Storage Safety and Security." August 8, 2006.