



Nuclear Waste Disposal: Alternatives to Yucca Mountain

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Summary

Congress designated Yucca Mountain, NV, as the nation's sole candidate site for a permanent high-level nuclear waste repository in 1987, following years of controversy over the site-selection process. Over the strenuous objections of the State of Nevada, the Department of Energy (DOE) submitted a license application for the proposed Yucca Mountain repository in June 2008 to the Nuclear Regulatory Commission (NRC). During the 2008 election campaign, now-President Obama lent support to Nevada's fight against the repository, contending in an issue statement that he and now-Vice President Biden "do not believe that Yucca Mountain is a suitable site."

Under the current nuclear waste program, DOE hopes to begin transporting spent nuclear fuel and other highly radioactive waste to Yucca Mountain by 2020. That schedule is 22 years beyond the 1998 deadline established by the Nuclear Waste Policy Act (NWPA). Because U.S. nuclear power plants will continue to generate nuclear waste after a repository opens, DOE estimates that all waste could not be removed from existing reactors until about 2066 even under the current Yucca Mountain schedule. Not all the projected waste could be disposed of at Yucca Mountain, however, unless NWPA's current limit on the repository's capacity is increased.

If the Obama Administration decides to halt the Yucca Mountain project, it has a variety of tools available to implement that policy. Although the President cannot directly affect NRC proceedings, the Secretary of Energy could withdraw the Yucca Mountain license application under NRC rules. The President could also urge Congress to cut or eliminate funding for the Yucca Mountain project, and propose legislation to restructure the nuclear waste program.

Abandonment of Yucca Mountain would probably further delay the federal government's removal of nuclear waste from reactor sites and therefore increase the government's liabilities for missing the NWPA deadline. DOE estimates that such liabilities will reach \$11 billion even if Yucca Mountain opens as currently planned. DOE's agreements with states to remove defense-related high-level waste could also be affected. If the Yucca Mountain project were halted without a clear alternative path for waste management, the licensing of proposed new nuclear power plants could be affected as well. NRC has determined that waste can be safely stored at reactor sites for at least 30 years after a reactor shuts down and is proposing to extend that period to 60 years. While that proposal would allow at least 100 years for waste to remain at reactor sites (including a 40-year reactor operating period), NRC's policy is that new reactors should not be licensed without "reasonable confidence that the wastes can and will in due course be disposed of safely."

Current law provides no alternative repository site to Yucca Mountain, and it does not authorize DOE to open temporary storage facilities without a permanent repository in operation. Without congressional action, therefore, the default alternative to Yucca Mountain would be indefinite on-site storage of nuclear waste at reactor sites and other nuclear facilities. Private central storage facilities can also be licensed under current law; such a facility has been licensed in Utah but its operation has been blocked by the Department of the Interior.

Congress has considered legislation repeatedly since the mid-1990s to authorize a federal interim storage facility for nuclear waste but none has been enacted. Reprocessing of spent fuel could reduce waste volumes and long-term toxicity, but such facilities are costly and raise concerns about the separation of plutonium that could be used in nuclear weapons. Storage and reprocessing would still eventually require a permanent repository, and a search for a new repository site would need to avoid the obstacles that have hampered previous U.S. efforts.

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Proposals for a New Direction

Nevada's Yucca Mountain has been the sole candidate site for the nation's first permanent high-level nuclear waste repository since Congress singled it out in 1987 and halted consideration of any other location. After numerous delays, the Department of Energy (DOE), which was supposed to open a waste repository by 1998, submitted a repository license application for Yucca Mountain to the Nuclear Regulatory Commission (NRC) in June 2008. If NRC approves the license, DOE hopes to begin shipping nuclear waste to the repository by 2020.

The congressional decision to focus solely on Yucca Mountain was highly controversial and continues to face harsh criticism, particularly from the State of Nevada. Yucca Mountain opponents dispute DOE's determination that the site is suitable for long-term disposal of nuclear waste and call for fundamental change in the program. Nonetheless, the proposed Yucca Mountain repository has consistently maintained sufficient congressional support to continue moving forward. Congress explicitly rejected a Nevada "state veto" of the site in 2002, has blocked repeated efforts to halt the program's funding, and has not taken up any of numerous legislative proposals to delay the program or find a new site. President George W. Bush also steadfastly supported the Yucca Mountain project.

But Administration support for Yucca Mountain will apparently change under President Obama. In their campaign statement on nuclear energy policy, Obama and Vice President Biden laid out the following position:

In terms of waste storage, Barack Obama and Joe Biden do not believe that Yucca Mountain is a suitable site. They will lead federal efforts to look for safe, long-term disposal solutions based on objective, scientific analysis. In the meantime, they will develop requirements to ensure that the waste stored at current reactor sites is contained using the most advanced dry-cask storage technology available.¹

The Obama-Biden campaign statement on Yucca Mountain raises numerous questions about the future direction of U.S. nuclear waste policy. In particular, what type of long-term disposal solutions could be considered? Every option for handling nuclear waste ultimately requires a method of long-term isolation from the environment. If Yucca Mountain were rejected, it would appear that a new repository site search would need to be undertaken at some point. Given the criticism that DOE has drawn over its handling of the waste program, pressure may intensify for such a search to be handed over to a new organization entirely.

The current effort to develop a repository at Yucca Mountain began with the enactment of the Nuclear Waste Policy Act of 1982 (NWPA, P.L. 97-425), and opening a repository at a different location could take a long time as well, even if the process were started right away. During such an indefinite time period, how would the licensing of new nuclear power plants be affected? Would spent nuclear fuel and other highly radioactive waste remain at commercial reactors and other existing nuclear facilities, or would it be moved to centralized interim storage? Previous U.S. efforts to develop interim central nuclear waste storage facilities have drawn fierce opposition.

¹ Obama for America, "Barack Obama and Joe Biden: New Energy for America," campaign issue statement, 2008, http://www.barackobama.com/pdf/factsheet_energy_speech_080308.pdf.

Since the 1970s, U.S. nuclear waste policy has been based on the “once through” fuel cycle, in which nuclear fuel is to be used once in a reactor and then permanently disposed of. The major alternative is the “closed” fuel cycle, in which spent nuclear fuel would be reprocessed into new fuel for advanced reactors or particle accelerators. Fast reactors or accelerators would destroy the longest-lived radioactive components of the fuel, leaving only relatively short-lived radioactive isotopes, which would decay to background levels within 1,000 years, for permanent disposal. Under that scenario, spent fuel could be stored at reprocessing facilities while awaiting its turn to be made into new fuel, and the relatively short life of the resulting waste could make it easier to site a permanent repository. However, the material for nuclear fuel that results from reprocessing (primarily plutonium) can also be used for nuclear explosives, raising concerns about nuclear weapons proliferation.

Because current law specifies that Yucca Mountain is the sole candidate site for a high-level waste repository, legislation would probably be needed if a major change in direction in the nuclear waste program is sought. But the Obama Administration does have authority under current law to withdraw the Yucca Mountain license application, propose reductions in the program’s funding, and take other administrative actions to delay or halt the development of a repository at the Yucca Mountain site. This report discusses those options and the likely impact of indefinite delays in the waste program. It then discusses the mid- and long-term alternatives to the existing waste program, and finally reviews the history of U.S. efforts to site nuclear waste facilities.

Baseline: Current Waste Program Projections

DOE’s latest schedules for nuclear waste shipments and projected costs under the existing program provide a baseline for analyzing Yucca Mountain alternatives. Although the planned opening of the Yucca Mountain repository is at least 22 years later than NWPA’s 1998 deadline, and removing waste from existing storage sites would require many decades, a major redirection of the waste program would probably involve even longer time frames. Of course, there is no certainty that DOE will be able to meet its current schedules, or that the Yucca Mountain repository will receive a license from NRC under the current program. Moreover, policymakers could conclude that the benefits of redirecting the nuclear waste program now would outweigh the almost certain delays in developing a permanent repository and the increased costs of interim storage.

Under DOE’s current schedule, about 400 metric tons of spent nuclear fuel would be shipped to Yucca Mountain from reactor sites in 2020. Shipments would rise to 600 metric tons in 2021, 1,200 metric tons in 2022, and 2,000 metric tons in 2023, and reach the planned maximum annual capacity of 3,000 metric tons in 2024.² Because the total U.S. commercial reactor fleet discharges an average of about 2,000 metric tons of spent fuel per year, the above shipment schedule would not begin reducing the backlog of spent fuel stored at reactor sites until 2024.

² U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Total System Life Cycle Cost Report*, DOE/RW-0591, Washington, DC, July 2008, p. 20, http://www.ocrwm.doe.gov/about/budget/pdf/TSLCC_2007_8_05_08.pdf.

DOE estimates that the amount of commercial spent fuel stored in pools of water and dry casks at reactor sites and other facilities was 57,700 metric tons at the end of 2007.³ If commercial spent fuel continues to accumulate at the rate of 2,000 metric tons per year, then inventories would reach 81,000 metric tons before shipments are to begin in 2020 and peak at nearly 85,000 in 2023, after which shipments to Yucca Mountain would exceed reactor discharges by 1,000 tons per year. DOE projections indicate that shipments of all spent fuel from previous and existing U.S. nuclear power plants would continue until about 2066, totaling 109,300 metric tons (under existing reactor license periods and extensions). In addition, the equivalent of 12,800 metric tons of defense-related spent nuclear fuel and high-level radioactive waste would be received at Yucca Mountain during the same period, for a total of 122,100 metric tons.⁴

Although DOE's cost projections assume that all spent fuel from existing reactors, plus defense waste, will be shipped to the planned Yucca Mountain repository, NWSA section 114(d) caps Yucca Mountain's capacity at the equivalent of 70,000 metric tons of spent fuel until a second repository begins operating. No such repository is currently authorized. A recent DOE report on the need for a second repository concludes that all existing and anticipated spent fuel and high-level waste could be physically accommodated at Yucca Mountain.⁵ Legislation to lift the 70,000-ton limit proposed by the Bush Administration was introduced during the 109th (H.R. 5360) and 110th (S. 37) Congresses but not acted upon.

As amended in 1987, NWSA provides no backup plan for spent fuel management if the Yucca Mountain repository were to be halted. A "monitored retrievable storage" (MRS) facility is authorized by NWSA section 142, but construction is prohibited until NRC has authorized the construction of the Yucca Mountain repository.

Section 302 of NWSA requires nuclear power plant operators to sign contracts with DOE under which the nuclear plants must pay fees to the federal government in return for DOE's spent fuel disposal services. The nuclear power plant fees are deposited in a Treasury account called the Nuclear Waste Fund to pay for the DOE waste program but cannot be spent without congressional appropriation. The Fund's balance was about \$20 billion at the end of FY2008.⁶ Because the DOE waste program will also handle defense-related waste, Congress typically supplements annual appropriations from the Nuclear Waste Fund with appropriations from general revenues.

Annual spending for the nuclear waste program, focusing on Yucca Mountain site studies and the license application, has averaged about \$400 million in recent years. However, DOE projects that to build the repository and develop a transportation system within the next 12 years, annual funding would need to increase to nearly \$2 billion during the peak of construction. Disposal of all 122,100 metric tons of currently anticipated waste at Yucca Mountain is projected to cost \$96.18 billion (in 2007 dollars) through 2133.⁷

³ U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Report to the President and the Congress by the Secretary of Energy on the Need for a Second Repository*, DOE/RW-0595, Washington, DC, December 2008, p. 6, http://www.rw.doe.gov/info_library/program_docs/Second_Repository_Rpt_120908.pdf.

⁴ DOE, *Life Cycle Cost Report*, op. cit., p. A-3.

⁵ DOE, *Need for a Second Repository*, op. cit., p. 1.

⁶ Department of Energy, Office of Civilian Radioactive Waste Management, *Monthly Summary of Program Financial & Budget Information*, as of September 1, 2008, p. 7.

⁷ U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Total System Life Cycle Cost Report*, DOE/RW-0591, Washington, DC, July 2008, p. B-2.

NWPA section 302(d) restricts the use of the Nuclear Waste Fund to disposal activities and research authorized by the act. The section specifically prohibits DOE from expending the funds for any facility besides those expressly authorized by NWPA or subsequent act of Congress. As amended in 1987, NWPA currently authorizes only a repository at Yucca Mountain and a monitored retrievable storage facility tied to the operation of a Yucca Mountain repository.

The contracts that DOE signed with nuclear utilities required DOE to begin taking waste from reactor sites by January 31, 1998. Because that deadline was missed, DOE has been ruled liable for all waste storage costs that nuclear utilities would not have incurred had shipments to the planned repository begun on time. The U.S. Court of Federal Claims has already issued several judgments against DOE. Claims are paid from the federal judgment fund, rather than the Nuclear Waste Fund, and require no congressional appropriations. DOE calculates that its nuclear waste liabilities to nuclear reactor operators under current law will ultimately total \$11 billion if shipments begin by 2020 as currently planned and potentially much more if waste operations are further delayed.⁸

Options for Halting or Delaying Yucca Mountain

The Yucca Mountain repository is now in the final stages of the lengthy approval process established by NWPA. Therefore, if the Obama Administration does “not believe that Yucca Mountain is a suitable site,” what options are available at this point to stop the project?

NWPA sections 113-116 prescribed the following actions by the Secretary of Energy, the President, and the Nuclear Regulatory Commission toward developing a nuclear waste repository at the Yucca Mountain site:

- The Secretary were to determine whether the site is suitable for a repository, and, if so, notify the State of Nevada and recommend that the President approve the project.
- If the President agreed with the Secretary’s recommendation, the President were to submit an approval recommendation to Congress.
- After the presidential recommendation, the Nevada Legislature or Governor were allowed to submit a notice of disapproval to Congress.
- State disapproval would block the repository unless Congress voted within 90 days for an approval resolution that was signed by the President.
- Once the presidential site designation took effect, the Secretary were required to submit a repository license application to NRC.

All these steps have now taken place, and the Yucca Mountain license application has been docketed by NRC for consideration. NRC is an independent regulatory body not directly under the President’s control. But the President has a variety of tools at his disposal that could dramatically affect the nuclear waste program.

⁸ Christopher A. Kouts, Office of Civilian Radioactive Waste Management, “Yucca Mountain Program Status Update,” Presentation to Environmental Protection Agency Workshop on Energy and Environmental Sustainability in a Carbon Constrained Future, New York, NY, September 11, 2008, p. 9, http://www.epa.gov/region2/energyworkshop/workshop_presentations/session2/nuclear_session/panel1_nuclear_waste_disposal.pdf.

Withdraw License Application

To stop further action on Yucca Mountain, perhaps the most dramatic step would be for DOE to withdraw the repository license application, as allowed by NRC procedures.⁹ Such a withdrawal could be temporary, pending completion of some of the study options described below, or it could be permanent, with the intention of completely ending the Yucca Mountain project. If the license application were permanently withdrawn, the previous presidential site designation may have to be reversed as well, because NWPA section 114 requires that the license application be submitted 90 days after the presidential designation takes effect (a deadline that was missed by more than five years). The fact that, as noted above, the presidential designation of the Yucca Mountain site took effect pursuant to a congressional override of Nevada's "state veto" could be a complicating factor.

Reduce Appropriations

Restricting funding for the Yucca Mountain Project could be another approach. Congressional opponents of the waste program have succeeded in cutting its funds in recent years, although not enough to prevent DOE from submitting the license application. The Bush Administration requested an appropriation of \$37.3 million from the Nuclear Waste Fund for NRC's license review activities during FY2009,¹⁰ and substantial reductions could force significant delays in the planned four-year licensing schedule.

As noted above, DOE contends that it will need large funding increases to design and build the Yucca Mountain repository by 2020, so even steady funding would probably push back that schedule by many years. Of course, eliminating funding altogether for NRC licensing and DOE repository construction would halt further work on the project. The Obama Administration's ability to reduce or eliminate Yucca Mountain funding, if it so desired, would depend on its influence with Congress.

Key Policy Appointments

Although NRC is independent of the Administration, and Commissioners cannot be removed by the President without cause, the President can change the makeup of the Commission over time. Significant changes in the Commission could affect the Yucca Mountain licensing process and its ultimate outcome. The five NRC Commissioners serve five-year terms that are staggered so that one expires each year, on June 30. No more than three Commissioners may be from the same political party. One of the five slots is currently vacant. The President can also redesignate the Chairmanship of the NRC to a different Commissioner at any time.

Other presidential appointments could also have a strong effect on the Yucca Mountain project, the Secretary of Energy in particular. Senate Majority Leader Harry Reid had promised to block any nominee for that post who supported the Yucca Mountain site.¹¹ The Energy Secretary could

⁹ 10 C.F.R. § 2.107.

¹⁰ Nuclear Regulatory Commission, *Performance Budget Fiscal Year 2009*, NUREG-1100 Volume 24, February 2008, p. 2, <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1100/v24/>

¹¹ Erica Werner, "Reid Won't Allow Energy Secretary Who Supports Yucca Waste Dump," *Associated Press*, December 4, 2008, <http://www.rgj.com>.

initiate a redirection of the nuclear waste program, revisit DOE's complex computer models that predict low radioactive releases from Yucca Mountain, or, as noted above, withdraw the license application.

Senator Reid expressed support for President Obama's Energy Secretary, former Lawrence Berkeley National Laboratory Director Steven Chu, contending that "Dr. Chu also knows, like most Nevadans, that Yucca Mountain is not a viable solution for dumping and dealing with nuclear waste."¹² In a 2005 interview posted on the Lawrence Berkeley National Laboratory website, Chu noted projections from his lab that waste canisters in Yucca Mountain would begin to fail after about 5,000 years, which would require the underlying rock formations to prevent unacceptable migration of radioactive material into the groundwater.¹³ However, Chu also signed a nuclear policy statement with other national laboratory directors in August 2008 that called for "licensing of the Yucca Mountain Repository as a long-term resource."¹⁴

Another important appointment for Yucca Mountain is the Administrator of the Environmental Protection Agency (EPA), Lisa Jackson, who was confirmed January 22, 2009. Under NWPA, EPA sets the radiation protection standard that NRC must use in licensing Yucca Mountain. After an earlier version of the standard was struck down by a federal court, EPA published a final standard October 15, 2008, which sets individual radiation exposure limits of 15 millirems for the first 10,000 years after disposal and 100 millirems after 10,000 through one million years.¹⁵ The State of Nevada has sued to overturn the EPA regulations, contending that there is no justification for a higher limit after 10,000 years.¹⁶ If the EPA standard is overturned, licensing of the Yucca Mountain site could become more difficult.¹⁷

Waste Program Review

Rather than moving immediately to halt the Yucca Mountain repository, the Obama Administration could delay or suspend the project through the approaches described above and then initiate a major program review – a step implied by the Obama-Biden campaign policy statement. The scope of the review could include such topics as management issues, research and development needs, foreign waste management experience, and broad policy options.

Such a review could be conducted by an interagency task force within the new Administration or by an outside entity such as the National Academy of Sciences (NAS) or a presidential commission. Independent scientific reviews of the waste program are currently provided by the

¹² Senator Harry Reid, "Statement on the nomination of Dr. Steven Chu to be Secretary of Energy," press release, December 15, 2008, http://reid.senate.gov/newsroom/pr_121508_energysenom.cfm.

¹³ Lawrence Berkeley National Laboratory, "Growing energy: Berkeley Lab's Steve Chu on what termite guts have to do with global warming," press release, September 30, 2005, http://berkeley.edu/news/media/releases/2005/10/03_chu.shtml.

¹⁴ DOE National Laboratory Directors, *A Sustainable Energy Future: The Essential Role of Nuclear Energy*, August 2008, p. 1, http://www.ne.doe.gov/pdfFiles/rpt_SustainableEnergyFuture_Aug2008.pdf.

¹⁵ Nuclear Regulatory Commission, "Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada," *73 Federal Register* 61256, October 15, 2008.

¹⁶ *State of Nevada v. U.S. Environmental Protection Agency* (U.S. Court of Appeals for the District of Columbia Circuit 2008).

¹⁷ For more on this issue, see CRS Report RL34698, *EPA's Final Health and Safety Standard for Yucca Mountain*, by Bonnie C. Gitlin.

Nuclear Waste Technical Review Board (NWTRB), which, under NWP Title V, the President appoints from nominees provided by NAS. However, the President does not set the agenda for independent agencies such as NWTRB, so it is not clear what role the Board might play in a major policy review.

Consequences of a Yucca Mountain Policy Shift

A decision by the incoming Administration to halt or delay development of the Yucca Mountain repository could have significant impact on the federal budget, proposed new U.S. nuclear power plants, waste storage at existing reactor sites, and disposal of defense-related nuclear waste. Such consequences could be most pronounced if such a policy shift involved simply a halt of Yucca Mountain without legislation to forge a new direction – legislation that presumably would address the issues discussed below.

No matter what decision is made on Yucca Mountain, there is a broad scientific consensus that long-term isolation of nuclear waste from the environment – for at least 1,000 years – will still be required. In other words, if Yucca Mountain were abandoned, another repository site in the United States would almost certainly have to be found eventually. Reprocessing and recycling of nuclear spent fuel can reduce the amount of long-lived radioactive waste requiring isolation but cannot entirely eliminate the need for such isolation. Alternatives to deep geologic waste isolation have been studied, such as space and subseabed disposal, but they face daunting technical obstacles, and none has ever been developed beyond the conceptual stage.

If development of the Yucca Mountain repository were delayed or halted, commercial spent fuel and defense-related nuclear waste would almost certainly remain at numerous on-site storage facilities longer than currently planned. A new repository to replace Yucca Mountain would be unlikely to open by 2020 to prevent delays in DOE's current shipping schedule. Federal centralized interim storage has been proposed repeatedly as a solution, including the MRS facility authorized by NWP, but no such facility has been developed. If new legislation were to authorize a central interim storage facility, it possibly could begin receiving waste by 2020 and prevent further delays. Another possibility is a private spent fuel storage facility in Utah that has already received an NRC license and might be opened relatively quickly if other administrative approvals were granted (as discussed in a subsequent section). However, the Utah facility's licensed capacity is limited to 40,000 metric tons of spent fuel, which could be stored at the site for no longer than 40 years.

Federal Liabilities for Disposal Delays

As noted above, DOE is liable for utilities' nuclear waste storage costs resulting from the missed NWP disposal deadline. According to DOE, "for each additional year of delay, the Department estimates that there may be hundreds of millions of dollars of additional damages."¹⁸ These mandatory payments would be a direct cost to the federal government, but they would stretch over several decades because utilities cannot recover damages until their extra storage costs are

¹⁸ Department of Energy, Office of Civilian Radioactive Waste Management, *Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites*, DOE/RW-0596, Washington, DC, December 2008, p. 6, http://www.rw.doe.gov/info_library/program_docs/ES_Interim_Storage_Report_120108.pdf.

actually incurred. DOE projects that if disposal begins by 2020, \$11 billion in liabilities will be incurred by 2056.¹⁹

If the Yucca Mountain site were abandoned without an alternative storage or disposal process in place, court judgments against DOE could rise far higher. The nuclear industry has raised the possibility that DOE could be found in complete default on its NWPA contracts and be ordered to refund all the nuclear waste fees that had been collected, in addition to paying utilities' extra at-reactor storage costs.²⁰ Through the end of FY2008, DOE had collected more than \$28 billion in fees and interest payments – an amount that has been growing at about \$1.5 billion per year.²¹ In at least one of the nuclear utility cases before the Federal Court of Claims, a judge issued a show-cause order for why the DOE nuclear waste contracts should not be voided and all payments returned to utilities,²² although that step was not included in the court's final decision.²³

Licensing Complications for New Power Reactors

No new commercial reactors have been ordered in the United States since the 1970s, but concerns over potential carbon dioxide controls and high natural gas prices have prompted U.S. electric utilities to again consider the nuclear power option. License applications for 26 new reactors have been filed with NRC, and more are anticipated.²⁴ Further delays in the DOE nuclear waste program could pose an obstacle to licensing the proposed new reactors.

NRC established a policy in 1977 that it “would not continue to license reactors if it did not have reasonable confidence that the wastes can and will in due course be disposed of safely.”²⁵ NRC then began a Waste Confidence proceeding that resulted in 1984 findings that there was “reasonable assurance” that a nuclear waste repository would be available by 2007-2009 and that waste could be safely stored at reactor sites for at least 30 years after reactors have shut down.²⁶

After DOE's schedule for opening the Yucca Mountain repository slipped to 2010, NRC revised its Waste Confidence Decision in 1990 to find reasonable assurance that a repository “will be available within the first quarter of the twenty-first century.”²⁷ With DOE now planning to open Yucca Mountain by 2020 at the earliest, NRC is proposing a further revision to find reasonable assurance that a repository will be available within 50-60 years after a reactor's licensed operating life and that spent fuel can be stored safely for at least 60 years after a reactor's licensed

¹⁹ Kouts, *op.cit.*, p. 9.

²⁰ U.S. Congress, Senate Committee on Energy and Natural Resources, *Nuclear Waste Litigation*, To examine the impacts of federal court decisions on breach of federal nuclear waste contracts, 106th Cong., 2nd sess., September 28, 2000, S.Hrg. 106-918 (Washington: GPO, 2001), p. 46.

²¹ Department of Energy, Office of Civilian Radioactive Waste Management, *Monthly Summary of Program Financial & Budget Information*, as of September 1, 2008, p. 7.

²² Jeff Beattie, “Federal Judge Suggests Voiding Utilities' Yucca Mountain Contracts,” *Energy Daily*, April 29, 2005, p. 1.

²³ *Sacramento Municipal Utility District v. United States*, (Court of Federal Claims 2006).

²⁴ Nuclear Regulatory Commission, “Combined License Applications for New Reactors,” <http://www.nrc.gov/reactors/new-reactors/col.html>.

²⁵ Nuclear Regulatory Commission, 42 *Federal Register* 34391, July 5, 1977.

²⁶ Nuclear Regulatory Commission, 49 *Federal Register* 34658, August 31, 1984.

²⁷ Nuclear Regulatory Commission, 55 *Federal Register* 38472, September 18, 1990.

life.²⁸ Although the NRC's latest proposed revision would allow for decades of further slippage in the Yucca Mountain schedule, it is not clear that NRC's waste-related criteria for licensing new reactors would be satisfied if the Yucca Mountain project were canceled without an alternative plan in place.

Six states – California, Connecticut, Kentucky, New Jersey, West Virginia, and Wisconsin – have specific laws that link approval for new nuclear power plants to adequate waste disposal capacity. Kansas forbids cost recovery for “excess” nuclear power capacity if no “technology or means for disposal of high-level nuclear waste” is available.²⁹ The U.S. Supreme Court has held that state authority over nuclear power plant construction is limited to economic considerations rather than safety, which is solely under NRC jurisdiction.³⁰ No nuclear plants have been ordered since the various state restrictions were enacted, so their ability to meet the Supreme Court's criteria has yet to be tested.

The nuclear waste issue has also historically been a focal point for public opposition to nuclear power. Proposed new reactors that have no clear path for removing waste from their sites could face intensified public scrutiny, particularly at proposed sites that do not already have operating reactors.

Environmental Cleanup Penalties

For defense-related nuclear waste, which resulted from production of nuclear weapons and naval reactor fuel by DOE and its predecessor agencies, indefinite delays in developing a repository could also have legal consequences for DOE. Defense-related high-level radioactive waste resulted from decades of reprocessing spent fuel to extract plutonium for nuclear warheads or highly enriched uranium from spent naval reactor fuel. As noted above, DOE's inventory of defense high-level waste and unprocessed spent fuel, plus waste from other DOE nuclear programs, totals the equivalent of 12,800 metric tons (the mass of spent fuel before reprocessing). This material is located primarily at Hanford, WA, Savannah River, SC, and the Idaho National Laboratory.

Congress has given states the authority to enforce waste management laws against federal agencies, including DOE. Without Yucca Mountain or an alternative repository plan, DOE would not have a permanent disposal site for waste now stored at its defense-related facilities. A lack of repository capacity, according to DOE, “could threaten the Department's ability to fulfill [regulatory] agreements with the states hosting those sites to remove the waste for permanent disposal.”³¹

²⁸ Nuclear Regulatory Commission, “Waste Confidence Decision Update,” *73 Federal Register* 59551, October 9, 2008.

²⁹ David L. Lovell, Wisconsin Legislative Council Staff, *State Statutes Limiting the Construction of Nuclear Power Plants*, October 5, 2006.

³⁰ *Pacific Gas & Electric Co. v. State Energy Resources Conservation and Development Commission*, 461 U.S. (190 1983).

³¹ DOE, *Need for a Second Repository*, op. cit., p. 13.

Long-Term Risk

The near-term environmental impact of further Yucca Mountain delays or abandonment would be minimal for at least 100 years, according to DOE's supplemental environmental impact statement (SEIS) for the repository program.³² That assessment is consistent with the NRC Waste Confidence Decision cited above. As long as storage facilities at reactors and other sites are maintained and guarded through institutional controls, radioactive releases to the environment are expected to be small.

On-site storage of spent fuel will continue for many decades even if Yucca Mountain begins receiving waste shipments by 2020, as discussed in the baseline program section above. Moreover, some freshly discharged spent fuel will be stored on site as long as reactors are operating. Some environmental groups have argued that it would be safer to leave all nuclear waste for an extended period in hardened on-site storage facilities rather than begin sending it to a central facility as soon as possible, because allowing the waste's radioactivity to decay would reduce the consequences of transportation accidents or sabotage when the waste is ultimately moved.³³ Moreover, waste placed at a central interim storage facility would probably have to be moved a second time to a permanent repository, potentially further increasing transportation risks.

Beyond 100 years or so, the environmental risks of surface storage resulting from the lack of an underground repository become more uncertain. At some point in the future, maintenance and security of surface storage facilities would be expected to drop below adequate levels because of unforeseen circumstances. Whether that would occur after 500 years, 1,000 years, or 10,000 years is open to speculation. Federal nuclear waste policy would presumably continue to envision a permanent disposal method well before such a breakdown, but the risk would be expected to rise if delays continued indefinitely. The SEIS predicts that substantial amounts of radioactivity would reach the accessible environment within 10,000 years after the end of institutional controls on surface storage facilities, "with eventual catastrophic consequences for human health."³⁴

Nuclear Waste Policy Options

Because NWPA specifies that only Yucca Mountain may be considered for a repository site and that a federal storage facility cannot open before the repository is licensed, the government's waste management options are sharply limited under current law. Without congressional action, alternatives to Yucca Mountain would consist primarily of indefinite on-site storage or licensing of new private storage sites.

New legislation would open up much broader possibilities, ranging from a search for a new repository site and federal interim storage to reprocessing and alternative disposal technologies.

³² Department of Energy, Office of Civilian Radioactive Waste Management, *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250F-S1, Washington, DC, June 2008, p. S-50, http://www.rw.doe.gov/ym_repository/seis/index.shtml.

³³ U.S. Congress, House Committee on Commerce, Subcommittee on Energy and Power, *The Nuclear Waste Policy Act of 1997*, hearing on H.R. 1270, 105th Cong., 1st sess., April 29, 1997, Serial No. 105-27 (Washington: GPO, 1997), p. 125.

³⁴ DOE, *Final Supplemental Environmental Impact Statement*, op. cit., p. S-51.

Some – but probably not all – of the consequences of changing the current waste policy could also be mitigated through legislation. Any legislation dealing with nuclear waste siting is almost certain to prove extraordinarily controversial.

Institutional Changes

Almost since the beginning of the current nuclear waste program in 1982, DOE has regularly been accused of mismanagement and allowing political considerations to affect scientific decisions. Many proposals have been made by the nuclear industry and its critics alike to transfer the nuclear waste program to an independent organization that might be more efficient and less affected by politics. For example, a proposal in the 110th Congress (H.R. 6001, section 186) would have handed the DOE waste program to an independent High Level Waste Authority, headed by a presidentially appointed seven-member board. In implementing the nuclear waste program, the Waste Authority would have been authorized to consider all reasonable options, including alternative repository locations.

An independent waste agency could be a government agency, as in H.R. 6001, a government corporation, or a private-sector entity. Two studies conducted for DOE's Global Nuclear Energy Partnership recommended the establishment of a government corporation to manage nuclear waste, including spent fuel reprocessing. One of the studies, by a consortium led by the French firm Areva, called a government corporation the best option "because it allows the utilities to have some level of oversight while full government ownership keeps the cost of capital low."³⁵ A team led by EnergySolutions recommended that the government corporation have a board of directors drawn from the nuclear industry, with an independent oversight board "to assure that it meets its charter obligations."³⁶

Licensing and regulation by NRC could be continued unchanged under any option. The existing funding system could also be transferred largely unchanged to a new government agency, but a new funding system would probably be needed for a private entity. Whether a private entity should take permanent title to all nuclear waste could also be an issue. The nuclear industry has long contended that nuclear waste payments by reactor owners should be available directly for nuclear waste disposal activities without the need for congressional appropriation. But even if the program's management were improved, it is far from clear whether any new waste management organization could avoid the political controversy that has persistently accompanied the DOE program.

Short of establishing an entirely new organization to run the waste program, it has been suggested that additional independent oversight could improve public confidence in DOE's decisions. This was a major reason cited for creating the Nuclear Waste Technical Review Board in 1987. Some have proposed that technical oversight by a non-federal agency would be more credible, such as the Environmental Evaluation Group (EEG) in New Mexico.³⁷ Congress in 1988 required DOE to sign a contract with a New Mexico university, the New Mexico Institute of Mining and Technology, to administer the EEG to provide independent review and evaluation of the Waste

³⁵ International Nuclear Recycling Alliance, *Integrated U.S. Used Fuel Strategy*, May 1, 2008, p. 10.

³⁶ EnergySolutions, *GNEP Deployment Studies: Overall Summary Report*, Richland, WA, May 19, 2008, p. 2-2.

³⁷ Allison M. Macfarlane, Rodney C. Ewing, et al., *Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste* (Cambridge, MA: MIT Press, 2006), p. 407.

Isolation Pilot Plant (WIPP), a DOE repository for relatively low-radioactivity defense waste (P.L. 100-456, section 1433). The EEG closed in 2004 after DOE halted its funding,³⁸ and oversight activities are now carried out by the New Mexico Environment Department.³⁹

Extended On-Site Storage

It appears unlikely, based on the history of the nuclear waste program, that any alternative storage or disposal sites could become operational earlier than the planned opening of Yucca Mountain in 2020. Therefore, any alternative to the Yucca Mountain repository would almost certainly result in longer on-site storage of nuclear waste than under the current baseline program. Essentially, extended on-site storage is the default option, with the only question being how long. On-site storage could be extended for decades under some policy changes, such as a restart of the repository site search or the pursuit of alternative disposal technologies. Waste might be moved more quickly if central interim surface storage facilities were developed (as discussed below), but designating such sites may be nearly as controversial as siting a repository.

On-site nuclear waste storage at reactor facilities takes place primarily in deep pools of water that are built into the reactor building. The water is necessary to provide cooling and radiation shielding for extremely radioactive spent fuel that is freshly discharged from the reactor. After its radioactivity has sufficiently decayed, usually after several years, spent fuel can be transferred to dry storage casks and stored outside the pools. Most spent fuel pools were not designed to hold all the spent fuel generated during a reactor's operating life. Therefore, as DOE's target date for taking spent fuel from reactor sites has slipped, nuclear reactor operators have had to expand their on-site dry storage capacity (and have sued DOE for compensation).

NRC considers extended on-site storage to be safe as long as storage facilities are adequately maintained and guarded, as discussed above. However, the National Academy of Sciences (NAS) determined in 2005 that spent fuel pools could be vulnerable to terrorist attacks, particularly as spent fuel has been stored more densely in the pools to increase their capacity. NAS found that an attack could drain the cooling water from a spent fuel pool and cause the spent fuel's zirconium cladding to overheat and catch fire, releasing "large quantities of radioactive materials to the environment."⁴⁰ The Energy and Water Development Appropriations Act for FY2006 (P.L. 109-103) included \$21 million for NRC to assess the vulnerabilities found by NAS at each reactor site.

Keeping nuclear waste at reactor sites and other existing facilities has long been a major goal of Yucca Mountain opponents. Numerous bills have been introduced over the years to require DOE to take over all responsibility for storing spent fuel at reactor sites, including ownership of the waste and on-site storage facilities (such as S. 784 in the 110th Congress). Such an on-site DOE takeover is intended to reduce utilities' costs, and resulting federal liabilities, for DOE's failure to remove the spent fuel. However, states with nuclear reactors oppose indefinite on-site storage, and utilities and state regulators have opposed using the Nuclear Waste Fund to pay for on-site storage (as proposed by S. 784) rather than permanent disposal or central interim storage.

³⁸ John Fleck, "WIPP Oversight Bureau Planned," *Albuquerque Journal*, June 19, 2004.

³⁹ http://www.nmenv.state.nm.us/doe_oversight/wipp.htm

⁴⁰ National Academy of Sciences Board on Radioactive Waste Management, *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report*, Washington, DC, 2005, p. 6.

Federal Central Interim Storage

DOE does not believe it has the authority under current law to develop a central interim nuclear waste storage facility other than the “monitored retrievable storage” facility authorized by NWPA,⁴¹ and the 1987 NWPA Amendments prohibit such an MRS facility from opening until Yucca Mountain is licensed. Moreover, construction of an MRS cannot begin until NRC grants a construction permit for the repository; the MRS is limited to 15,000 metric tons of spent fuel; and the MRS cannot be located in Nevada (NWPA sections 145 and 148). Numerous legislative efforts have been mounted since the mid-1990s to establish central interim storage capacity without the MRS restrictions, but without success. No matter how they have been structured, such proposals have consistently faced overwhelming concerns that any “interim” storage facility would undercut political support for a permanent repository and therefore become a “de facto” permanent disposal site.

Central interim nuclear waste storage facilities would use dry cask technology that is similar to that currently in place at reactor sites. Sealed waste canisters would be placed in individual above-ground concrete casks or bunkers for radiation shielding and for cooling by natural air circulation. Because the systems are modular, they can be constructed relatively quickly. And because the waste is not expected to remain in storage after active maintenance of the facility has ceased, a wide variety of sites are likely to be considered geologically suitable. However, public concern about large quantities of highly radioactive waste stored for an extended period of time, and perhaps indefinitely, has proven to be a major obstacle to central storage proposals.

DOE had proposed to build an MRS facility near Oak Ridge, TN, as a central receiving point for small waste shipments from individual plant sites east of the Rocky Mountains. Spent fuel was to be repackaged if necessary at the MRS facility for consolidated long-distance shipments to the planned Western repository.⁴² The Oak Ridge selection was specifically nullified by the 1987 NWPA amendments, which established a new siting procedure along with the restrictions listed above. The 1987 Amendments also established an alternative, voluntary siting procedure for the MRS and other nuclear waste facilities. Under Title IV, a presidentially appointed “nuclear waste negotiator” was authorized to reach agreements with any states or Indian tribes to host nuclear waste facilities under any “reasonable and appropriate” terms. Such agreements could not take effect without being enacted into law, however.

By the early 1990s, finding a voluntary site for a central storage facility appeared to be DOE’s best chance for meeting NWPA’s 1998 waste acceptance deadline. DOE began providing feasibility study grants to potential volunteers, mostly Indian tribes. Potential agreements with Indian tribes proved highly objectionable to the states in which the tribes were located, and Congress blocked the grant funding in October 1993 (P.L. 103-126). The authority for the nuclear waste negotiator expired on January 21, 1995, without any proposed siting agreements having been reached.

The next major legislative push for an alternative to the MRS took place after it became clear that DOE would be unable to meet the NWPA disposal deadline. In the 104th Congress, nuclear power supporters developed legislation to authorize DOE to open an interim surface storage facility at

⁴¹ DOE, *Report to Congress on Interim Storage*, op. cit., p. 14.

⁴² Department of Energy, Office of Civilian Radioactive Waste Management, *Monitored Retrievable Storage Submission to Congress*, DOE/RW-0035, Washington, DC, February 1986.

the Yucca Mountain site by 1998, well before the then-anticipated opening of the underground repository in 2010 (H.R. 1020). The State of Nevada and nuclear power opponents contended that waste should not be transported to Yucca Mountain before the repository was licensed, because if the repository ultimately did not receive a license, the waste would have to be moved again, increasing potential transportation risks and costs. The bill was approved by the Commerce Committee (H.Rept. 104-254) but was not enacted. Similar bills were passed by the House and Senate in the 105th Congress (H.R. 1270, S. 104), but President Clinton threatened a veto and a conference was not held. A final try in the 106th Congress (S. 1287) drew a presidential veto that was narrowly sustained in the Senate.

After the proposals to develop interim storage capacity at Yucca Mountain were rejected, language was included in several appropriations bills and reports to require DOE to store commercial spent fuel at unspecified federal sites. The House Appropriations Committee included language in its report on the FY2006 Energy and Water Development Appropriations Bill to require DOE “to begin the movement of spent fuel to centralized interim storage at one or more DOE sites within fiscal year 2006” (H.Rept. 109-86), although the Senate did not go along with the idea. The Senate Appropriations Committee included an extensive provision in its version of the FY2007 Energy and Water bill (H.R. 5427, section 313) to authorize the Secretary of Energy to designate interim storage sites for spent nuclear fuel. The proposal, which was not enacted, would have required the Secretary to designate a storage site in each state with a nuclear power plant, after consultation with the governor, or to designate regional storage facilities.

A more limited central storage proposal was aimed solely at nine decommissioned reactor sites. Because the decommissioned sites have no ongoing nuclear activities except spent fuel storage, the removal of spent fuel would allow all nuclear-related maintenance and security at those locations to cease, producing significant operational cost savings, according to the nuclear industry. The House Appropriations Committee included report language with the FY2008 Energy and Water bill requiring DOE to “develop a plan to take custody of spent fuel currently stored at decommissioned reactor sites” (H.Rept. 110-185). The resulting DOE report concluded that all 2,800 metric tons of spent fuel at the nine decommissioned sites could be shipped to a federal central storage facility by 2018, but that DOE had no statutory authority to implement such a plan.⁴³

DOE has taken spent fuel for storage at its facilities in the past in special cases, such as the damaged core from the 1979 Three Mile Island accident and from the unique Fort Saint Vrain gas-cooled reactor in Colorado. The Three Mile Island core material was shipped to DOE’s Idaho National Laboratory for research. DOE is storing the Fort Saint Vrain spent fuel pursuant to a cooperative agreement signed with the reactor supplier and local utility before the demonstration reactor was built.⁴⁴ In addition, DOE stores highly enriched, U.S.-origin spent fuel from foreign research reactors because of its potential use in nuclear weapons. Some have contended that those precedents indicate that DOE has sufficient general authority under the Atomic Energy Act to store larger amounts of commercial spent fuel. However, DOE contends that its broad authority under the Atomic Energy Act is restricted to narrow circumstances under the more recently enacted and specific waste management provisions of NWPA.⁴⁵

⁴³ DOE, *Report to Congress on Interim Storage*, op. cit., p. 14.

⁴⁴ Department of Energy, “DOE Holds License for Colorado Spent Fuel Facility,” press release, June 28, 1999, http://newsdesk.inl.gov/press_releases/1999/DOE_Holds_Licen.htm.

⁴⁵ DOE, *Report to Congress on Interim Storage*, op. cit., p. 6.

Private Central Storage

Although DOE does not believe it has authority under current law to construct a federal central interim storage facility for commercial nuclear waste, NRC regularly licenses private-sector interim storage facilities under the Atomic Energy Act.⁴⁶ Such “independent spent fuel storage installations” typically are licensed for on-site storage at reactor sites, but they can also include central storage facilities.

After a nearly nine-year licensing process, NRC issued a license for a private central storage facility on February 21, 2006, that was intended to receive waste from commercial reactor sites.⁴⁷ The facility was to be developed by a nuclear utility consortium called Private Fuel Storage (PFS) on the reservation of the Skull Valley Band of the Goshute Indians in Utah. The 20-year license, renewable for an additional 20 years, allows up to 40,000 metric tons of spent fuel to be stored in 4,000 dry casks pending shipment by DOE to a permanent repository. PFS will not take title to the spent fuel, so waste is to be returned to the utilities that own it if DOE cannot take it away before the PFS license expires.⁴⁸

On September 7, 2006, the Department of the Interior issued two decisions blocking the PFS project. The Bureau of Indian Affairs disapproved a proposed lease of tribal trust lands to PFS, concluding there was too much risk that the waste could remain at the site indefinitely, among other objections.⁴⁹ The Bureau of Land Management rejected the necessary rights-of-way to transport waste to the facility, concluding that a proposed rail line would be incompatible with the Cedar Mountain Wilderness Area and that existing roads would be inadequate.⁵⁰ Contending that the Interior Department was motivated by political pressure from the State of Utah, which strongly opposed the facility, the Skull Valley Band of Goshutes and PFS filed a federal lawsuit July 17, 2007, to overturn the decisions.⁵¹

The PFS project was intended to provide a waste storage option for nuclear plants that might have trouble gaining approval for on-site storage facilities or decommissioned reactors that want to remove remaining spent fuel from their sites. If the PFS facility were considered potentially useful as part of a revised spent fuel strategy, the new Administration could revisit the Interior Department’s administrative decisions that are blocking the project. However, if those decisions were reversed, the project would still need to overcome a challenge to the NRC license filed by the State of Utah.⁵² Another consideration for this option is that, because the waste would have to be returned after 40 years, and utilities would be paying for the service, the PFS facility might not significantly reduce DOE’s liabilities for delays in spent fuel acceptance.

⁴⁶ 42 U.S.C. § 2011 et seq., 10 CFR Part 72.

⁴⁷ Nuclear Regulatory Commission, *License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste SNM-2513*, February 21, 2006.

⁴⁸ Private Fuel Storage, LLC, *Frequently Asked Questions: Financial Accountability*, <http://www.privatefuelstorage.com/faqs/faqs.html>.

⁴⁹ Bureau of Indian Affairs, *Record of Decision for the Construction and Operation of an Independent Spent Fuel Storage Installation (ISFSI) on the Reservation of the Skull Valley Band of Goshute Indians (Band) in Tooele County, Utah*, September 7, 2006.

⁵⁰ Bureau of Land Management, *Record of Decision Addressing Right-of-Way Applications U 76985 and U 76986 to Transport Spent Nuclear Fuel to the Reservation of the Skull Valley Band of Goshute Indians*, September 7, 2006.

⁵¹ *Skull Valley Band of Goshute Indians and Private Fuel Storage, LLC, v. James E. Cason et al.* (U.S. District Court for the District of Utah, Central Division 2007).

⁵² Todd D. Lovinger, “Utah Challenges License Issuance to PFS,” *LLW Forum News Flash*, March 12, 2006.

Spent Fuel Reprocessing and Recycling

The major alternative to direct disposal of spent fuel (the “once through” fuel cycle) is the “closed” fuel cycle, in which spent fuel is reprocessed into new fuel. The closed fuel cycle could reduce the volume and long-term radioactivity of nuclear waste and potentially postpone the need for permanent disposal. However, a National Academy of Sciences study of reprocessing technologies found that “none of the S&T [separations and transmutation] system concepts reviewed eliminates the need for a geologic repository.”⁵³ Recycling spent fuel could also greatly increase the amount of energy extracted from a given supply of uranium. However, the closed fuel cycle is generally considered to be substantially more expensive than the once-through cycle.⁵⁴ Moreover, the separation of plutonium from spent fuel has long been a subject of national policy debates because of its potential role in nuclear weapons proliferation.

Fuel for U.S. nuclear reactors currently consists of uranium in which the fissile isotope U-235 has been increased (enriched) to 3-5%, with the remainder being the non-fissile isotope U-238. During the fuel’s several-year irradiation period in the reactor, most of the U-235 splits, or fissions, releasing energy. Some of the U-238 is transmuted into fissile isotopes of plutonium, some of which also fissions. In reprocessing, the uranium and plutonium are chemically separated to be made into new fuel, while the lighter elements resulting from the fission process, called fission products, are stored for disposal.

New fuel made from reprocessed uranium and plutonium can be recycled in existing commercial light water reactors, which is being done in other countries, primarily France. After being recycled once, however, the buildup of undesirable plutonium isotopes makes further recycling in today’s commercial reactors problematic. Without multiple recycling, the plutonium and other long-lived isotopes cannot be fully fissioned or transmuted into shorter-lived radioactive isotopes, and the benefits for waste disposal would therefore be modest.

For multiple recycling of spent fuel, advanced reactors would be necessary. DOE has evaluated a wide variety of options as part of its Global Nuclear Energy Partnership (GNEP) program. These include initial recycling in existing light and heavy water reactors, and subsequent recycling in high-burnup gas-cooled reactors, reactors fueled by thorium and plutonium, and “fast” reactors (in which neutrons are not slowed by water or other materials).⁵⁵ A reprocessing and recycling system with sufficient capacity could eventually treat existing spent fuel inventories along with newly generated spent fuel.

For waste disposal, the goal of such a recycling system would be to send only the fission products and other short-lived radioisotopes to a permanent repository and feed all the uranium, plutonium, and other long-lived radioisotopes back into a reactor after each cycle. If that could be accomplished, the nuclear waste in a repository would decay to insignificant levels within about 1,000 years and eliminate longer-term uncertainty about the repository’s performance. Spent fuel

⁵³ National Academy of Sciences, National Research Council, *Nuclear Wastes: Technologies for Separations and Transmutation*, Washington, DC, August 1995, p. 17.

⁵⁴ Peter R. Orszag, *Costs of Reprocessing Versus Directly Disposing of Spent Nuclear Fuel*, Congressional Budget Office, Statement Before the Senate Committee on Energy and Natural Resources, Washington, DC, November 17, 2007, <http://www.cbo.gov/ftpdocs/88xx/doc8808/11-14-NuclearFuel.pdf>.

⁵⁵ Department of Energy, Office of Nuclear Energy, *Draft Global Nuclear Energy Partnership Programmatic Environmental Impact Statement*, DOE/EIS-0396, Washington, DC, October 2008, <http://www.gnep.energy.gov/peis.html>.

recycling could also save space in an underground repository by reducing the near-term heat load, which is the primary limit on repository capacity.⁵⁶ To address nuclear nonproliferation concerns, the GNEP program is conducting research on reprocessing technology that would not separate plutonium in a pure enough form for direct use in nuclear weapons.

A potential nearer-term benefit of a reprocessing strategy would be to provide an alternative destination for spent fuel currently stored at reactor sites if Yucca Mountain were to be abandoned. Because DOE is still conducting R&D on a variety of possible reprocessing technologies, however, a U.S. reprocessing facility would probably not open earlier than the current Yucca Mountain target date.

Earlier waste shipments might be possible under proposals that have been made for foreign reprocessing of U.S. spent fuel. Several foreign reprocessing plants are currently in operation. The Senate Energy and Natural Resources Committee included a provision in a nuclear waste bill in the 104th Congress (S. 1271) that would have authorized DOE to take title to spent fuel and ship it to a reprocessing plant in England. However, the provision proved highly contentious and was dropped from the final bill passed by the Senate (S. 1936). In a 2008 report for GNEP, a consortium led by the French nuclear firm Areva recommended that U.S. spent fuel be reprocessed overseas from 2010 to 2019 before the startup of a U.S. reprocessing plant after 2020.⁵⁷ The use of inactive defense-related reprocessing facilities at DOE's Savannah River Site in South Carolina has also been suggested for U.S. commercial spent fuel.⁵⁸

The amount of spent fuel that could be shipped to reprocessing plants would be another consideration. Existing reprocessing plants in France and England are designed to handle about 800 metric tons of spent fuel per year. Therefore, at least three plants of that size would need to be constructed in the United States (assuming minimal foreign reprocessing) to handle the 2,000 metric tons of spent fuel discharged annually from U.S. reactors. About four plants would be needed to exceed the planned shipment rate to Yucca Mountain.

Many decades would be required to implement a reprocessing and recycling strategy. For example, the Areva consortium projected that a steady-state recycling system would not be fully in place until about 2070, even if the currently planned 63,000 metric tons of spent fuel were emplaced in Yucca Mountain rather than being reprocessed. The first U.S. reprocessing plant would become operational after 2020.⁵⁹ Proposals by three other GNEP consortia included similar time frames. (For more discussion of reprocessing policy, see CRS Report CRS Report RL34579, *Advanced Nuclear Power and Fuel Cycle Technologies: Outlook and Policy Options*, by Mark Holt).

⁵⁶ Electric Power Research Institute, *Projected Waste Packages Resulting From Alternative Spent-Fuel Separation Processes*, EPRI NP-7262 Project 3030 Final Report, Palo Alto, CA, April 1991, pp. 5-3.

⁵⁷ International Nuclear Recycling Alliance, *Presentation for GNEP Deployment Studies*, April 2008, p. 6, <http://www.gnep.energy.gov/pdfs/INRA%20Presentation.pdf>.

⁵⁸ David Kramer, "Report by SRS Contractor Appears to Advocate Reprocessing at Site," *Inside Energy/with Federal Lands*, January 8, 1996, p. 8.

⁵⁹ International Nuclear Recycling Alliance, *op. cit.*, p. 43.

Non-Repository Options

The inherent difficulty of siting a permanent geologic repository for high-level nuclear waste has led to a variety of proposals over the past few decades for non-repository disposal options. NWPAA section 222 authorizes DOE to conduct research on such disposal alternatives. The most seriously analyzed ideas involve launching waste into space or burying it in the deep seabed. Some plausible concepts for implementing these ideas have been developed, but a great deal of development work would still be required to determine their likely feasibility.

Congress established a DOE Office of Subseabed Disposal Research in the Nuclear Waste Policy Amendments Act of 1987 (P.L. 100-203). The office was required to organize a Subseabed Consortium among leading research institutions to develop a research plan for identifying subseabed disposal sites, developing conceptual designs for subseabed disposal systems, and assessing potential environmental impacts. However, few resources were provided for the subseabed office before it was abolished in 1996 by P.L. 104-66.⁶⁰

Previous research on subseabed disposal was conducted by the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development. The United States participated in the effort through the DOE Subseabed Disposal Project, on which about \$125 million was spent from 1974-1986.⁶¹ The NEA program studied the emplacement of nuclear waste canisters in ocean sediments with gravity-driven penetrators or in drilled holes. NEA concluded in 1988 that the sediments would probably contain the waste well enough to keep the maximum dose to humans – occurring after about 100,000 years – “many orders of magnitude below present standards” and pose “insignificant risk to the deep sea environment.” However, NEA also concluded that more research would be needed to confirm the safety of the subseabed disposal concepts.⁶²

Subseabed disposal is currently prohibited under the 1996 Protocol to the 1972 London Dumping Convention, which was signed by the United States on March 31, 1998, and entered into force March 24, 2006, but has not been ratified by the Senate. The Protocol amended the definition of “dumping” to include “any storage of wastes or other matter in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea.”⁶³ Previously it had been unclear whether the Convention prohibited subseabed disposal. Annex 1 of the Protocol requires parties to the agreement to complete a scientific study of sea disposal of radioactive material other than high-level waste by 2019 and every 25 years thereafter.

Disposal of nuclear waste in outer space has also been studied by DOE and its predecessor agencies. In a 1974 draft environmental statement on nuclear waste management, the Atomic Energy Commission (AEC) reviewed government studies of such concepts as “solar system escape, solar impact, high-earth orbit, and a solar orbit other than that of the planets.” The report concluded that space disposal “does not seem an attractive alternative to the geological

⁶⁰ Steven Nadis, “The Sub-Seabed Solution,” *The Atlantic Monthly Digital Edition*, October 1996.

⁶¹ Office of Technology Assessment, *Staff Paper on the Subseabed Disposal of High-Level Radioactive Waste*, Washington, DC, May 1986, p. 3.

⁶² Organization for Economic Cooperation and Development, Nuclear Energy Agency, *Feasibility of Disposal of High-Level Radioactive Waste into the Seabed, Overview of Research and Conclusions*, Volume 1, Paris, 1988, p. 60.

⁶³ *1996 Protocol to Convention on Prevention of Marine Pollution by Dumping of Wastes*, Treaty Doc. 110-5, September 4, 2007.

development program.”⁶⁴ Major concerns include launch costs, launch safety, and the potential for future waste re-entry into Earth’s atmosphere. Proposed alternatives to conventional rocket-based launch systems, such as laser propulsion and electromagnetic rail guns, might have safety and cost advantages, but a major federal commitment would be needed to determine their feasibility.⁶⁵

Other disposal concepts studied by DOE and its predecessors include waste emplacement in polar ice sheets, deep boreholes, and deep well injection of liquid waste. AEC’s draft environmental statement dismissed those alternatives as not viable,⁶⁶ and they have since received relatively little attention.

New Repository Site

Even if nuclear waste is placed in extended surface storage and is reprocessed to remove the longest-lived radioactive isotopes, a permanent disposal method almost certainly would still be required. Barring the non-repository options discussed above, that would mean that the abandonment of Yucca Mountain for any reason would eventually require a search for another repository site.

The history of site selection efforts under NWPA indicates that a new repository site search would be slow-moving and extremely controversial. Vast areas of the United States would again be under consideration, after having been eliminated by the 1987 congressional designation of Yucca Mountain as the sole candidate site. Every decision made by whatever entity were to be placed in charge of the site search would probably face intense opposition, especially as the search began to narrow. Designing a selection process that could overcome such pressures would be a major challenge.

NWPA was intended to set up a fair and technically sound process for selecting among numerous potential repository sites that DOE and its predecessor agencies had been considering. Without such a legislative mandate, DOE’s previous efforts to find a waste site appeared unlikely to overcome the controversy that had arisen at every potential location.⁶⁷ However, the explicit waste siting process created by NWPA lasted only about five years before being paralyzed by renewed controversy.

Under NWPA as originally enacted, the Secretary of Energy was required to establish guidelines that DOE would follow in nominating at least five suitable sites, of which three were to be recommended to the President for detailed study, or “characterization” by January 1, 1985. Sites that DOE had been considering included salt domes along the Gulf Coast, bedded salt in the Great Plains and Midwest, volcanic tuff in the West, and basalt in the Pacific Northwest. Energy Secretary John S. Herrington recommended Hanford, WA; Deaf Smith County, TX, and Yucca

⁶⁴ Atomic Energy Commission, *Draft Environmental Statement on Management of Commercial High Level and Transuranium-Contaminated Radioactive Waste*, WASH-1539, September 1974, pp. 5.3-6.

⁶⁵ Jonathan Coopersmith, “Nuclear Waste in Space?,” *The Space Review*, August 22, 2005, <http://www.thespacereview.com/article/437/1>.

⁶⁶ Atomic Energy Commission, op. cit., p. 5.3.

⁶⁷ Luther J. Carter, *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste* (Washington, DC: Resources for the Future, 1987), p. 198.

Mountain for site characterization on May 27, 1986.⁶⁸ After completing the characterization of the three sites, the Secretary was to recommend one of them to the President for the nation's first permanent nuclear waste repository. The President was required to submit his choice to Congress by March 31, 1987.

To address concerns about whether a single site or region should take all of the nation's high-level nuclear waste, NWPA limited the first repository to 70,000 metric tons until a second repository was opened. A separate track was established for locating a second repository site. By July 1, 1989, the Secretary of Energy was to nominate five sites for a second repository, including at least three sites that had not been among the five sites nominated for the first repository, and recommend three of them to the President. The recommended sites were to be located, "to the extent practicable," in different geologic media. The President was to recommend a second repository site to Congress by March 31, 1990, from any of the sites previously characterized.

Unlike the process for the first repository, which started with specific candidate sites that were already under consideration, the site search for the second repository was conducted more systematically. DOE began by focusing on major formations of granite and other crystalline rock, which had not been included in the first repository effort, in 17 states in the upper Midwest and Atlantic coast. In consultation with states, DOE developed a screening methodology to rank candidate bodies of rock for their potential suitability as a repository.⁶⁹ DOE released preliminary rankings that identified 12 promising rock bodies in seven states in January 1986.⁷⁰

DOE's identification of potential sites for the second repository drew intense opposition from the affected states. The three potential host states for the first repository also raised strong objections, which intensified when Secretary Herrington announced on May 28, 1986, that work on the second repository would be indefinitely postponed. Herrington said the decision was based on lower growth projections for nuclear power that delayed the need for a second repository, but officials from the first repository candidate states in the West contended that the Reagan Administration had responded to political pressure from the Eastern candidate states and had unraveled a key regional compromise in NWPA.⁷¹ Opposition from Tennessee to DOE's proposed MRS site near Oak Ridge added to the controversy. The Senate Appropriations Committee made note of the deteriorating situation:

Intense and widespread criticism, controversial programmatic decisions by the Secretary of Energy, and a proliferation of substantial litigation have taken a toll on progress toward the goals of the program.⁷²

⁶⁸ Department of Energy, *Recommendation by the Secretary of Energy Regarding the Suitability of the Yucca Mountain Site*, February 2002, p. 4, http://www.ocrwm.doe.gov/ym_repository/sr/sar.pdf.

⁶⁹ Department of Energy, Office of Civilian Radioactive Waste Management, *Draft Mission Plan for the Civilian Radioactive Waste Management Program*, DOE/RW-0005 DRAFT Volume 1, Washington, DC, April 1984, pp. 3-A-23.

⁷⁰ Carter, op. cit., p. 410.

⁷¹ Mary Louise Wagner, "DOE Decision to Halt Second Repository Program Could Derail Entire Waste Act," *NuclearFuel*, June 2, 1986, p. 7.

⁷² U.S. Congress, Senate Committee on Appropriations, *Energy and Water Development Appropriation Bill, 1987*, Report to accompany H.R. 5162, 99th Cong., 2nd sess., September 15, 1986, S.Rept. 99-441 (Washington: GPO, 1986), p. 157.

In addition to the controversy over site selection, it had become apparent that NWPA's timelines for characterizing the candidate sites and the anticipated cost of the characterization effort were unrealistic. With the future of the nuclear waste program in doubt, the 100th Congress decided to reopen NWPA for fundamental revision. The resulting NWPA Amendments Act of 1987 cancelled the second repository program, nullified DOE's selection of Oak Ridge for an MRS facility, and statutorily designated Yucca Mountain as the sole candidate site for a repository. Supporters of the legislation contended that characterizing only one site rather than three would be faster and save money, and noted that Yucca Mountain had been the most highly rated of the three candidates by DOE.⁷³ Some lawmakers, however, contended that the statutory designation of Yucca Mountain was made primarily for political reasons.⁷⁴

The NWPA Amendments Act also provided for annual payments as an inducement to states for hosting nuclear waste facilities. States could receive up to \$20 million per year for hosting a repository and \$10 million for an MRS site if they agreed not to exercise their right under the law to disapprove those facilities. However, Nevada expressed no interest in the payments and, as noted previously, exercised its "state veto" in 2002. DOE did not conduct an MRS site search under the NWPA Amendments, relying instead on the Nuclear Waste Negotiator to find a voluntary site, as discussed earlier.

Although naming a single site for characterization was intended to speed up the development of a nuclear waste repository, the process actually took another 15 years after the 1987 Amendments, plus another five years to complete the license application to NRC. Supporters of the waste program contend that chronic underfunding by Congress was a major reason for the slow progress, while opponents primarily blamed DOE management problems. The State of Nevada was also able to slow the repository by denying state permits for various characterization activities and through successful lawsuits, such as the challenge to EPA's environmental standards. Nevada filed a 1,500-page petition with NRC in December 2008 to intervene in the Yucca Mountain license proceeding, raising dozens of safety, environmental, and other contentions.⁷⁵

The history of U.S. efforts to site a nuclear waste repository illustrates the difficulty in successfully addressing local, state, and regional objections to such facilities. The United States did not succeed with the administrative process started by the Atomic Energy Commission, with the site-ranking system used for the NWPA first repository selection, the broad screening process used for the second repository, the benefits offered under the NWPA Amendments, or the voluntary selection process by the Nuclear Waste Negotiator. If Yucca Mountain is abandoned, that would arguably spell failure for the statutory designation method as well.

Just because those approaches were unsuccessful in the past does not mean they could not work in the future with program design modifications, better management, and changed circumstances. For example, it has been recently suggested that a negotiated benefits agreement with Nevada

⁷³ Department of Energy, Office of Civilian Radioactive Waste Management, *A Multiattribute Utility Analysis of Sites Nominated for Characterization for the First Radioactive-Waste Repository—A Decision-Aiding Methodology*, DOE/RW-0074, Washington, DC, May 1986, Chapter 5.

⁷⁴ Sen. Quentin Burdick, "Nuclear Waste Provisions," Remarks in the Senate, *Congressional Record*, vol. 133, part 26 (December 21, 1987), p. 37697.

⁷⁵ State of Nevada's Petition to Intervene as a Full Party in the Matter of Docket No. 63-001 (High Level Waste Repository), before the Nuclear Regulatory Commission, December 19, 2008. <http://www.state.nv.us/nucwaste/news2008/pdf/nv081219nrc.pdf>

might now be feasible, given the current economic downturn.⁷⁶ During the debate on the 1987 Amendments, Representative Morris Udall, Chairman of the House Interior Committee, contended that the original NWPA selection process would have worked had it been implemented properly:

We created a principled process for finding the safest, most sensible places to bury these dangerous wastes. We were confident that while no State wanted a nuclear waste repository, the States ultimately chosen would accept the outcome because the selection process would have been fair and technically credible.

Today, just 5 years later, this great program is in ruins. To help a few office seekers in the last election, the administration killed the eastern repository program, shattering the delicate regional balance at the heart of the 1982 act. Since then the Western States have felt they are being treated unfairly, and they no longer trust the technical integrity of the Department of Energy's siting decisions.⁷⁷

Others have expressed doubt that a purely scientific and objective selection process is possible, given the inherent difficulties in making extremely long-term projections of repository behavior. The Director of the Office of Civilian Radioactive Waste Management recently described the siting of nuclear waste facilities as a “technically informed political decision.”⁷⁸

DOE's long but ultimately successful struggle to open a deep geologic repository for mid-level waste – the WIPP facility near Carlsbad, NM – indicates that siting of nuclear waste facilities is not necessarily impossible. State and local officials had invited AEC to consider the deep salt beds in the economically depressed area in the early 1970s for a high-level waste repository. After a great deal of statewide controversy, although with consistent local support, Congress authorized WIPP in 1979 to hold defense-related transuranic waste (P.L. 96-164).⁷⁹

Transuranic (TRU) waste is not considered to be as hazardous as spent fuel and high-level waste, but it nevertheless requires long-term isolation in a geologic repository. TRU waste consists of relatively low-radioactivity material contaminated with more than a minimum concentration of long-lived plutonium.

DOE's efforts to implement the 1979 WIPP authorization were hampered by concerns by state officials that spent fuel and high-level waste would eventually be disposed of along with the transuranic waste.⁸⁰ After a dozen years of controversy over the project's implementation, Congress in 1992 enacted the Waste Isolation Pilot Plant Land Withdrawal Act (P.L. 102-579), detailing the regulations and procedures that DOE would have to follow to open the facility and banning high-level waste and spent fuel. Slow progress prompted Congress to amend the WIPP Land Withdrawal Act in 1996 to exempt WIPP waste from some land disposal restrictions and provide \$20 million for New Mexico bypass roads for waste shipments (P.L. 104-201). The first

⁷⁶ Elaine Hiruo, “Funding Prospects Look Bleak for Yucca Project,” *NuclearFuel*, January 12, 2009, p. 11.

⁷⁷ Rep. Morris Udall, House Debate, *Congressional Record*, vol. 133, part 26 (December 21, 1987), p. 37068.

⁷⁸ Edward F. Sproat III, Director, DOE Office of Civilian Radioactive Waste Management, speech to the Center for Strategic and International Studies, November 6, 2008.

⁷⁹ Carter, op. cit., p. 177.

⁸⁰ Carter, op. cit., p. 188.

waste was shipped to the repository in March 1999, nearly 20 years after the facility was authorized.⁸¹

It has recently been suggested that WIPP again be considered as a site for high-level waste disposal. Spent nuclear fuel could be more technically problematic, because the physical flow of the salt within a period of years will close in on stored waste and eliminate the option to retrieve the waste after 100 years or so, as could be done at Yucca Mountain.⁸² Such “salt creep” occurs more quickly at higher temperatures, which could result from the disposal of high-level waste and spent fuel. A potential advantage of salt creep is that it can provide a natural seal around the waste.⁸³ Nevertheless, the State of New Mexico continues to strongly oppose any disposal of high-level waste at WIPP.⁸⁴

Concluding Discussion

Significant scientific uncertainty – if not clear technical unsuitability – has arisen at every potential high-level nuclear waste repository site evaluated by the federal government. Such doubts have fed the public controversy that inevitably accompanies the announcement of such sites. As a result, the federal government has not succeeded in opening any central facilities for permanent disposal or interim storage of spent nuclear fuel and high-level waste.

The controversial nature of siting nuclear waste facilities increases the likelihood that alternatives to the proposed Yucca Mountain repository would leave waste at existing storage sites longer than under the current program schedule. Major consequences under current law could include increased liability by the federal government for utility storage costs, and fines and penalties for missing cleanup deadlines at defense-related nuclear facilities. Although NRC has determined that waste can be stored safely at reactor sites for many decades, the licensing of new plants could be affected by the lack of a definite disposal plan. Extremely long disposal delays would also increase the risk that adequate maintenance and security at storage sites would end before the waste could be removed.

Central interim storage of nuclear waste has regularly been suggested as the quickest way to begin moving waste from existing storage sites. However, without a plan for permanent disposal, the development of interim sites could be especially controversial. Reprocessing of spent fuel has long been proposed as a way to reduce the hazards of nuclear waste by removing plutonium and other long-lived radioactive material. While such a technological approach could make it easier to site a permanent repository, the separation of plutonium raises significant opposition because of its potential use in nuclear weapons and effects on U.S. nonproliferation policy. DOE is researching reprocessing techniques that could reduce the separation of pure plutonium, but their effectiveness and potential high cost continues to be a subject of controversy.

⁸¹ Shawn Terry, “Waste Isolation Pilot Plant Opens Doors,” *Inside Energy/with Federal Lands*, March 29, 1999, p. 1.

⁸² Rick Michal, “James Conca: On WIPP and Other Things Nuclear,” *Nuclear News*, February 2008, p. 44.

⁸³ D.J. Clayton, “Effects of Heat Generation on Nuclear Waste Disposal in Salt,” American Geophysical Union Fall Meeting, abstract #H53A-1010, 2008, <http://adsabs.harvard.edu/abs/2008AGUFM.H53A1010C>.

⁸⁴ “New Mexico Bars High-Level Waste From Carlsbad Salt Caverns,” *Environment News Service*, November 4, 2004.

The 1987 designation of Yucca Mountain as the nation's sole candidate site for a national high-level nuclear waste repository was a calculated risk that the site could be developed successfully. There is no backup plan in place. Yucca Mountain opponents contend that, as a result, the federal government has stuck with the site no matter what technical problems have been discovered. But if Yucca Mountain is determined to have significant problems, an alternative course will have little existing policy framework to build upon.

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