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Civilian Nuclear Spent Fuel Temporary Storage Options

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Mark Holt
Specialist in Energy Policy
Environment and Natural Resources Policy Division

Congressional Research Service ❖ The Library of Congress

ABSTRACT

The Department of Energy (DOE) is studying a site at Yucca Mountain, Nevada, for a permanent underground repository for highly radioactive spent fuel from nuclear reactors, but delays have pushed back the facility's opening date to 2010 at the earliest. In the meantime, spent fuel is accumulating at U.S. nuclear plant sites at the rate of about 2,000 metric tons per year. Major options for managing those growing quantities of nuclear spent fuel include continued storage at reactors, construction of a DOE interim storage site near Yucca Mountain, and licensing of private storage facilities. Arguments for development of a federal interim storage facility include DOE legal obligations, long-term costs, and public controversy over new on-site storage facilities. Opposition to centralized storage centers on the potential risks of a large-scale nuclear waste transportation campaign.

Civilian Nuclear Spent Fuel Temporary Storage Options

Summary

Highly radioactive spent fuel has been accumulating in pools of water at commercial reactors since the early years of the U.S. nuclear power industry. Originally it was expected that spent fuel would be removed from reactor sites to be dissolved in reprocessing plants to extract uranium and plutonium for use in new fuel. When the United States abandoned commercial reprocessing in the mid-1970s, a new policy had to be developed for spent fuel disposal. The result was the Nuclear Waste Policy Act of 1982 (NWPA), which required the Department of Energy (DOE) to develop a permanent underground repository for spent nuclear fuel by January 1998. The multibillion-dollar cost of the program was to be covered by a fee on nuclear power.

Development of such a repository has fallen years behind schedule. DOE, which is investigating a proposed repository site at Yucca Mountain in Nevada, does not expect to be able to begin taking waste from reactor sites before 2010. NWPA currently forbids DOE from building an interim storage facility for spent fuel until construction of a permanent repository is licensed. As a result, nuclear power plants may have to store spent fuel much longer than originally planned. By the end of the decade, according to DOE, about a third of the nation's commercial reactors will need additional storage capacity to supplement their spent fuel pools. Such additional capacity would probably be in the form of dry storage facilities, which are more efficient and less costly than spent fuel pools.

Nuclear utilities and state regulators are urging Congress to authorize construction of an interim spent fuel storage facility near the Nevada repository site that could begin receiving waste as soon as possible after 1998. Supporters of that plan contend that storage at reactor sites should be minimized because of concerns about safety, costs, public controversy, and the future of nuclear power. They maintain also that DOE faces legal sanctions under NWPA if waste is not taken from reactor sites by 1998. Opponents counter that continued storage at reactor sites would be less expensive than building a central storage facility and would reduce unnecessary transportation risks.

Alternatives to federal interim storage that might be considered include measures to mitigate the problems with long-term storage at reactor sites, such as reducing the nuclear waste fees paid by nuclear utilities and eliminating regulatory obstacles to the expansion of on-site storage capacity. Private central storage facilities have also been proposed; a utility consortium has applied for a license for such a facility on the Utah reservation of the Skull Valley Band of Goshutes. Another option that has been suggested is overseas storage and reprocessing of some U.S. commercial spent fuel.

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Introduction and Overview

When Congress enacted the Nuclear Waste Policy Act of 1982 (NWPA, P.L. 97-425), the Department of Energy (DOE) was given more than 15 years to begin taking highly radioactive spent fuel from commercial nuclear power plants. But DOE proved unable to open a waste facility by the NWPA deadline of January 31, 1998. Repeated delays have pushed back the scheduled opening of a permanent underground nuclear waste repository to 2010, and DOE appears to be barred by NWPA from starting to build a temporary storage facility for commercial spent fuel until the permanent repository is licensed for construction.

Nuclear utilities and state utility regulators are urging Congress to authorize DOE to construct an interim storage facility to receive spent fuel from nuclear plants as soon as possible after the 1998 deadline. They note that spent fuel storage pools at nuclear power plants are filling up, a situation that could eventually require the construction of additional storage capacity at most of the nation's 66 operating reactor sites. In the 105th Congress, bills have been approved by the Senate (S. 104) and the House (H.R. 1270) to construct a federal interim storage facility near Yucca Mountain, Nevada, the site of DOE's planned permanent underground nuclear waste repository.

Reactor Storage Versus Central Storage

According to the Nuclear Regulatory Commission (NRC), providing adequate spent fuel storage capacity at nuclear power plants is not a very difficult engineering problem. Nevertheless, nuclear utilities and their supporters cite several reasons for minimizing storage at reactor sites through federal central storage, such as reduced costs, increased safety, and the fulfillment of DOE's statutory obligations. Utility opponents counter that the risk of transporting spent fuel to a central storage facility would outweigh any problems created by leaving the material at reactor sites. There is also concern that development of a federal central storage site could preempt the completion of a permanent underground nuclear waste repository.

When spent nuclear fuel is first removed from a reactor, after it can no longer efficiently sustain a nuclear chain reaction, it is intensely radioactive and thermally hot. Until its radioactivity has sufficiently subsided, spent fuel must be cooled in pools of water that are adjacent to each commercial reactor. After several years, spent fuel can safely be removed from the storage pools and transferred to dry storage facilities outside the reactor building.

In dry storage systems, sufficiently cooled spent fuel is transferred from underwater storage in the pools to thick metal casks or thinner canisters, which are then drained, filled with inert gas, and sealed. The thick casks can be placed directly on a concrete pad, while the thinner canisters are placed in concrete casks or bunkers to provide radiation shielding. Such dry storage facilities have been constructed on small parcels of land at several nuclear power plants that have run out of space in their spent fuel pools. NRC has determined that dry storage of spent fuel at reactor sites is safe for at least 100 years, and generally considers dry storage safer than pool storage.[1]

According to DOE, about 1,000 metric tons of spent fuel is currently in dry storage at reactor sites. That number is projected to grow to above 2,000 metric tons by the turn of the century and exceed 10,000 metric tons by 2010.[2] (The tonnage refers to the weight of the original nuclear fuel, excluding metal cladding and assembly hardware.)

Although dry storage of spent nuclear fuel at reactor sites is a proven technology, nuclear utilities would prefer to move their spent fuel as soon as possible to a federal interim storage facility. Utilities are particularly concerned about incurring indefinite responsibility for maintaining on-site storage facilities — a concern that has grown with each delay in DOE's schedule for opening a permanent underground waste repository.

Supporters of federal storage contend that a centralized interim storage facility would be safer and less expensive in the long run than storage at each reactor site, and it would allow DOE to meet its obligation to nuclear power users, who have been assessed billions of dollars of fees to pay for waste disposal. Utilities and state utility regulators sued DOE for determining that it could disregard the 1998 disposal deadline if storage and disposal facilities were unavailable; a federal circuit court panel agreed with the utilities that the deadline was legally binding and vacated DOE's determination July 23, 1996.[3] In a subsequent decision, issued November 14, 1997, the court ordered DOE to develop an acceptable remedy for its failure to begin taking waste from plant sites as required.[4]

Some utilities may want to avoid building their own dry storage facilities because of the possibility of public controversy. Several proposals for dry storage at reactor sites have drawn strong state and local opposition; tight storage capacity

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[1]U.S. Nuclear Regulatory Commission. *Waste Confidence Decision Review*. 55 Federal Register 38508. September 18, 1990.

[2]U.S. Department of Energy. *Spent Fuel Storage Requirements 1994-2042.* DOE/RW-0431-Rev. 1. June 1995. p. B.78

[3]*Indiana Michigan Power Company, et al., v. Department of Energy and United States of America*. U.S. Court of Appeals, District of Columbia Circuit. Docket Nos. 95-1279, 95-1321, 95-1463. Decided July 23, 1996.

[4]*Northern States Power Company, et al., v. U.S. Department of Energy and United States of America.* U.S. Court of Appeals, District of Columbia Circuit. Docket Nos. 97-1064, 97-1065, 97-1370, 97-1398. Decided November 14, 1997.

limits were imposed at one nuclear plant, but no dry storage facility has yet been blocked altogether. The nuclear industry also is concerned that indefinite storage at reactor sites could pose a major obstacle to future nuclear power growth.

Opponents of federal interim storage contend that those problems do not justify moving spent fuel from nuclear power plants and incurring transportation risks before a permanent disposal site is ready. Strong state and local opposition has blocked previous proposals for centralized nuclear waste storage, particularly because of concern that such storage would become permanent.

The Nuclear Waste Technical Review Board, a scientific advisory body established by NWPA, warned that immediate development of a DOE central storage facility could jeopardize the effort to develop a permanent underground repository. In a March 1996 report, the Board argued that a storage facility could divert scarce funding from the planned repository and could erode political support for the repository program. The Board was also concerned that locating the storage facility at the proposed repository site would make it appear that the results of future scientific studies of the site's suitability for permanent disposal had been predetermined. To minimize those problems, the Board recommended that development of a DOE central storage facility be put off for a decade or more.[5]

Waste Policy Background

Throughout the history of the civilian nuclear power program, which started in the 1950s, indefinite storage of spent fuel at reactor sites has never been official U.S. policy. Yet, except for a small fraction that has been reprocessed or transferred to remote storage sites, U.S. commercial spent fuel has remained in pools of water or casks at individual nuclear plants. The oldest commercial spent fuel now has been stored at plant sites for more than three decades.

In the early years, reactor spent fuel was not considered by many in government and industry to be waste material, but a source of valuable uranium and plutonium for use in new fuel. The plutonium was expected to prove most useful for fueling "breeder" reactors, which could produce spent fuel containing more plutonium than the amount that had been fissioned to produce energy. It was envisioned that extracting plutonium from reactor spent fuel would be the only way to sustain a commercial nuclear power industry without exhausting limited deposits of natural uranium.

Spent fuel was expected to cool in pools at commercial reactor sites for only a few years until being shipped to "reprocessing" plants, where the uranium and plutonium would be chemically separated from the relatively small quantity of highly radioactive "fission products" that result from the splitting of heavy nuclei. The fission products, along with other unusable radioactive material and contaminated chemicals, would become waste for permanent disposal.

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[5]Nuclear Waste Technical Review Board. *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance*. March 1996. P. ix.

All of today's nuclear power plants were designed and ordered by electric utilities when U.S. policy called for spent fuel to be sent to reprocessing plants, so most of their spent fuel pools are relatively small. But the scarcity of natural uranium, which was expected to drive demand for reprocessed uranium and plutonium, never materialized, and the economic outlook for commercial reprocessing plants dimmed during the late 1970s. At the same time, concerns that plutonium from civilian spent fuel could be used for nuclear weapons helped end federal support for commercial reprocessing.

When the United States abandoned commercial reprocessing, the "once through" nuclear fuel cycle became official policy, calling for permanent disposal of spent fuel as quickly as possible after its discharge from reactors. That policy was enacted into law with the Nuclear Waste Policy Act, which required DOE to begin disposing of commercial spent fuel at an underground repository by January 1998. To fund the program, utilities were required to pay a fee of one mill (a tenth of a cent) per kilowatt-hour of nuclear electricity, with the fees to be deposited in a Treasury account called the Nuclear Waste Fund. The DOE Office of Civilian Radioactive Waste Management (OCRWM) was established to run the program.

Opening a disposal facility has proven more expensive, and politically and technically more difficult, than expected. After DOE made little progress toward finding a site during the program's first five years (at least partly because of opposition from states and regions under DOE's consideration), Congress designated Yucca Mountain in Nevada as the sole candidate repository site in 1987 (P.L. 100-203). But opposition from the State of Nevada and other problems continued to create delays, and DOE now does not expect to begin operating a repository before 2010. The 1987 nuclear waste amendments also authorized construction of a central storage facility for commercial spent fuel but blocked DOE from building the facility until construction of the repository was licensed. No site was specified, except that it could not be located in Nevada.

Current law provides arguments for both sides of the debate over spent fuel storage. On one hand, the Nuclear Waste Policy Act establishes a statutory timetable for DOE to begin taking spent fuel from nuclear power plants, to minimize long-term storage at reactor sites. But because the law forbids DOE from taking spent fuel until a permanent repository is approved for construction, long-term storage at reactor sites appears to be the current policy by default. Congress now is being asked to determine which of those conflicting principles should take precedence, or whether other steps should be taken to mitigate the problems created by delays in the federal nuclear waste program.

Options for Spent Fuel Storage

A range of options is available for meeting the anticipated U.S. need for additional spent fuel storage capacity. Major alternatives include continuing the expansion of dry storage at reactor sites, construction of federal or private interim storage facilities, and reprocessing of spent fuel to extract plutonium and uranium. Each alternative would have a different way of addressing the issues involved with long-term storage — such as public opposition, costs, DOE's legal responsibilities, the future growth of nuclear power, and transportation. The major alternatives are not necessarily mutually exclusive, and each would raise its own set of controversial issues.

Expansion of On-site Storage

The Nuclear Waste Policy Act appears to require that commercial reactors provide sufficient on-site or other non-federal storage capacity for their own spent fuel at least until DOE receives an NRC construction permit for a permanent repository. At that point, DOE is authorized to begin accepting waste at a "monitored retrievable storage" facility. (However, the law also may penalize DOE for failing to begin receiving utility waste by 1998, as indicated by the U.S. appeals court decision noted above.)

Supporters of continued on-site storage point to NRC's confidence about the safety of long-term storage at reactor sites and contend that the problems associated with such storage could be sufficiently mitigated. Environmental and other groups also contend that on-site storage would eliminate the near-term risks of transporting highly radioactive spent fuel to a central storage facility.

To offset the added on-site storage costs under this option, it has been proposed in the 105th Congress (S. 296) that utilities receive credits to reduce their nuclear waste fees. Some utilities have requested such credits from DOE to pay for on-site dry storage facilities, although none have been granted. A drawback to that idea is that nuclear waste fee rebates or credits would reduce the total funding available for the nuclear waste program.

Although the Nuclear Waste Fund currently holds a large surplus — $6.2 billion at the end of FY1997, according to DOE[6] — future funding could fall short and require an increase in nuclear waste fees. As a result, nuclear utilities could end up paying for rebates and credits with future fee increases. Questions about equity might also be raised by such a system; utilities with adequate storage capacity would be required to help pay, through the Nuclear Waste Fund, the storage costs of utilities that had run out of storage space.

DOE had suggested that it could partially compensate for missing the 1998 repository deadline by providing multi-purpose canisters (MPCs) to nuclear power plants that needed additional storage capacity.[7] DOE planned to design the sealed canisters to fit into different shielded "overpacks" for storage, transportation, and permanent disposal. However, sharp budget cuts in FY1996 forced DOE to halt design work on an MPC system, although private-sector systems are becoming available. DOE could provide a waste fee credit to utilities purchasing private-sector

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[6]Nuclear Waste Fund Status. Table provided by Nick DiNunzio, U.S. Department of Energy, March 18, 1998.

[7]U.S. Department of Energy. Office of Civilian Radioactive Waste Management. Notice of Inquiry: Waste Acceptance Issues. Federal Register. May 25, 1994. P. 27007.

MPCs in the hope that such systems would reduce the waste program's future transportation and disposal costs.

Obstacles to long-term storage posed by public opposition could be mitigated by Congress. For example, NWPA could be amended to preempt all state and local jurisdiction over spent fuel storage facilities, with NRC regulating safety and the Federal Energy Regulatory Commission (FERC) determining whether storage costs could be passed through to electricity customers. However, state officials would undoubtedly oppose restrictions on their regulatory authority.

Congress has several options for addressing the lack of permanent disposal facilities to meet the 1998 deadline. The simplest action might be to change the deadline to give DOE more time to develop a disposal facility. Congress also could formally establish a national policy of long-term storage at reactor sites, and modify the law to explicitly stipulate that DOE should begin taking spent fuel from reactor sites only when licensed facilities become available.

Arguments might be raised that a statutory change in the 1998 waste disposal deadline would take away vested rights for which nuclear utilities have already paid, and that utilities would be due compensation. The Supreme Court recently ruled that the federal government cannot "break its contractual promises without having to pay compensation."[8] However, it is not clear that NWPA's waste disposal requirements would constitute a contract under the Supreme Court ruling. DOE did sign waste disposal contracts with utilities pursuant to NWPA, but those contracts contain an explicit delay clause. The recent appeals court decision upholding the 1998 deadline appeared to be based on statutory provisions, rather than on the contracts.

Private Central Storage Facilities

With DOE apparently blocked by law from developing a central storage facility for commercial spent fuel, it may be possible for the private sector to step in. Two private central storage facilities already exist — at former reprocessing plants in New York and Illinois — although neither is currently accepting additional spent fuel. Privately owned central storage facilities would require NRC licensing under the same regulations that would apply to a DOE-owned MRS facility (10 CFR Part 72).

A consortium of seven nuclear utilities applied to NRC June 25, 1997, for a license to build a commercial spent fuel storage facility on the Utah reservation of the Skull Valley Band of Goshutes. The license application would allow the storage of up to 40,000 metric tons in about 4,000 sealed canisters.[9] The storage facility, which would begin receiving spent fuel beginning in 2002, would cost about $130 million to license and construct.[10] The State of Utah strongly opposes the storage

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[8]*United States v. Winstar Corp.*, 116 S.Ct. 2432 (July 1, 1996).

[9]"Utilities Apply to NRC to Site Dry Cask Storage Facility on Utah Reservation of Skull Valley Goshutes." *SpentFuel*. June 30, 1997. p. 1

[10]Behrens, Lira. "Utility Coalition Asks NRC to License Private Waste Storage Facility."
(continued...)

plan, but the Goshutes' sovereignty over their reservation appears to preclude state authority to regulate or block it.

Previous proposals for private storage facilities have required nuclear utilities to retain ownership of any spent fuel that they shipped to such sites. As a result, utilities would risk being required to take back their spent fuel if DOE were unable to begin accepting it before a storage facility closed. Although such private storage facilities would not necessarily solve nuclear utilities' long-term waste problems, they could provide an alternative for power plants that were facing state and local obstacles to the expansion of on-site storage.

A privately developed nuclear waste storage facility at the Yucca Mountain site was proposed by Sen. Grams during the 104th Congress (S. 1478). Under that plan, a consortium of nuclear utilities and other firms would receive money from the Nuclear Waste Fund to build a storage facility on DOE land at Yucca Mountain for at least 40,000 metric tons of commercial spent fuel.

Once the facility authorized by S. 1478 were licensed by NRC, it would receive spent fuel taken by DOE from reactor sites, allowing DOE to fulfill its responsibilities under its contracts with nuclear utilities. Unlike the situation at other proposed private storage facilities, therefore, spent fuel sent to the private facility under S. 1478 would have been owned by DOE and no longer been the responsibility of the utilities that generated it. DOE also would assume ownership of the storage facility before decommissioning, with costs to be paid from the Nuclear Waste Fund.

Federal Interim Storage

Nuclear utilities and state regulators are urging Congress to reverse its 1987 waste storage policy and authorize DOE to immediately construct an interim storage facility at Yucca Mountain. Under current law, DOE cannot build a central storage facility until NRC grants a construction permit for a permanent repository, and is prohibited from siting the facility in Nevada. The nuclear industry and its supporters argue that a Nevada storage facility represents the best hope for DOE to begin taking spent fuel from nuclear power plants within a few years after the 1998 deadline.

Storage at Yucca Mountain. In the 105th Congress, legislation to authorize a DOE storage facility at the Nevada Test Site near Yucca Mountain was approved by the House on October 30, 1997 (H.R. 1270, H.Rept. 105-290). The House bill would require DOE to begin receiving waste at the storage facility in 2002, clearing away regulatory, logistical, and legal obstacles that might prevent DOE from meeting that deadline. The storage facility authorized by the committee bill would be developed and licensed in two phases. The first phase would consist of relatively simple dry-storage facilities for up to 10,000 metric tons of spent fuel and would be licensed for 20 years. In the second phase, the facility could be expanded to hold up to 40,000 metric tons and be licensed for a renewable term of 100 years.

[10](...continued)
Inside Energy/with Federal Lands. June 30, 1997. p. 5

A similar bill (S. 104, S.Rept. 105-10) was passed by the Senate April 15, 1997. The Senate-passed bill would require the President to determine the suitability of the Yucca Mountain site for a permanent underground repository by 1999, before a license application could be submitted for an interim surface storage facility at the site. If the site were declared suitable for the permanent repository, temporary storage could begin by 2002. If not, there would be a two-year moratorium on the project to allow for congressional approval of an alternative interim storage site. If no alternative were approved, then interim storage would proceed at Yucca Mountain. (For more details of the House and Senate bills, see CRS Issue Brief 92059, *Civilian Nuclear Waste Disposal*.)

By focusing on areas near Yucca Mountain, the bills are attempting to address some of the concerns that prompted Congress in 1987 to prohibit DOE from opening a storage facility before beginning construction of a permanent repository — in particular, the concern that a storage facility could become permanent. Because Yucca Mountain is intended to be the permanent disposal site if NRC issues a license, it could be argued that long-term storage would impose a relatively low additional burden. Supporters of Yucca Mountain storage also contend that the remote site is appropriate for central storage of highly radioactive waste and that the site would minimize the additional transportation risk and expense that would be needed to move the stored waste into the Yucca Mountain permanent repository, if it is built as planned.

A potential variation on the Yucca Mountain storage plan would require DOE to store commercial spent fuel underground at the site rather than in surface storage facilities. Essentially, DOE would begin building and loading the Yucca Mountain repository before it was licensed for permanent disposal. Once the repository was licensed, the stored waste could remain permanently, and DOE would have begun receiving waste earlier than currently planned without having to construct a large surface storage facility. Studying the effects of underground stored nuclear waste might also prove helpful to DOE in preparing a repository license application. If the repository ultimately failed to receive a license, alternative facilities could be developed while the waste remained securely stored in Yucca Mountain.

Potential objections to the underground storage idea primarily involve time and cost. It would almost certainly take DOE several more years to prepare underground storage facilities at Yucca Mountain than to open a surface facility of the type already existing at nuclear power plants. Although cost savings could be achieved by reducing the need for surface storage facilities (primarily concrete structures for radiation shielding), the emplacement of large quantities of radioactive material in underground chambers could increase the cost of DOE's ongoing repository studies by necessitating radiological health controls and other safety measures. Moreover, DOE has not developed waste containers or determined the optimum container configuration and spacing for permanent disposal, so waste stored underground probably would have to be repackaged and moved into new tunnels after the permanent repository was licensed.

Storing waste at Yucca Mountain could reduce general public confidence in the safety of permanent disposal at the site, because it might appear that the federal government had prejudged the site's suitability for a repository before completing the necessary scientific evaluations. Such concerns could be exacerbated by a decision to store nuclear waste underground at Yucca Mountain before a repository were licensed by NRC.

Accusations of federal prejudgment have already been prompted by Congress' 1987 selection of Yucca Mountain as the sole repository candidate site. State officials in Nevada have long contended that the potential for earthquakes, volcanoes, and other hazards at Yucca Mountain render the site scientifically unsuitable for a repository, although DOE maintains that no insurmountable problems with the site have yet been found. The Nuclear Waste Technical Review Board recently concurred with DOE's opinion.[11]

The Clinton Administration's position is that interim storage should not be established at Yucca Mountain until DOE completes a technical viability determination expected in 1998. DOE's most recent Civilian Radioactive Waste Program Plan calls for construction of an interim storage facility to begin in 2001 and for waste to be received at the selected site in 2002. The plan notes that the proposed interim storage schedule could not be implemented without modifying NWPA's current restrictions on DOE waste storage.[12]

The Nuclear Waste Technical Review Board recently warned that immediate efforts to develop an interim storage facility could reduce the resources available for the permanent repository program.

Nevada's Lincoln County and City of Caliente have offered a site a few hundred miles northeast of Yucca Mountain for DOE to store up to 15,000 metric tons of spent fuel. The proposal, issued February 21, 1995, calls for DOE to pay the two localities up to $30 million per year and provide other benefits. Under the two nuclear waste bills, the Lincoln County site, which is along a main railway, would be used for transferring waste casks from rail cars to trucks for final transport to the Yucca Mountain site.

Alternative Approaches. Various nuclear-related DOE installations other than Yucca Mountain also have been suggested as storage sites for commercial spent fuel. DOE already is receiving U.S.-origin spent fuel from foreign research reactors at the Savannah River Site in South Carolina, although less than 20 metric tons is involved in that program.[13] Sen. Murkowski, Chairman of the Senate Energy and Natural Resources Committee, suggested in a floor statement May 25, 1995, that DOE store commercial spent fuel at its Savannah River and Hanford, Washington, nuclear installations.

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[11]U.S. Nuclear Waste Technical Review Board. Letter to Energy Secretary Hazel O'Leary from Review Board Chairman John E. Cantlon. Feb. 23, 1996.

[12]U.S. Department of Energy. Draft Civilian Radioactive Waste Management Program Plan, Revision 1. DOE/RW-0458, Revision 1. May 1996. P. 22.

[13]U.S. Department of Energy. Draft Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel. DOE/EIS-0218D. March 1995. P. 13.

The Monitored Retrievable Storage (MRS) Commission, a temporary three-member panel established by the 1987 NWPA amendments, recommended that Congress authorize two storage facilities at DOE sites. Issued in 1989, the MRS Commission's report proposed a low-capacity emergency storage facility and a larger, user-funded storage facility instead of the repository-linked MRS facility authorized by NWPA.

The proposed emergency storage facility would be limited to 2,000 metric tons of spent fuel and would be built at a DOE nuclear site with spent-fuel handling experience. The estimated $300-$400 million facility would be large enough to accept all the waste from one or more nuclear plants if they suffered accidents that required their spent-fuel pools to be emptied. Noting that such a facility would provide emergency backup for all nuclear power plants, the Commission recommended that its costs be paid by all nuclear utilities through the Nuclear Waste Fund.

The Commission's proposed user-funded, NRC-licensed storage facility would hold up to 5,000 metric tons of spent fuel and would provide utilities an alternative to on-site storage. Users of such a facility would primarily consist of utilities wanting to reduce spent-fuel monitoring costs at decommissioned reactors, according to the MRS Commission report, which estimates such costs at $2-$3 million annually. Such a facility also could take spent fuel from reactors with problems providing sufficient on-site storage. As the name implies, the $500-$600 million user-funded storage facility would be built only if enough utilities were willing to sign contracts to cover its cost. The MRS Commission reasoned that only users should pay for such a facility because it would be inequitable to impose part of its costs on utilities that were willing to pay for storing their waste on-site.[14]

Congressional authorization of a "small, limited-capacity backup storage facility" was recently suggested by the Nuclear Waste Technical Review Board as "one way to accommodate the storage needs of any utilities that, for one reason or another, cannot continue to store their own spent fuel."[15]

The primary obstacle to such facilities, even the relatively small ones proposed by the MRS Commission, would be the type of regional opposition that blocked DOE's 1986 proposal for an MRS facility in Tennessee. Without direct linkages to the repository, as imposed by Congress in 1987, a proposed storage facility is vulnerable to arguments that it could become permanent.

Spent Fuel Reprocessing

Reassessing current U.S. policy and sending spent nuclear fuel to reprocessing plants has been suggested as an alternative to storing the material at reactor sites or a central facility. Possible reprocessing locations include a newly constructed facility in Great Britain and underused defense reprocessing facilities at DOE's Savannah

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[14]Monitored Retrievable Storage Review Commission. Report to Congress. Washington. November 1989.

[15]U.S. Nuclear Waste Technical Review Board. *Op. Cit.*

River Site. Reprocessing of spent fuel could alleviate near-term storage problems and extract uranium and plutonium for use in new nuclear fuel. However, the highly radioactive waste produced by reprocessing would still require long-term storage and disposal, and the separation of plutonium would probably raise serious concerns about nuclear weapons proliferation.

British Nuclear Fuels Ltd. (BNFL) has proposed that spent fuel from nuclear power plants with severe on-site storage problems be shipped to BNFL's new Thermal Oxide Reprocessing Plant (THORP) in northern England.[16] BNFL already is receiving spent fuel shipments from Japan and other countries, using a fleet of special ships. Under the BNFL proposal, DOE could send U.S. spent fuel to THORP to be stored for at least a decade and then reprocessed. The storage and reprocessing cost of $1 million per metric ton would be paid from the Nuclear Waste Fund. If DOE storage and disposal facilities became available before the U.S. spent fuel was reprocessed, the material could be returned and the reprocessing contract terminated. DOE would pay a termination fee covering BNFL's transportation and storage costs.

If the U.S. spent fuel were reprocessed, the plutonium (about 1 percent) and uranium (about 95 percent) would be separated from highly radioactive waste products. The resulting liquid high-level waste would be vitrified — dissolved in molten glass — and poured into stainless steel canisters at a new facility that adjoins THORP. The uranium, plutonium, and waste canisters would then be returned to DOE, or, for an additional fee, BNFL could produce mixed-oxide (MOX) fuel from the plutonium and some of the uranium. Most U.S. nuclear plants could load at least a third of their reactor cores with MOX fuel.

The Senate Energy and Natural Resources Committee included a provision in a nuclear waste bill in the 104th Congress (S. 1271) that could have been used to implement the BNFL reprocessing proposal. Utilities lacking spent fuel storage space would have been authorized to contract for "interim storage and conditioning" with "qualified entities." DOE would take title to "all spent nuclear fuel and high-level radioactive waste resulting from the treatment of that fuel." However, the controversial provision was dropped from the final bill as passed by the Senate (S. 1936).

A report by the operator of the Savannah River Site suggested that the site's reprocessing facilities, which formerly extracted highly enriched uranium and plutonium primarily for defense needs, could economically reprocess spent fuel from commercial reactors. A new vitrification plant at the site could solidify the resulting high-level waste for disposal. However, questions have arisen about the ability of the 40-year-old SRS reprocessing facilities to meet current safety standards.[17]

Reprocessing costs are intended to be offset at least partly by the value of the uranium and plutonium extracted from spent fuel, a value that depends primarily on the market price of newly mined uranium. Uranium has been relatively inexpensive

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[16]BNFL Inc. Issues for BNFL's Congressional Staff Tour. August 1995.

[17]Kramer, David. *Report by SRS Contractor Appears to Advocate Reprocessing at Site.* Inside Energy/with Federal Lands. January 8, 1996. P. 8.

since the early 1980s, but reprocessing supporters expect prices to rise in the future. The value of reprocessed uranium is difficult to assess. On the downside, reprocessed uranium contains a relatively high percentage of undesirable uranium isotopes and may be slightly contaminated with highly radioactive residues. However, it also usually has a higher percentage of the crucial isotope uranium-235 than found in natural uranium.

Reprocessing proponents maintain that waste disposal costs would be lowered by the reduction in waste volume and by the recycling of plutonium, which poses a long-term radioactive hazard. However, the waste-management benefits of reprocessing remain largely undemonstrated. Most of the near-term radioactivity and heat in spent fuel would remain in the vitrified high-level waste, so the separation between waste canisters in a repository (and therefore total acreage requirements) might not be significantly reduced. Also, because plutonium can be recycled only a few times in today's reactors before becoming unusable, some reprocessed plutonium would eventually require permanent disposal unless advanced reactor technology became commercialized.

Reprocessing of U.S. commercial reactor fuel would require a substantial change in U.S. nuclear nonproliferation policy. Although the Clinton Administration does not attempt to block the United States' economically advanced allies from reprocessing civilian spent fuel, it "does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes."[18] Supporters of the Administration policy contend that any U.S. reprocessing would undermine efforts to prevent non-nuclear-weapons nations from building plutonium stockpiles.

Major Storage Issues

Long-term storage of spent nuclear fuel at commercial reactor sites should be minimized for a variety of reasons, according to nuclear utilities and their supporters. They contend that serious problems with storage at reactor sites include higher costs, safety concerns, public opposition, violations of DOE's statutory responsibility, and the hindrance of future nuclear power growth in the United States. The nuclear industry argues that the best solution for those problems would be to build a federal interim storage facility as quickly as possible.

Opponents of that view disagree about the severity of the problems cited by nuclear utilities, contending that spent fuel should remain in place until an acceptable permanent disposal site can be developed. Of particular concern to nuclear industry opponents is the risk posed by spent fuel transportation, although NRC considers such risks to be relatively low.[19]

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[18] White House, Office of the Press Secretary. *Fact Sheet: Non-Proliferation and Export Control Policy.* Sept. 27, 1993.

[19] U.S. Nuclear Regulatory Commission. *Transporting Spent Fuel: Protection Provided Against Severe Highway and Railroad Accidents*. NUREG/BR-0111. March 1987.

Legal Consequences of Missing 1998 Deadline

Nuclear utilities and state regulatory officials contend that federal interim storage is necessary for DOE to come close to fulfilling its obligation under NWPA to begin taking waste from reactor sites by 1998. Payment of billions of dollars by nuclear utilities into the Nuclear Waste Fund, they argue, requires DOE to provide disposal services on time. The utilities and state regulators warn that DOE faces legal sanctions for missing the statutory deadline, a position that has been endorsed by a federal Circuit Court panel.

The argument over DOE's legal requirements hinges on NWPA Section 302(a), which requires nuclear utilities to sign contracts with DOE for the disposal of spent nuclear fuel in return for the payment of nuclear waste fees. Section 302(a)(5) reads as follows:

> (5) Contracts entered into under this section shall provide that—
>
> (A) following commencement of operation of a repository, the Secretary shall take title to the high-level radioactive waste or spent nuclear fuel involved as expeditiously as practicable upon the request of the generator or owner of such waste or spent fuel; and
>
> (B) in return for the payment of fees established by this section, the Secretary, beginning not later than January 31, 1998, will dispose of the high-level radioactive waste or spent nuclear fuel involved as provided in this subtitle.

Pointing out that the provision above requires DOE to take title to utility waste "following commencement of operation of a repository," the Department published a Federal Register notice May 3, 1995, concluding that the 1998 deadline was not legally binding if storage or disposal facilities were not ready in time (60 FR 21793). The only interim storage facility DOE currently is authorized to construct is an MRS facility, and construction cannot begin until a permanent repository receives an NRC construction permit, which is not anticipated until about 2005 at the earliest. A permanent repository is not expected to be opened before 2010. Therefore, DOE concluded in its 1995 notice, NWPA does not unconditionally require the Department to begin taking waste from utilities by January 1998.

The standard waste disposal contract that DOE signed with nuclear utilities also specifies that DOE services should begin by January 31, 1998, but "after commencement of facility operations" (10 CFR 961.11, Art. II). Article IX of the contract protects the federal government from liability for damage caused by "unavoidable delays," including delays caused by "acts of Government in either its sovereign or contractual capacity."

Fourteen utilities and officials representing 20 states filed two lawsuits June 20, 1994, in the U.S. Circuit Court of Appeals for the District of Columbia to require compliance with the 1998 deadline; the suits were subsequently refiled to overturn DOE's determination that the deadline was not necessarily legally binding. The Court agreed with the utilities and vacated the DOE determination July 23, 1996.[20] DOE announced October 22, 1996, that it would not appeal.[21]

Although the Court ruled that DOE remains subject to the 1998 deadline, it did not determine an appropriate remedy if the deadline were missed. In response, nuclear utilities and states filed similar lawsuits asking the same panel to specify a remedy for DOE's anticipated noncompliance. The Court ruled November 14, 1997, that DOE is liable for unspecified damages to nuclear utilities for failing to begin the removal of spent nuclear fuel from commercial reactors by the NWPA deadline. However, the Court did not order DOE to begin moving the waste to its existing facilities, as some utilities had urged. Instead, DOE was ordered to work out a remedy with the utilities under the procedures of the standard disposal contract between DOE and all nuclear utilities.[22] The Clinton Administration on December 3, 1997, requested a review of the decision by the full Appeals Court.

After DOE missed the disposal deadline, a coalition of state officials filed a new lawsuit February 2, 1998, asking the Appeals Court to order DOE to begin taking waste from reactors quickly and that payments to the nuclear waste fund be placed in escrow. In addition, the suit asked the Court to prevent DOE from reimbursing utilities for damages from the Nuclear Waste Fund — funds previously collected from ratepayers — and consider a court-appointed master to ensure compliance with court orders. A similar suit was filed by 36 nuclear utilities February 19, 1998. The potentially broad ramifications of court-imposed sanctions could increase the pressure for congressional intervention.

Separately from the ongoing court case, state utility regulators have been considering steps they could take in response to DOE's failure to meet the NWPA deadline. State utility regulatory bodies in Virginia, Minnesota, and South Carolina are particularly concerned about the fairness of requiring electric utility customers to pay the nuclear waste fee without receiving waste disposal benefits.

Options under consideration by state regulators include forbidding utilities from passing the fee through to their customers and ordering utilities to pay the fees collected from customers into an escrow account. However, comments filed by Virginia Power with the state regulatory commission suggested that a state could not order such steps without creating an unconstitutional conflict with NWPA.[23] The State of Minnesota enacted legislation in May 1997 allowing nuclear waste fees collected in the state to be placed in escrow, if authorized by a federal court, until DOE began taking waste from reactor sites.

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[20] *Indiana Michigan Power Co., op. cit.*

[21] Newman, Pamela. *Nuclear Utilities Win Major Waste Battle*. Energy Daily. Oct. 24, 1996. p. 1.

[22] *Northern States Power Co., op. cit.*

[23] Virginia Electric and Power Company. *Initial Comments on Virginia State Corporation Commission Investigation of Spent Nuclear Fuel Disposal, Case No. PUE950060.* October 31, 1995.

Safety of On-site Storage

Nuclear utilities contend that while on-site storage is safe, consolidated storage at a remote site would be safer. Storage at Yucca Mountain or another unpopulated site would be expected to reduce the already low risk of public exposure from accidents, sabotage, theft, or routine radiation emissions. But opponents of central storage contend that the risks of transporting spent fuel from reactor sites would outweigh any safety advantages of a central storage facility. They also note that any benefits of consolidated storage would require decades to fully achieve, because of the time required for transportation and the continued generation of spent fuel at operating reactor sites.

NRC concluded in its 1990 Waste Confidence Decision Review that spent fuel could be stored safely at reactor sites for at least 100 years.[24] That determination, according to NRC, indicates that even if the opening of a permanent waste repository were delayed until 2025 — 15 years later than DOE's most recent goal — all spent fuel could be removed from today's nuclear power plants before public health and safety would be threatened. The 100 years of anticipated safe storage consists of 40 years during a reactor's initial operating license, 30 years during a possible extended license, and at least another 30 years after shutdown.

The waste confidence finding allowed NRC to conclude that waste being generated by today's nuclear power plants would pose no unacceptable hazard to the public before going to a permanent disposal site. According to DOE, once the Department begins taking waste deliveries, it will take 25-30 years to remove all spent fuel from non-pool storage at today's reactors,[25] and it could take a decade or more to remove spent fuel from the pools of all reactors after they were shut down. If DOE began accepting waste in 2025, therefore, it could be 2065 before all waste from today's reactors could be removed for permanent disposal — well within NRC's 100-year storage period if the oldest spent fuel were taken first.

NRC regulations allow nuclear reactors to seek an indefinite number of renewals of their operating licenses, allowing up to 20 years of additional operation per renewal (10 CFR 54.31). However, it is uncertain how many reactors will extend their licenses beyond their initial 40-year periods, or how many will shut down early. The waste confidence finding concludes that spent fuel can be stored on site safely for 100 years no matter when a reactor ceases operation:

> Even in the case of premature shutdowns, where spent fuel is most likely to remain at a site for 30 years or longer beyond [operating license] expiration, the Commission has confidence that spent fuel will be safely managed until safe disposal is available.[26]

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[24]U.S. Nuclear Regulatory Commission. *Waste Confidence Decision Review. September 18, 1990. 55 Federal Register 38474.*

[25]U.S. Department of Energy. *Final Version Dry Cask Storage Study*. DOE/RW-0220. February 1989. P. I-35.

[26]U.S. Nuclear Regulatory Commission. *Waste Confidence Decision Review*. 55 Federal

(continued...)

NRC bases its 100-year storage period on confidence in today's storage technology in the short term and on confidence in its long-term regulatory authority to require whatever safety steps might be needed. The Waste Confidence Review declares dry storage systems to be "simple, passive and easily maintained," and contends that "adequate regulatory authority exists and will remain available to require any measures necessary to assure safe storage of spent fuel." NRC received some criticism of its assertion that institutional controls over spent fuel could be assured for 100 years, but the waste confidence finding cites numerous human institutions that have lasted longer.

Spent fuel pools require greater operator attention and maintenance than dry storage facilities. A minimum amount of water must be kept in the pools, and the pools include a variety of active cooling, cleaning, and other systems that must be carefully maintained. NRC has studied a number of pool accident scenarios, including fuel-cladding fires in an accidentally drained pool, and found a low probability of serious accidents.[27] Spent-fuel pool safety questions that have arisen more recently include the possible loss of cooling at some boiling water reactor (BWR) pools, and the degradation of neutron absorbers in reracked pools.

Although NRC believes both dry and pool storage are adequately safe, the dry storage systems are considered more immune from operational errors. In a 1994 speech, then-NRC Chairman Ivan Selin remarked:

> Based on our safety reviews and actual experience to date, we conclude that dry cask storage is preferred in many instances, especially for operating plants with limited pool storage capacity and for shut-down plants.[28]

A recent incident at a Wisconsin nuclear power plant, however, demonstrated the possibility of unanticipated safety problems even in dry storage systems. While technicians were welding the lid on a fully loaded cask at the Point Beach plant May 28, 1996, hydrogen that had unexpectedly accumulated in the cask was ignited with enough force to lift the heavy lid. Subsequent analysis determined that the hydrogen had formed from the interaction of borated water in the cask and the zinc coating on internal cask components. Measures to prevent future hydrogen accumulations during cask loading are now under consideration. Such a problem is unlikely after loaded casks are placed in storage, because the water is drained and replaced by inert gas.

Operating plants must have pools of water to receive spent fuel immediately after it is discharged from a reactor. The radioactivity and resulting heat of spent fuel must decay for at least a year before the material is considered safe by NRC for dry storage (10 USC 72.2(a)), and currently licensed dry storage systems require longer cooling periods. After a reactor has been shut down for several years, however, it

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[26](...continued)
Register 38508. Parenthetical note omitted.

[27]*Ibid*. 55 FR 38481.

[28]Selin, Ivan. *Timely Topics on Spent Fuel Storage*. Remarks before the Annual Meeting of the Institute of Nuclear Materials Management. Naples, Florida. July 18, 1994.

would be possible to empty and decommission its spent fuel pool and rely entirely on dry storage.

Public radiation exposure from spent fuel storage facilities during normal operations is low. Under NRC regulations (10 CFR 72.67), the nearest individual to a storage facility must not receive an annual radiation dose to the whole body above 25 millirems, about a tenth of average background radiation in the United States. Two spent fuel storage sites were analyzed by DOE in 1989. According to that analysis, the nearest individual's annual exposure at the H.B. Robinson nuclear plant in North Carolina was 0.4 millirem, while the nearest individual at the Surry plant in Virginia received 0.00006 millirem.[29]

The Nuclear Waste Technical Review Board recently concluded, "There is no compelling technical or safety reason ... to move spent fuel to a centralized storage facility in the next few years." The Review Board warned that long-term safety could be reduced if an interim storage facility were to undermine the nation's commitment to developing a permanent underground repository. However, the Review Board recommended that DOE develop a central storage facility in the future at the repository site to take spent fuel from closed reactors.[30]

Cost of Dry Storage at Reactor Sites

The average cost of dry storage systems has dropped in recent years as the need for on-site capacity has grown, but dry storage costs could represent a significant burden to some nuclear reactors facing competition in a deregulated electricity market. In the view of nuclear utilities, the billions of dollars they have paid into the Nuclear Waste Fund should have allowed DOE to meet NWPA's 1998 deadline for starting to take waste from reactors. Timely waste acceptance by DOE could minimize the need for additional utility expenditures for on-site storage.

Storage of nuclear spent fuel must be paid for by nuclear utilities (from customer revenues) whether such storage takes place at reactor sites or at a central DOE facility. The difference is that utilities directly and immediately cover the costs of at-reactor storage, while the cost of a central DOE storage facility would be paid from utility fees collected in the Nuclear Waste Fund. DOE is required to increase the fee if revenues are projected to fall short of the program's total costs, but the fund currently has a surplus of several billion dollars, so any increase would probably occur well in the future.

Utilities and their customers could also realize savings if the total cost of central storage were lower than the total cost of storage at reactor sites. That calculation depends primarily on the estimated cost of storing spent fuel at reactors that have closed, because the continued presence of spent fuel would require maintenance, security, and other expenditures at plant sites that could otherwise be left largely untended or put to other uses. The longer spent fuel would be likely to remain at a

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[29]U.S. Department of Energy. *Final Version Dry Cask Storage Study*, *op. cit*. p. I-97.

[30]U.S. Nuclear Waste Technical Review Board, *op. cit*.

reactor after it had ceased operation, the greater the potential savings from a central storage facility.

Construction and Transportation Costs. The cost of building on-site spent fuel storage facilities depends on the type of storage system selected and the capacity required. Dry storage systems can use all-metal casks or inner metal canisters placed within outer concrete casks or modules. All-metal casks are generally the most expensive dry storage system, because the metal must be thick enough to provide effective radiation shielding; concrete casks and modules provide radiation shielding less expensively. Additional costs are incurred if the storage casks or inner canisters are designed to be transportable.

A 1993 study by the Electric Power Research Institute (EPRI) estimated that dry storage capital costs ranged from $350,000-$500,000 for each concrete cask or module. The cost of an all-metal storage cask was estimated to be no lower than $750,000.[31] With average cask capacity estimated at 11.2 metric tons, the storage facility cost per metric ton would average about $35,000 for concrete systems and $65,000 for metal casks. Those costs are substantially lower than the approximately $110,000 per metric ton paid for the first at-reactor metal casks in the 1980s, according to the EPRI study's project manager.[32]

Each U.S. reactor discharges an average of about 20 tons of spent fuel annually, so a reactor that had filled its pool storage would need to spend an average of $700,000 to $1.3 million per year to construct additional dry storage capacity. If DOE does not take any spent fuel from reactor sites until 2010, nuclear utilities will need dry storage facilities for about 10,000 metric tons, according to DOE projections (see Table 1). Based on the EPRI cost projections, therefore, total reactor dry storage construction costs could reach $350-650 million by 2010 and double by 2020.

If DOE were to build an interim storage facility, its construction costs to store the same amount of spent fuel would be similar to the cost of on-site storage capacity, because similar dry storage technologies would be employed. Additional construction costs would probably be incurred at a DOE storage facility to replicate the fuel-handling capacity and other infrastructure that already exists at operating nuclear power plants. On the other hand, some overall savings might be realized by licensing a single DOE storage facility rather than conducting the necessary safety analyses for a large number of individual facilities at plant sites.

Interim storage at a central facility would incur substantial transportation costs. But if the storage facility were located at the site of a permanent repository — such as Yucca Mountain if found acceptable — the cost of shipping spent fuel for central storage would probably be about the same as would have been spent later to ship it directly to the repository. Additional costs would be incurred, however, if the Yucca Mountain repository were rejected and the stored spent fuel had to be shipped to a different location for permanent disposal.

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[31]Electric Power Research Institute. *Comparative System Economics of Concrete Casks for Spent-Fuel Storage*. EPRI TR-102415. June 1993. p. 2-11.

[32]Telephone conversation with EPRI Project Manager R.W. Lambert, December 18, 1995.

Operational Costs. The major net cost saving from a DOE interim storage facility could result from a reduction in long-term operational costs of at-reactor storage facilities. The incremental costs of operating on-site dry storage facilities would be relatively small as long as a reactor continued to operate, because many of the technicians, guards, and other necessary staff would be at the site anyway. But after a nuclear power plant is permanently shut down, the continued presence of spent fuel at the site could pose significant additional long-term costs to a utility.

Most of today's reactors are not expected to face that problem for at least two decades, although four large, single-unit nuclear plants have already ceased operation — Rancho Seco in California, Trojan in Oregon, and the Yankee plants in Connecticut and Maine, as well as the two-unit Zion plant in Illinois. Several other reactors at multi-reactor sites have also closed. The licenses of 10 currently operating reactors are scheduled to expire before 2010 and another 37 by 2015, although 20-year license extensions are an available option. The Calvert Cliffs plant in Maryland announced in March 1998 that it would be the first to seek an extension from NRC.

A 1991 DOE study estimated that continued operation of a spent-fuel pool at a closed nuclear plant would cost about $4 million per year.[33] The Edison Electric Institute estimated in 1992 that those annual costs would range from $8-25 million.[34] Utilities would probably reduce those costs by transferring their spent fuel to on-site dry storage facilities and closing the pools, but the overhead costs of maintaining spent fuel in dry storage could be significant if DOE acceptance of spent fuel were indefinitely delayed. The closed Rancho Seco plant, which is transferring all its spent fuel to dry storage, estimates the annual cost of operating its dry storage facility at $3.8 million.[35] An NRC study estimated that a typical on-site dry storage facility would cost $2.1 million per year to operate.[36]

Because of the additional spent fuel storage costs that might be incurred at closed reactors, the Monitored Retrievable Storage Commission concluded that a federal central storage facility could reduce the total cost of spent fuel management in the United States if a permanent repository were significantly delayed. Depending on the time value of money (the discount rate), the Commission calculated, such savings could occur if the repository were delayed until sometime between the years 2013 and 2023.[37]

A widely quoted analysis prepared for the Nuclear Energy Institute (NEI) found that an interim storage facility opening in 1998 could cut $7.7 billion from the total

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[33]Rod, S.R. *Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown*. PNL-7778/UC-812. August 1991.

[34]Letter from Steven P. Kraft, Edison Electric Institute, to Ronald A. Milner, Department of Energy. January 23, 1992.

[35]Miller, Kenneth R. *Utility On-Site Spent Fuel Storage Issues*. Presentation to Fuel Cycle '96 conference, March 24-27, 1996.

[36]Smith, R.I., *et al. Revised Analyses of Decommissioning for the Reference Boiling Water Reactor Power Station*. NUREG/CR-6174, Vol. 2. Draft, September 1994. p. D-19.

[37]Monitored Retrievable Storage Review Commission, *op. cit*.

cost of managing the spent fuel from existing commercial reactors, if a permanent repository did not become available until 2015.[38] The savings would result almost entirely from reducing the number of years that spent fuel would remain at nuclear plant sites after the reactors had shut down. The NEI study assumes that spent fuel at closed reactors will remain in pool storage for an average of 24 years, at an annual cost of $8 million per site. Reactors are assumed to operate 40 years, with no license extensions.

The cost savings calculated by the NEI study depend largely on the assumed annual cost of storing spent fuel at reactor sites after shutdown. If it were assumed that reactors would shift to dry storage facilities after shutdown, their annual storage costs would be greatly reduced. At the $2.1 million annual cost for dry storage estimated by NRC, the NEI study's total savings from centralized interim storage would drop below $1.4 billion. NEI's projected savings may also be significantly reduced if future costs are discounted, because the bulk of utilities' projected costs without central interim storage could occur several decades in the future. Reactor license extensions would also reduce the projected savings, by reducing the number of years that spent fuel would remain at plant sites after shutdown. Conversely, early shutdowns might increase the potential savings.

More recently, NEI projected that extended on-site storage through 2030 could cost the federal government up to $56 billion.[39] Using an annual storage cost estimate of $4-$8 million per site, the September 1997 report concluded that spent fuel management costs, in 1997 dollars, would total $10-$20 billion more by 2030 than if federal interim storage were immediately available. NEI further contended that DOE's failure to begin taking spent fuel from utilities could require the federal government to refund all $8.5 billion in fees paid to the Nuclear Waste Fund, plus $15-$28 billion in interest.

As with NEI's earlier cost study, the 1997 storage cost projections depend on assumptions about annual storage site operating costs, discount rates, and the dates when reactors are decommissioned. Extending the lack of federal storage to 2030 dramatically boosts the total estimated on-site storage cost from NEI's earlier projections, which assumed federal storage or disposal would begin by 2015. The assumption that spent fuel will remain at nuclear plant sites until 2030 would imply a 20-year delay in DOE's current schedule. Such a delay could occur if NRC rejected the repository license for Yucca Mountain, because current law does not authorize an alternative course of action. The State of Nevada has long contended that Yucca Mountain cannot be licensed, because of volcanism, earthquakes, water intrusion, and other technical problems, but DOE maintains that its studies so far have found no insurmountable obstacles.

NEI's assertion that the federal government should have to repay all nuclear waste fees, plus interest, to nuclear utilities would appear to involve the abandonment

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[38]Energy Resources International, Inc. *Need for Interim Storage*. Draft Table 4: Summary of Total System Costs for a 2015 Repository. Feb. 20, 1996.

[39]Nuclear Energy Institute. *Fact Sheet: Congress Faces $56 Billion Liability for Default on Nuclear Fuel Storage Contracts*. September 1997.

of the federal government's civilian nuclear waste disposal effort. In that situation, nuclear utilities would apparently be responsible for civilian spent fuel indefinitely.

State and Local Controversy

State and local controversy, which has accompanied some proposals for spent fuel storage facilities, is a significant consideration in the expansion of at-reactor storage capacity. Opponents have questioned the safety of proposed on-site dry storage systems and charged that, because of DOE's uncertain waste acceptance schedule, storage facilities at reactor sites could become permanent. No proposed dry storage facilities have yet been blocked by such opposition, but some have faced long delays. There is concern that successful opposition to expansion of on-site storage capacity could force reactors to shut down.

NRC's general license for on-site dry storage allows any nuclear power plant to install NRC-approved dry storage systems without further formal NRC action. To operate such systems under the general license, a reactor owner must analyze site-specific safety issues for dry storage, notify NRC 90 days before placing spent fuel in dry storage, and provide NRC the results of fuel-transfer testing at least 30 days before beginning operation. The general license provides relatively few opportunities for opponents to use NRC procedures to block or delay dry storage facilities.

Nevertheless, efforts to block new storage facilities at reactor sites can be mounted on several fronts. In some cases, opponents can fight NRC approval of new storage facilities, through NRC licensing procedures and in the courts. State laws and regulatory proceedings, as well as local ordinances, have also been employed.

If a nuclear plant wants to use new storage systems that have not yet received NRC approval, a site-specific license is required. In those cases, opponents have an opportunity for NRC hearings before approval can be granted. Site-specific dry-storage licenses have been issued in the past with relatively little opposition, but environmental and other groups in recent years have used most procedural opportunities to oppose additional on-site spent fuel storage. In Michigan, the state attorney general and citizens groups went to court to overturn NRC approval of concrete casks at the Palisades plant, but the court upheld the NRC action Jan. 11, 1995.

The Atomic Energy Act preempts states from regulating nuclear reactor safety, but states may regulate other aspects of nuclear plant operations, particularly their economic aspects. State public utility commissions (PUCs) typically grant approval for electric utilities to construct and operate generating facilities, power lines, and other necessary facilities. Once approved, those costs, plus a reasonable return for utility investors, can be charged to electricity customers.

Opponents of expanded reactor waste storage capacity often oppose the approval of such facilities by state economic regulators. For example, an application to the Wisconsin Public Service Commission (PSC) to build concrete casks at the Point Beach nuclear plant and charge those costs to electricity customers has been held up by public controversy. After the PSC approved construction of the casks, opponents went to court and charged that a state-required environmental impact statement (EIS) was inadequate. A state circuit court agreed Dec. 22, 1995, interrupting further cask loading until an acceptable EIS was approved in April 1996. (The program was further interrupted a month later after hydrogen ignited in one of the casks.)

States may also attempt to pass laws blocking nuclear waste storage facilities. Whether such laws would run afoul of federal preemption of nuclear safety regulation has not been tested, but a 1983 decision by the U.S. Supreme Court may bear on the question. In that case, the Supreme Court upheld a California law that blocked construction of nuclear power plants unless the California Energy Commission determined that nuclear waste disposal technology had been demonstrated.[40] The state statute, the Court ruled, was justifiable on economic grounds and did not fall within the preempted area of nuclear safety regulation.

Plans for dry storage at the Prairie Island nuclear plant, owned by Northern States Power Company, were delayed by a Minnesota nuclear waste disposal statute. The law, originally passed to fight DOE consideration of a permanent nuclear waste repository in Minnesota, required approval by the state legislature of any nuclear waste "permanent storage" facility in the state. After the state PUC approved a dry storage facility at Prairie Island, opponents argued in court that the storage facility would be "permanent" because no federal system had been developed to remove the waste from the site. The state court of appeals agreed on May 28, 1993, and ruled that legislative approval would be required for the Prairie Island storage facility.

An 18-month legislative debate then ensued, pushing the two-unit Prairie Island plant close to a shutdown for lack of storage capacity, according to Northern States Power. The state legislature approved the operation of five casks May 6, 1994, with up to 12 additional casks contingent on the identification of an alternative storage site within the same county and Northern States Power's development of 600 megawatts of wind and biomass electrical generation capacity. The utility calculates that the 17 casks would handle the plant's spent fuel discharges through 2004.

Local ordinances have created problems for a proposed dry storage facility at the Oyster Creek plant in New Jersey. Lacey Township, where the plant is located, granted a zoning change in April 1994 to allow construction of the facility, but local opponents have filed suit to require the township to reconsider the action, on the grounds that an environmental impact statement was not prepared.

Hindering Nuclear Power Growth

The lack of any system for removing spent fuel from reactor sites has been cited by nuclear power supporters as a major obstacle to the future growth of nuclear power in the United States. The prospect of indefinite on-site nuclear waste storage could have a strong effect on an electric utility's consideration of options for new

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[40] *Pacific Gas & Electric Co. (PG&E) v. State Energy Resources Conservation and Development Commission.* 461 U.S. 190 (1983).

generating plants, as well as on public reaction to any proposal to build a nuclear reactor.

A 1992 nuclear industry plan for future industry growth identifies progress on nuclear waste disposal as one of 14 primary "building blocks" that would be required to pave the way for new commercial reactor orders. Other building blocks include improved performance of existing reactors, greater public acceptance of nuclear power, and completion of designs for advanced nuclear power plants that would be less expensive to build and operate than existing reactors.[41] Relatively high construction costs are generally identified as the main obstacle to the growth of U.S. nuclear generating capacity in the near future. Primarily because of such economic factors, the Energy Information Administration projects that no new commercial reactors will begin operating in the United States before 2015 at the earliest.[42]

Some argue that a federal interim storage facility with sufficient capacity could ensure more timely removal of spent fuel from reactor sites and possibly reduce utility and public resistance to new nuclear power plants. They believe that even a relatively small storage facility might provide an important demonstration of DOE's waste management system and help overcome institutional barriers to a permanent repository. However, interim storage would not appear to satisfy the California statute noted above that requires permanent nuclear waste disposal to be demonstrated before new nuclear reactors can be built in the state. Similar state laws have been enacted in Connecticut, Kansas, Kentucky, Maine, Oregon, and Wisconsin.

Industry opponents have long argued that no safe options can be developed for handling nuclear waste, and that the federal government should take no action to encourage nuclear power growth. Unacceptable risks are posed by storage of spent fuel at reactor sites, transportation to central storage and disposal facilities, and permanent disposal, according to many nuclear power critics. They argue, therefore, that halting nuclear power growth and shutting down existing reactors is the best way to minimize the nuclear waste problem.

Transportation Risks

Substantial controversy has arisen over the risks of transporting spent nuclear fuel from reactors to a central storage facility. Environmental groups and others opposed to central storage contend that, because NRC has determined on-site storage to be safe, any risks posed by transporting spent fuel from reactor sites is unnecessary. Nuclear utilities respond that the benefits of central storage of spent fuel far outweigh the minimal transportation risks involved.

Unless spent nuclear fuel remains at reactor sites permanently, it will have to be transported somewhere eventually. As a result, on-site storage can delay but not

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[41] Nuclear Power Oversight Committee. *Strategic Plan for Building New Nuclear Power Plants*. Second Annual Update. November 1992.

[42] Energy Information Administration. *Nuclear Power Generation and Fuel Cycle Report 1997*. DOE/EIA-0436(97). September 1997. p. 8.

eliminate the risks involved in nuclear waste transportation. But central storage opponents point out that extended on-site storage would allow for radioactive decay in spent fuel before it was shipped. After 100 years, radioactivity in spent fuel would drop by more than 99 percent, although it still would contain more than 10,000 curies per metric ton.[43] During that period, the reduction of plutonium and other long-lived radionuclides would be negligible.

No radioactive releases above regulatory limits have occurred during previous U.S. commercial spent fuel shipments, according to NRC. NRC statistics show that 1,413 metric tons of spent fuel was commercially transported in the United States from 1979 through 1996, in 1,319 separate shipments. A total of 356 metric tons were transported in 1,172 highway shipments, while 1,057 metric tons were carried in 147 rail shipments. The highest amount commercially transported in one year was 193.4 metric tons in 1985. According to NRC's assessment of spent fuel transportation safety:

> The safety record for spent fuel shipments in the U.S. and in other industrialized nations is enviable. Of the thousands of shipments completed over the last 30 years, none has resulted in an identifiable injury through release of radioactive material.[44]

If spent fuel is to be removed from reactor sites, future commercial shipments will involve many times the amount of waste transported previously in the United States. As passed by the House, H.R. 1270 would require DOE to accept 1,200 metric tons of spent fuel in 2002 and 2003, 2,000 metric tons in 2004 and 2005, 2,700 metric tons in 2006, and 3,000 metric tons per year afterward. A similar schedule is included in S. 104, although waste shipments would start in FY2003. More than 80,000 metric tons would eventually be transported if all current reactors completed their expected 40-year operating periods.

DOE plans to rely primarily on railroads to transport spent nuclear fuel and high-level waste to Yucca Mountain. According to a 1995 study, "Approximately 11,230 shipments by rail are planned from waste producer sites to Nevada, with an additional 1,041 shipments by legal-weight truck from four reactor sites not capable of upgrading for rail shipment."[45] However, a study for the State of Nevada calculated that the total number of cask shipments could reach 91,981, if nuclear plants declined to upgrade their facilities to handle rail casks and truck shipments relied solely on the relatively small casks currently available.[46]

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[43]U.S. Department of Energy. *Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*. DOE/RW-0006, Rev. 9. March 1994. p. 21.

[44]U.S. Nuclear Regulatory Commission. *Public Information Circular for Shipments of Irradiated Reactor Fuel*. NUREG-0725, Rev. 12. October 1997. p. 2.

[45]TRW Environmental Safety Systems Inc. *Nevada Potential Repository Preliminary Transportation Strategy Study 1, Rev. 01.* Prepared for DOE Office of Civilian Radioactive Waste Management. April 1995. P. vii.

[46]Planning Information Corporation. *The Transportation of Spent Nuclear Fuel and High-*

(continued...)

(For more background on this topic, see CRS Report for Congress 97-403 ENR, *Transportation of Spent Nuclear Fuel*, March 27, 1997.)

Accident Vulnerability. A key element in nuclear waste transportation safety is the vulnerability of shipping casks to accidental damage. Spent fuel transportation casks must be certified by NRC, which requires that each model be capable of surviving a variety of hazards (10 CFR 71, Subpart F). Included in those requirements is a sequential series of tests intended to simulate accident conditions; the test sequence requires a 30-foot drop onto a hard surface, a one-meter drop onto a six-inch-thick vertical steel rod, 30-minute engulfment by a fire of 1,475 degrees Fahrenheit, and then immersion in three feet of water for eight hours. At NRC's discretion, compliance with those tests may be verified with actual production casks, scale models, or engineering analyses.

Critics maintain that the tests do not realistically simulate the most severe accidents that spent fuel casks might encounter. For example, they point out that some fires could be hotter and last longer than NRC's test fires. In such cases, "heat could vaporize some radioactive materials and sweep them up into the air," according to a fact sheet distributed by the Nuclear Information and Resource Service.[47] Critics also contend that NRC should require full-scale testing for each certified cask design.

A 1987 study for NRC analyzed historical truck and rail accident data to predict radiological risk from spent fuel shipments.[48] The report concluded that few of the accidents studied would have released radioactivity if spent fuel had been involved; most accidents involved energy-absorbing targets such as other vehicles, insufficient velocity to damage shipping casks, little or no fire, or other mitigating factors. No documented accident was found in the NRC study that would have caused extensive cask or spent fuel damage, but it was estimated that such damage would occur in about one in 100,000 truck accidents and one in 10,000 rail accidents.

Two of the most severe historical accidents evaluated by the NRC study include a 1979 derailment in Alabama that knocked a rail car off a 75-foot river bridge and a 1982 derailment of a train containing vinyl chloride and petroleum tanks cars. It was estimated that the fall from the bridge could have subjected a spent fuel cask to nearly the greatest mechanical strain it could suffer without posing a radiological hazard. The 1982 petroleum-car derailment could have subjected a spent fuel cask to oil fires for as long as 4 days and heated its lead shielding to as much as 720 degrees Fahrenheit, probably posing a radiological hazard exceeding regulatory limits, the study found.

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[46](...continued)
Level Waste: A Systematic Basis for Planning and Management at National, Regional, and Community Levels. Prepared for Nevada Nuclear Waste Project Office. September 10, 1996. P. 104.

[47]Radioactive Waste Management Associates. *Hot Cargo: Radioactive Waste Transportation*. New York. January 1995.

[48]U.S. Nuclear Regulatory Commission. *Transporting Spent Fuel: Protection Provided Against Severe Highway and Railroad Accidents*. NUREG/BR-0111. March 1987.

Sabotage Risks. The potential for sabotage of nuclear waste transportation casks has also been cited as an argument against the large-scale transfer of spent fuel to a central storage facility. Opponents point out that a wide variety of armor-piercing weapons could penetrate the heavy steel transportation casks, pulverize some of the nuclear waste inside, and allow highly radioactive waste particles to escape into the environment.

Studies of potential sabotage damage to nuclear waste transportation casks were conducted during the 1980s by Sandia National Laboratories and Battelle Columbus Laboratories.[49] In those studies, armor-penetrating explosive devices were fired directly at a variety of full- and partial-scale casks containing real and simulated spent nuclear fuel. The explosions breached the test casks and damaged some of the nuclear material inside, but far less radioactivity escaped than had previously been estimated.[50]

Battelle and Sandia researchers selected an M-3 conical shaped charge as the most hazardous weapon that saboteurs would be likely to deploy against nuclear waste transportation casks. Such a shaped charge consists of high explosives surrounding a conical cavity lined with metal, such as copper or iron. Upon detonation, the high explosive collapses the metal-lined cavity and ejects the metal in an extremely high-velocity jet with great penetrating power.

The M-3 is a relatively low-precision shaped charge designed primarily for penetrating concrete structures, and is one of the largest shaped charges in the U.S. inventory. It will penetrate 20 inches of armor steel and 30 inches of mild steel, and makes an entrance hole averaging nearly 4 inches in diameter.[51] It carries a greater mass of high explosives than anti-tank systems cited by Jane's Infantry Weapons,[52] and makes a wider hole than high-precision shaped charges. Although there may be weapons and other explosive devices that could make a larger hole in a transportation cask, the M-3 is considered by Battelle and Sandia researchers to be a valid indicator of the potential threat.

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[49]Miller, N.E, et al., Battelle's Columbus Division. *Radiological Source Terms Resulting From Sabotage to Transportation Casks*. Prepared for U.S. Nuclear Regulatory Commission. NUREG/CR-4447, BMI-2131. November 1986.

Sandoval, R.P., et al., Sandia National Laboratories. *An Assessment of the Safety of Spent Fuel Transportation in Urban Environs*. SAND82-2365. June 1983.

Schmidt, E.W., et al., Battelle Columbus Laboratories. *Final Report on Shipping Cask Sabotage Source Term Investigation. Prepared for U.S. Nuclear Regulatory Commission*. NUREG/CR-2472, BMI-2095. October 1982.

[50]Sandoval, *op. cit*. p. 4.

[51]Vigil, Manuel G., and Sandoval, Robert P. *Development of a Method for Selection of Scaled Conical Shaped Explosive Charges. Sandia National Laboratories*. SAND80-1770. March 1982. P. 2.

[52]Gander, Terry J., and Hogg, Ian V. *Jane's Infantry Weapons, 1995-96.* Jane's Information Group. 1995.

In the Battelle and Sandia experiments, the metal jet produced by each shaped charge produced an entrance hole and, usually, an exit hole in the casks. (A full-scale cask test at Sandia produced an entrance hole about 6 inches in diameter and no exit penetration.) The real or simulated spent fuel in the path of the metal jet was pulverized, but cask contents that were not directly hit by the jet suffered little or no damage. Unlike tanks and other typical targets of armor-piercing weapons, nuclear waste casks contain no explosive or combustible materials that could be touched off by the shaped-charge jets, so little secondary damage occurred in the tests.

The Sandia researchers calculated from the experimental data that an attack on a truck cask carrying three spent fuel assemblies would release a maximum of 34 grams of respirable irradiated fuel. If the attack took place in a densely populated urban area, such a release could cause as many as 14 latent cancer fatalities, the report concluded.[53] Larger truck or rail casks, holding substantially more spent fuel, might release greater quantities of radioactive material, depending on the penetration and diameter of the shaped-charge jet.

A 1997 report for the State of Nevada criticized the conclusions of the Battelle and Sandia studies.[54] The Nevada report contended that the earlier studies had understated the potential hazard of up to 2,000 curies of non-respirable radioactive material that could be released from a spent fuel cask by a shaped-charge attack. Moreover, the Nevada report contended that the shaped-charge attacks simulated by Battelle and Sandia did not represent a "credible worst-case scenario," such as the capture of a cask and the placement of multiple charges around it.

NRC physical protection regulations for spent fuel transportation (10 *CFR* 73.37), which DOE follows, are designed to reduce the risk of sabotage. Under the rules, each shipment of spent fuel by NRC licensees requires the prior notification of NRC, regular monitoring by a licensee-operated communications center, and constant surveillance by trained escorts. Licensees must also arrange for emergency response by local law enforcement agencies along planned transportation routes and meet other general requirements. Specific physical protection requirements for highway, railroad, and sea shipments are also mandated by the NRC regulations.

Even without accidents or sabotage, small amounts of radiation are emitted by spent fuel transportation casks. During a normal shipment, low exposure levels would be received by the transportation crew, passengers on other vehicles (during a highway shipment), and residents near the transportation route. The dose to each exposed individual would normally be extremely low, but the total population dose resulting from all planned spent fuel shipments could be an issue in the debate.

Need for Additional Storage Capacity

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[53]Sandoval, *op. cit*. p. 4.

[54]Halstead, Robert J., and Ballard, David James. *Nuclear Waste Transportation Security and Safety Issues: The Risk of Terrorism and Sabotage Against Repository Shipments*. Prepared for Nevada Agency for Nuclear Projects. October 1997.

Although the physical space in a nuclear reactor's spent fuel storage pool is fixed, projections of when additional capacity will be required depend on a number of variables. According to DOE, about 1,000 metric tons of spent fuel is currently in dry storage at reactor sites. That number is projected to grow to above 2,000 metric tons by the turn of the century and to 10,000 metric tons by 2010, the latest scheduled date for opening a permanent repository.

Two major types of variables must be considered in such projections: the operating characteristics of the reactor, and the way the spent fuel is stored in the pool. A key limitation is that reactor pools are usually not filled completely — enough capacity is maintained to hold all the fuel assemblies currently in the reactor core, usually about 100 tons, in case of emergency. However, utilities may fill some of that extra capacity to delay the need for dry storage.

The major relevant operational characteristics of a reactor are its capacity factor — the percentage of its potential electrical output that is actually generated — and its fuel efficiency, or "burnup." Capacity factors are one of the largest unknowns, particularly for an individual reactor. A plant's capacity factor is determined primarily by the amount of time it is shut down for refueling, by unexpected problems, for maintenance, and regulatory requirements. Some reactors have shut down for years at a time when major maintenance or other work was needed. The less a reactor operates, the less fuel it will require, and the slower its spent fuel pool will be filled. Capacity factors at most reactors have been rising in recent years.

Increasing the level of burnup — the amount of energy produced by each ton of nuclear fuel — affects pool capacity by allowing a reactor operating at a given capacity to be refueled less often. The typical U.S. reactor now refuels every 18 months. Burnup depends primarily on the design of the nuclear fuel and has been rising in recent years. Further increases would continue to reduce the amount of spent fuel being discharged from U.S. reactors.

Operation of a spent fuel pool involves two main variables: the amount of space between fuel assemblies, and the amount of space between individual fuel rods in the assemblies. Utilities have been able to significantly increase spent fuel pool capacity by "reracking" their pools to place spent fuel assemblies closer together. Neutron-absorbing material such as boron is placed between the closely spaced assemblies to prevent nuclear chain reactions. Minimum space between assemblies depends on such factors as the seismic characteristics of the site, the reactivity of the spent fuel, and weight limits on pool support structures (particularly in the case of elevated BWR pools).

The other option for saving space is to break down the assemblies so the individual fuel rods can be placed closer together, a process called rod consolidation. Typically, the fuel rods are removed from the assembly grid structures and packed about twice as tightly into new assemblies of the same dimensions; the old grid structures, which also are radioactive, must then be crushed and stored as well. Rod consolidation has been tried so far only experimentally.[55]

Some multi-plant utilities also may delay the need for additional storage by shipping spent fuel from their older nuclear plants to newer ones with larger and emptier storage pools. Such intra-utility transfers have constituted most previous commercial spent fuel transportation.

DOE's projections of when reactors will exceed their spent-fuel pool capacity depend partly on analyses of the above factors carried out by nuclear utilities, who must report their fuel storage situation to the Energy Information Administration (DOE Nuclear Fuel Data Form RW-859). Each reactor is required to estimate fuel discharges for its subsequent five refuelings and its maximum pool capacity for intact (unconsolidated) fuel assemblies. Combining the utility analyses with its own forecasting models, DOE then estimates total dry storage needs for current reactors for their entire 40-year licensing periods.

The latest DOE projection of reactor dry storage needs covers 1994 through 2042, and assumes that no spent fuel will be transferred to central storage or disposal facilities.[56] According to that study, whose results are summarized in Table 1, cumulative spent fuel discharges will exceed reactor pool capacity by 2,333 metric tons in 2000. Additional storage needs will total 10,686 metric tons by 2010, double by 2020, and plateau at 25,244 in 2039. Intra-utility transhipment of spent fuel could reduce those storage needs by about 10 percent, according to DOE.

Those projections indicate the minimum amount of spent fuel that DOE would have to accept at a central storage facility or repository to eliminate the need for additional dry storage facilities at reactor sites, if that goal were to become public policy. DOE would need to accept about 1,000 metric tons per year from 1998 through 2010, if shipments from reactors were based solely on lack of storage capacity.

However, DOE's contracts with nuclear utilities, signed pursuant to NWPA, stipulate that the Department will take the oldest spent fuel first.[57] According to DOE's Annual Capacity Report, the oldest spent fuel is not necessarily located at the sites with the greatest need for additional storage capacity.[58] Under that priority system, therefore, DOE would have to accept substantially more spent fuel than 1,000 metric tons per year to eliminate the need to expand storage capacity at reactor sites.

Table 1. Projected Spent Fuel Discharges and Dry Storage Needs

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[55]Baker, Gary (editor). *Spent Fuel Storage Options*. McGraw-Hill, Inc. October 1988. P. 5.

[56]U.S. Department of Energy. *Spent Fuel Storage Requirements 1994-2042*. DOE/RW-0431-Rev. 1. June 1995.

[57]Standard Disposal Contract, Article IV.

[58]U.S. Department of Energy. Office of Civilian Radioactive Waste Management. Annual Capacity Report. DOE/RW-0457. March 1995.

Year	Cumulative dry storage needs		Total spent fuel discharges (metric tons)	Reactors needing dry storage (total)
	Metric tons	Fuel assemblies		
1995	692	1,595	32,300	12
1996	885	2,058	34,100	16
1997	1,187	3,079	36,100	21
1998	1,461	3,822	38,100	25
1999	1,803	4,836	40,000	25
2000	2,333	6,611	42,200	34
2001	2,835	8,331	44,200	40
2002	3,525	10,924	46,200	45
2003	4,205	13,658	48,200	47
2004	5,182	17,420	50,400	52
2005	5,733	19,732	51,900	53
2010	10,686	37,806	62,500	85
2015	16,679	59,896	71,900	97
2020	20,682	74,159	77,700	97
2030	24,713	87,894	85,300	99
2040	25,244	89,123	86,500	99

Source: U.S. Department of Energy

DOE's projections also assume that spent fuel will remain in spent fuel pools after reactors have shut down. However, utilities would probably prefer to remove all fuel from reactor sites as soon as possible after they shut down, which could create additional demand for DOE storage and disposal acceptance capacity. If DOE were unable to take spent fuel rapidly enough, nuclear utilities would be likely to transfer all spent fuel from the pools of closed reactors to on-site dry storage, to reduce long-term maintenance costs.

Table 2. Licensed Dry Storage Facilities at Reactor Sites
(through March 1998)

Nuclear Plant	Location	Year Approved	Type of Storage	Filled Spent Fuel Casks
Surry	Surry, Va.	1986	metal cask	34
H.B. Robinson	Hartsville, S.C.	1986	concrete module	8
Oconee	Seneca, S.C.	1990	concrete module	40
Fort St. Vrain	Platteville, Colo.	1991	modular vault	247
Calvert Cliffs	Lusby, Md.	1992	concrete module	14
Palisades	Covert, Mich.	1993	concrete cask	13
Prairie Island	Red Wing, Minn.	1993	metal cask	7
Point Beach	Two Rivers, Wis.	1995	concrete cask	2
Davis Besse	Oak Harbor, Ohio	1995	concrete module	3
Arkansas	Russellville, Ark.	1996	concrete cask	4

Source: Nuclear Regulatory Commission

Utilities that have faced the earliest need for additional capacity, beyond reracking their spent fuel pools, have so far selected dry storage over rod consolidation. Most if not all nuclear plant sites are believed to have sufficient capacity for fuel storage casks, although some may face other operational hurdles, such as crane capacity and insufficient pool size in which to transfer fuel to the casks. Depending on cask spacing and the size of a buffer area, all the spent fuel discharged from a typical reactor over 40 years could be stored on about 10 acres, which is a small fraction of the typical nuclear plant site.[59]

Dry-storage options currently in use at U.S. nuclear utilities are metal storage casks, concrete casks, and horizontal concrete modules. Also in use is a modular vault at the closed Fort St. Vrain plant, a unique gas-cooled reactor. Those storage facilities are listed in Table 2.

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[59]Electric Power Research Institute. Comparative System Economics of Concrete Casks for Spent-Fuel Storage. EPRI TR-102415. June 1993. P. 7-2.

Appendix: History of U.S. Nuclear Waste Policy

Permanent disposal of highly radioactive waste has been an elusive federal goal since the beginning of the U.S. nuclear weapons program during World War II. Storage has always been assumed to be only for the short term, until a permanent solution could be developed. But as decades passed and a permanent solution appeared increasingly distant, policymakers periodically examined the potentially more practical option of placing nuclear waste into facilities designed for long-term storage. Each serious move toward long-term storage, however, has been eventually quashed by concerns that such a step would undermine the federal government's motivation for developing permanent disposal facilities.

Early Storage Policies

Although the type of waste expected to be generated by the nuclear power industry has changed from the highly radioactive residue of spent fuel reprocessing to unreprocessed spent fuel, the federal government consistently intended to take ultimate responsibility for permanent disposal. The need for storage by commercial waste generators, either reprocessing plants or nuclear power plants, was expected to be minimized.

Disposal of Reprocessing Waste. When the U.S. Atomic Energy Commission (AEC), a DOE predecessor, began its commercial nuclear power development program in the 1950s, it asked the National Academy of Sciences to convene a panel to study the disposal of the high-level radioactive waste that was expected to result from spent fuel reprocessing. The panel recommended in 1957 that high-level waste be permanently emplaced in deep underground salt beds;[60] the search for such a site became the basis for much of AEC's subsequent disposal policy.

AEC issued a policy statement in 1970 that high-level commercial reprocessing waste would have to be solidified within five years after being produced and transferred to a permanent federal repository within 10 years. AEC planned to take title to the waste in return for utility payments that would cover all the government's costs. In its explanation of the statement, the Commission anticipated that the first repository would be in salt beds near Lyons, Kansas.[61]

In implementing its nuclear waste policy, the AEC encouraged the development of commercial fuel reprocessing capacity to take spent fuel from the emerging nuclear power industry. The first commercial reprocessing plant, at West Valley, New York, opened in 1966; it primarily handled spent fuel from one of AEC's nuclear weapons materials production reactors, because relatively little spent fuel was then available from commercial reactors. Closed in 1972 for a planned expansion and modifications to reduce worker radiation exposure, the plant was never reopened.

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[60]National Academy of Sciences/National Research Council. *The Disposal of Radioactive Waste on Land*. 1957.

[61]Atomic Energy Commission. *Siting of Fuel Reprocessing Plants and Related Waste Management Facilities.* 35 Federal Register 17530. Nov. 14, 1970.

While the West Valley plant was operating, General Electric Company (GE) began building a reprocessing plant using somewhat different technology near Morris, Illinois. GE signed contracts with several electric utilities that purchased GE nuclear power plants, promising to take away spent fuel for reprocessing. However, testing of the facility's reprocessing equipment showed that it would not work properly, and GE decided in 1974 not to put the plant into operation. GE agreed to accept some spent fuel from utilities that had signed reprocessing contracts and store it indefinitely at the Morris facility, where the material remains to date. Despite GE's problems, an industrial consortium proceeded with construction of a commercial spent fuel reprocessing facility near Barnwell, South Carolina.

Once-Through Fuel Cycle. The Barnwell project was suspended when President Carter changed federal nuclear energy policy in April 1977. Because of concerns that widespread commercial reprocessing could lead to the diversion of plutonium for nuclear weapons, Carter announced that the United States would indefinitely defer commercial reprocessing and the use of plutonium fuel, as well as deferring the commercial use of breeder reactors.[62]

Carter's policy, which expanded on the Ford Administration's doubts about reprocessing, ended the Barnwell consortium's hopes for federal assistance to complete and operate the plant. Barnwell's owners had sought federal funding in 1975 after concluding that reprocessing costs would be too high and the price of newly mined uranium too low for the plant to be commercially viable, at least in the near term. It had become apparent that utilities could buy fresh fuel from newly mined uranium more cheaply than fuel made from reprocessed uranium and plutonium, and that commercial breeder reactors requiring plutonium fuel were far in the future.

After Carter's policy change, NRC canceled its preparations for licensing of plutonium fuel, eliminating the remaining hope of a market for Barnwell's primary product. However, Congress provided $10-20 million per year to keep Barnwell open as a research and development facility.

President Reagan reversed Carter's nuclear policies upon taking office four years later, but the Administration also ended Barnwell's annual research and development funding. Because the economics of commercial reprocessing had not improved, Barnwell's owners shut the plant permanently in 1983. The same year, Congress canceled the breeder reactor demonstration program for the second time. Since then the United States has relied on the "once-through fuel cycle," in which spent fuel is considered waste to be discarded.

Without reprocessing plants to receive spent fuel, commercial nuclear power plants had to deal with growing accumulations of spent fuel on site. The pools of water at each reactor, which had been designed to cool discharged spent fuel until it was shipped out for reprocessing, became indefinite storage facilities instead.

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[62] President Carter. *Nuclear Power Policy: Statement on Decisions Reached Following a Review*. April 7, 1977.

Progress on the promised federal waste repository also did not go as planned during the 1970s. The proposed site at Lyons, Kansas, was abandoned as technically unsuitable in 1972. AEC then attempted to develop a "retrievable surface storage facility" at a federal site for solidified commercial and defense high-level waste. But the initiative was dropped by the Energy Research and Development Administration (ERDA), a successor to AEC, after drawing objections that development of a long-term storage facility could supplant development of a permanent disposal site. Salt beds near Carslbad, New Mexico, were considered for a repository after the abandonment of the Lyons site, but the site was subsequently limited to disposal of low-activity, long-lived defense waste. Now called the Waste Isolation Pilot Plant (WIPP), the facility has been under development since the early 1980s. Following repeatedly missed target dates, DOE plans to begin disposal operations at WIPP in 1998.

ERDA and its successor in 1977, the Department of Energy (DOE), began investigating a variety of sites throughout the nation for a permanent high-level waste repository. States strongly resisted those investigations, however, and the program became embroiled in controversy. To prevent reactor spent fuel pools from filling up in the meantime, President Carter in 1980 proposed a federal "away from reactor" storage program for commercial reactor spent fuel, but Congress did not authorize such a facility before Carter left office in 1981.

NWPA Storage Provisions

Dissatisfaction with DOE's progress on nuclear waste disposal prompted Congress to act in the early 1980s. Supporters of legislative action hoped that the controversy that had previously stymied the search for nuclear waste storage and disposal sites could be overcome if Congress were able to establish a fair and technically sound site selection framework. However, many lawmakers from potential waste disposal regions expressed doubts that such a system could be properly devised and implemented.

After several years of difficult debate, Congress passed the Nuclear Waste Policy Act (NWPA) in December 1982 (P.L. 97-425). The new law required DOE to narrow its repository candidate sites to three for intensive underground testing and study; a repository would be constructed at one of those sites, if found suitable, and opened by January 1998. To cover the program's anticipated multibillion-dollar costs, utilities were required to pay a fee on nuclear power generation. The fee, which was passed through to ratepayers, was to be deposited in the Nuclear Waste Fund.

NWPA clarified that DOE's top priority in nuclear waste management should be permanent disposal. Implicit in the act was the policy that any federal facilities for central storage of commercial spent fuel should not undermine progress on a permanent repository. Nevertheless, there was a strong sentiment that temporary spent fuel storage facilities might be necessary to relieve crowded reactor storage pools or to improve the operation of the planned DOE waste management system.

NWPA attempted to resolve the tension between permanent disposal and temporary storage by giving DOE three years to submit to Congress a proposal for a "monitored retrievable storage" facility. It was specified that such a facility, if authorized, would not take the place of the planned permanent repository, and the costs would be paid from the Nuclear Waste Fund. NWPA also authorized a small federal "interim storage program" for commercial reactors facing shutdown for lack of spent fuel storage capacity.

Monitored Retrievable Storage. DOE initially envisioned the MRS facility as a central collection site where reactor spent fuel would be received, inspected, consolidated, packaged, and stored before shipment to a permanent repository. DOE contended that such a facility would allow spent fuel to be taken sooner from nuclear plant sites, perform functions that would otherwise be carried out at the repository site, and improve the performance of the waste management system.

DOE's proposal for an MRS facility was submitted to Congress in February 1986, recommending a federally owned site near Oak Ridge, Tennessee, and two alternative sites also in Tennessee.[63] The Tennessee sites were intended to minimize the transportation distances from most reactors, which were predominantly in the East. DOE planned for small shipments from plant sites to be consolidated into larger waste-only rail shipments to the Western repository, minimizing the number of long-distance waste shipments.

Under the DOE plan, the MRS facility would have included a large waste-handling building, where spent fuel casks were to be loaded and unloaded in shielded "hot cells" to protect workers from radiation. Additional hot cells were envisioned for spent fuel consolidation — reducing the spacing between individual fuel rods — for more efficient storage, transportation, and disposal. The total amount of spent fuel stored at the site, in sealed concrete casks, was to be limited to 15,000 metric tons, or about 20 percent of the amount planned for the permanent repository.

Reaction in Tennessee to the MRS siting proposal was strongly negative, and the state's congressional delegation fought DOE's plan. The primary concern in the state was that the MRS would become a "de facto" permanent repository, because the availability of spent fuel storage would reduce the pressure for progress on the planned underground repository. Once the underground repository fell far enough behind schedule or was canceled, MRS opponents feared, the 15,000-metric-ton restriction would eventually be lifted.

Congress responded to those concerns when it amended NWPA in 1987 (P.L. 100-203). DOE was authorized to site, construct, and operate an MRS facility, but not until substantial progress was achieved on the permanent underground repository. The 1987 NWPA amendments revoked DOE's selection of the Tennessee sites and placed additional restrictions on the MRS facility:

- DOE cannot search for a site until a special commission reports on the need for an MRS facility (NWPA §144);

[63] U.S. Department of Energy. Monitored Retrievable Storage Submission to Congress. Vol. 1-3. DOE/RW-0035/1. February 1986.

- DOE cannot select an MRS site until the Energy Secretary recommends a repository site for presidential approval (§145(b));
- No site in Nevada may be selected for the MRS facility (§145(g));
- Construction of an MRS facility cannot begin until NRC has licensed the construction of a permanent repository (§148(d)(1)), and MRS construction must halt whenever the repository license is revoked or construction of the repository ceases (§148(d)(2));
- No more than 10,000 metric tons of spent fuel may be stored at the MRS facility until waste is shipped to a permanent repository (§148(d)(3)), with a limit of 15,000 metric tons after that (§148(d)(4)).

Those provisions have effectively prevented DOE from developing a monitored retrievable storage facility, since only the first condition (the special commission report) has been met. The restrictions also eliminate one of the major benefits of an MRS facility sought by utilities — central storage of spent fuel during delays in repository development. Under the 1987 amendments, delays in the repository would also delay the opening of an MRS facility.

Interim Storage Provisions. The interim storage program established by the 1982 act was extremely limited in scope and availability; it was intended to provide emergency relief to nuclear reactors with no other storage alternatives. DOE was authorized to provide storage for up to 1,900 metric tons of spent fuel at new or existing storage facilities at federal sites, and by constructing additional storage capacity at commercial reactor sites. DOE would take title to commercial spent fuel placed in federal interim storage and transfer the material to a repository or MRS facility within three years of their availability. As with MRS siting, federal interim storage was prohibited in any state with a candidate repository site.

Unlike the MRS facility, whose costs were to be covered by the Nuclear Waste Fund, the DOE interim storage program was to be financed solely by the nuclear utilities that needed it. A Treasury account called the Interim Storage Fund was established to receive the fees for that service. As a result, any utility making use of federal interim storage would have paid a separate fee into the Interim Storage Fund as well as the standard fee that all nuclear utilities contribute to the Nuclear Waste Fund.

Commercial reactors were allowed to use DOE interim storage facilities only if NRC determined that they could not reasonably provide sufficient storage capacity of their own. NWPA specified that such reactors had to be "diligently pursuing" alternative storage arrangements, including expanding their existing storage capacity, procuring spent fuel storage casks, and transferring spent fuel to other reactor sites.

After the enactment of NWPA and the interim storage provisions, nuclear utilities began demonstrating the feasibility of moving spent fuel from reactor pools into dry casks, which could be stored at reactor sites. Spent fuel has generally cooled sufficiently to be removed from pools in 5-10 years. A dry cask storage facility was licensed by NRC for the Surry nuclear plant in Virginia in 1986, and dry cask storage at other sites soon followed. Because of the availability of the dry cask storage option, and the charges for federal interim storage, the NWPA interim storage program was never implemented. No applications for storage were submitted to NRC, and DOE did not identify any potential interim storage sites.[64] DOE's authority to provide interim storage expired Jan. 1, 1990.

Nuclear Waste Negotiator. The 1987 NWPA amendments established an alternative method for finding sites for nuclear waste facilities. In addition to having DOE select sites and then try to impose them on states and localities, the alternative system was designed to develop negotiated terms for voluntary sites. Because DOE was viewed as having little credibility with potential volunteers, the amendments set up an independent Office of the Nuclear Waste Negotiator to approach state and local governments and Indian tribes. Funding for the office was to be appropriated from the Nuclear Waste Fund. Although the Waste Negotiator was authorized to seek voluntary sites for both nuclear waste storage and disposal, the office focused almost exclusively on finding a site for an MRS facility.

DOE attached substantial importance to the Waste Negotiator in the early 1990s, because the voluntary siting process appeared to be the only way to open an MRS facility in time to begin receiving spent fuel by NWPA's 1998 deadline. As noted above, DOE was barred by the 1987 amendments from selecting an MRS site until recommending a repository site to the President, a recommendation that was not expected until the late 1990s. The Bush Administration's 1991 National Energy Strategy proposed unlinking the MRS from the repository, but that provision was excluded from the resulting Energy Policy Act of 1992.

Any "reasonable and appropriate" inducements for hosting a waste facility were allowed to be offered by the Waste Negotiator. Among the benefits suggested by the Negotiator's office were guarantees of local oversight, highway and airport improvements, higher education programs, tax benefits, economic development activities, health care programs, direct federal payments, and the siting of desirable federal facilities. However, no agreement produced by the Negotiator was allowed to take effect without congressional approval. It was presumed that such approval would include a waiver of the statutory restrictions on MRS facility siting and operation, allowing storage to begin well in advance of repository operations.

The first Negotiator, former Idaho Lt. Governor David H. Leroy, was confirmed in August 1990. The office issued a formal intent to negotiate waste site agreements June 5, 1991; on the same day, DOE announced the availability of grants from the Nuclear Waste Fund to state, tribal, and qualifying local governments for MRS site feasibility studies. DOE awarded 16 "phase I" and "phase IIa" feasibility study grants totaling $1.9 million.

DOE had planned to award "phase IIb" grants of up to $2.8 million apiece to qualified applicants, but Congress halted the IIb grants in October 1993 (P.L. 103-126), largely because of opposition by the New Mexico delegation to a IIb grant

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[64] U.S. Department of Energy. *Implementation Plan for Deployment of Federal Interim Storage Facilities for Commercial Spent Fuel*. DOE/RW-0218. January 1989. p. 10.

application from the Mescalero Apache Tribe of New Mexico. After their grant was blocked, the Mescalero Apaches suspended discussions with the Negotiator's office and began pursuing a non-government spent fuel storage facility in partnership with nuclear utilities. The Mescaleros and the utility consortium ended their joint effort in April 1996.

Former Representative Richard Stallings of Idaho took over as Waste Negotiator in November 1993. At the request of the Negotiator's office, DOE performed preliminary site assessments for the Mescaleros and three other Indian tribes: the Ft. McDermitt Paiute-Shoshone Tribe in Oregon, the Tonkawa Tribe of Oklahoma, and the Skull Valley Goshutes of Utah. After the Mescaleros withdrew from the process, the Negotiator carried out preliminary dialogues with the other three tribes.

Several local governments expressed interest in pursuing MRS negotiations, but they either were overruled by their state governments or by local voters. As a result, discussions proceeded almost entirely with Indian tribes, who were not subject to state control. The Negotiator faced difficult questions about whether to seek an agreement with an Indian tribe over the objections of the state, and what congressional reaction to such an agreement might have been. Authority for the Office of the Waste Negotiator expired Jan. 21, 1995, without any proposed siting agreements having been reached. However, the Skull Valley Goshutes have continued working with a utility consortium to develop a spent fuel storage facility in Utah.