‘Plan D’ for Spent Nuclear Fuel

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Dry storage casks for spent nuclear fuel (source: Holtec International, http://www.holtecinternational.com/).

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Preface

This report documents the recent success achieved in reaching a consensus on how to revise U.S. management of spent nuclear fuel. This consensus was reached at a workshop held on March 16, 2009, at the University of Illinois at Urbana-Champaign. Organized by the university's Program on Arms Control, Disarmament, and International Security, the workshop attracted participants from nuclear engineering programs at seven Midwestern universities. In their deliberations, these participants drew upon the findings of an earlier workshop held on June 6, 2008, at the American Association for the Advancement of Science Center for Science, Technology and Security Policy and upon interviews in Washington, D.C., with dozens of congressional staff members. Appendix A lists the contributors to these two workshops. All of these efforts were supported by the John D. and Catherine T. MacArthur Foundation through its Science, Technology, and Security Initiative.

The development of the recommendations in this report followed a step-by-step process. It began with interviews of staff of members of Congress from both major parties. Those interviews revealed essentially universal support for the idea of an escrow arrangement in which funds would be set aside for the management of spent nuclear fuel. These interviews presaged a wide-ranging discussion at the 2008 workshop by participants with broad-based experience on topics relevant to spent fuel management. More interviews with congressional staff then revealed the need for additional input from the states that generate spent nuclear fuel. Because Illinois produces the most nuclear power of all U.S. states and is at the center of a region of nuclear power–producing states, a natural starting point was to assemble faculty from nuclear engineering programs in Illinois and adjacent states. This decision led to convocation of the March 2009 workshop.

To focus the discussion in the second workshop on the mechanics of revising spent fuel management policy, the participants were given a very specific example of how such a revision might be initiated. The example (reproduced in Appendix B) proved to be generally consistent with the workshop consensus except in one area: management of that portion of the escrow funds reserved for supporting the movement of spent nuclear fuel out of the state in which it was generated. Although the example called for such funds to be managed in the same way as funds for reactor decommissioning, the workshop consensus was that the use of such escrow funds should initially be controlled by a tightly regulated private corporation rather than by the individual generators of spent fuel. The workshop consensus also called for encouraging neighboring states to cooperate on consolidating spent nuclear fuel at sites with operating nuclear reactors—for example, in cases in which a shutdown reactor in one state is no longer able to supply substantial amounts of electrical energy to a neighboring state.

Caveats

The June 2008 workshop provided only background information; no attempt was made to frame a consensus. Presented here, then, is simply the rapporteurs' understanding of the outlines of a general consensus from the March 2009 workshop. In describing the findings of that workshop, this report is not meant to represent in any way the positions of the University of Illinois at Urbana-Champaign, the universities of any of the rapporteurs, or any other institution. Nor is it meant to represent the views on any particular topic of any participant in the March 2009 workshop. These caveats notwithstanding, this report constitutes what could be a significant step toward building a broader national consensus on spent nuclear fuel management.

Executive Summary

An impasse on spent nuclear fuel management would have several effects. It would render the U.S. government liable to billions of dollars in legal fees for failure to take title to spent nuclear fuel. It would result in extra costs and security risks from suboptimal management of spent fuel at reactor sites. It would also leave nuclear fuel cycle research and development without a clear roadmap. Such a situation not only would be deleterious domestically but also would undermine U.S. influence on matters related to energy and security internationally.

The reality appears to be that most U.S. spent nuclear fuel is likely to remain where it was generated for an extended period of time. Managing this situation efficiently and laying the groundwork for a functional transition to long-term spent fuel management require paying careful attention to the financial situations of nuclear reactor site owners and the host states for long-term spent fuel management facilities. These observations led to seven recommendations, each of which would each require U.S. congressional action for implementation:

1. Set up regulated escrow funds for utilities to draw on to meet the costs of on-site management of aged spent nuclear fuel in dry casks.
2. Explicitly allow shipment of spent fuel from one utility to another utility's operating nuclear reactor site in the same state.
3. Provide a financial incentive for states to agree to have spent fuel shipped from an inoperative reactor site in one state to an operating reactor site in a neighboring state.
4. Require any licensed spent fuel reprocessing facility to be licensed as well for possible continuing on-site storage of any spent fuel intake and of all reprocessing product streams.
5. Should the federal government not succeed in licensing long-term spent fuel management facilities in a timely manner, consider turning this task over to a tightly regulated corporation set up for this purpose.
6. Allow states to require that they receive substantially larger financial incentives for cooperating on hosting long-term spent nuclear fuel management facilities. Transferring nuclear waste management payments into a permanent fund set up to insure such a facility and allowing a state to tap interest earnings on that fund is one possible approach.
7. Consider licensing long-term management facilities for taking in spent fuel produced at many different reactor sites, but not utilizing such facilities until it becomes clear that it is more economically advantageous to do so than to continue holding spent fuel in dry casks at operating reactor sites.

Three guiding principles underlie these recommendations. First, only in the distant future will it likely become clear whether and when it is commercially advantageous to reprocess spent nuclear fuel one or more times before permanent disposal. Second, a spent fuel management system will be fully functional only when key stakeholders have substantial financial incentives to cooperate. And third, forging a broader consensus on a process for establishing a viable long-term management system well before individual long-term management facilities are utilized should provide a sufficient condition for success. Meanwhile, success will hinge on adoption of as many of the seven recommendations as possible.

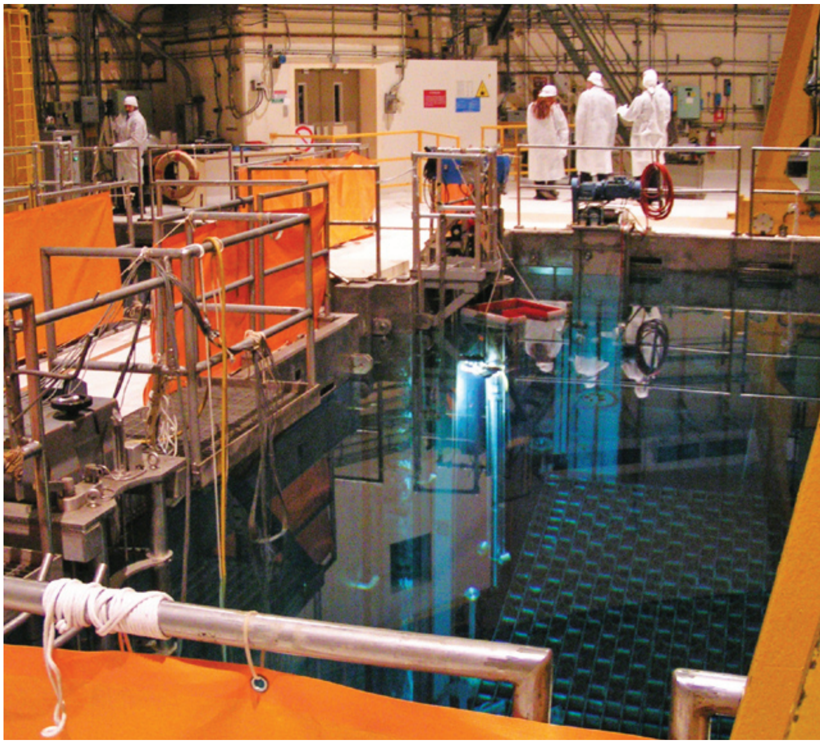
1 | Statement of the Problem

The new presidential administration that entered office in January 2009 found itself facing this situation: limited funds budgeted for pursuing licensing of the Yucca Mountain repository, the absence of effective near-term steps toward extensive actinide burning, and the absence of any proposal to centralize surface storage of spent fuel. Thus the administration is likely to decide to hold old spent nuclear fuel at reactors in dry casks for an extended period.

The United States is already increasingly storing spent fuel in dry casks at nuclear reactor sites. So why should the spent fuel management approach defined by Nuclear Waste Policy Act of 1982 (NWPA) be changed again? There are five reasons:

1. **Lawsuits:** Currently, the U.S. government is losing individual lawsuits over its failure to take title to spent fuel. If nothing is done, billions of dollars will be lost to legal fees. (The liability through 2020 is estimated to be about $11 billion, and settlements as of June 2008 added legal fees amounting to nearly one-third of the liability awards made.)
2. **Stranded Fuel:** Spent fuel is stranded at several inoperative reactor sites, which prevents such sites from being fully decommissioned. The costs of managing and making stranded fuel secure average millions of dollars per year per inoperative reactor site, although the costs at each site vary considerably, depending on its other ongoing activities. However, added up over time and all inoperative reactor sites, the cost of securing stranded spent fuel is substantial.
3. **Densely Packed Pools:** In the absence of a legislative change giving utilities an incentive to adopt dry cask storage at reactor sites, they will continue to densely pack wet pool storage. Such a method presents more difficulties in recovering from some forms of sabotage, with potentially disastrous results.
4. **R&D:** Enacting a clearer and more stable approach to spent nuclear fuel management could save billions of dollars by helping to better define the type and timeframe needed for fuel cycle research and development.
5. **Nuclear Energy:** Until the current legislation is changed, legal impediments in many states will effectively prevent new reactor siting. Opinions differ on how many new nuclear reactors the United States should build. In any case, continuing ambiguity about how U.S. spent nuclear fuel will be handled undermines U.S. influence internationally on climate change, nuclear nonproliferation, and the future global trajectory for nuclear technology.

An underlying problem is that the legal requirement that the Department of Energy (DOE) take title to spent nuclear fuel has not been met for twenty-seven years—since passage of the NWPA in 1982. And there is no particular reason to expect this approach will change in the foreseeable future. It appears, then, that spent nuclear fuel is destined to remain at about seventy U.S. nuclear reactor sites for several reasons. First, even if licensed, Yucca Mountain will not start accepting spent fuel for a long time. Second, nuclear reactors will soon produce more spent fuel than Yucca Mountain would be licensed to receive. And, third, it may be difficult to license Yucca Mountain at all, much less to amend the license for it to take more spent fuel. Thus a lot of spent nuclear fuel will continue to accumulate at reactor sites around the country, leaving those sites to manage this material. There is no question but that this management will remain subject to oversight by the Nuclear Regulatory Commission. The question raised here is how or even whether the federal government should take title to spent nuclear fuel, especially as long as the spent fuel remains in the state in which it was generated. This question, in turn, raises the one of how funds for spent fuel management will be administered.



Storage of spent nuclear fuel in a pool at a power plant.

2 | The Questions Posed

The questions posed in this chapter served as background for a discussion of possible changes in the NWPA that might lead to a more orderly process for the management of spent nuclear fuel. These questions focus attention on sections of the amended U.S. Nuclear Waste Policy Act of 1982 that seem particularly pertinent to the difficulties the U.S. government is having with spent nuclear fuel management. (The references in square brackets in this chapter are to particular sections of the NWPA.) In particular, what changes to the NWPA would be needed if the U.S. commercial nuclear reactor fleet were expanded beyond the lifetime of its current reactors without concurrent licensing of adequate deep underground storage for the spent fuel of all old and new reactors? For the sake of brevity, the questions addressed here are about Plan D, among these alternatives:

- **Plan A. Breeding.** Reprocess spent fuel, after brief underwater storage, for use in breeder reactors.
- **Plan B. Prompt Deep Burial.** Send spent fuel to a permanent deep burial facility after removal from pool storage.
- **Plan C. Actinide Burning.** Reprocess spent fuel promptly for the purpose of deep actinide burning to reduce the deep underground storage space required.
- **Plan D. Holding in Dry Casks.** Hold fuel removed from wet pools in dry cask storage until it becomes clearer whether reprocessing will precede permanent disposal.
- **Plan E. Elimination.** Build no more reactors for nuclear electric power production and abandon spent fuel reprocessing.

The NWPA as amended is aimed at the Plan B solution. This approach was adopted in preference to Plan A based on a reassessment of available uranium resources, cessation of the exponential growth of nuclear power use, and concerns about the international security implications associated with promoting reprocessing.

The previous presidential administration supported Plan C in an attempt to use the same capacity specified in the Yucca Mountain license application to accommodate most of the spent fuel to be produced in the United States in the

TABLE 2.1 Some Spent Fuel Isotopes with 10- to 1,000,000-Year Half-lives

Transuranic actinide		$t_{1/2}$ (year)	% of Pu	Impact
Plutonium	Pu-242	380,000	5	Minor
Plutonium	Pu-241	14	14	Am-241 source
Plutonium	Pu-240	6,537	23	Hard to burn out
Plutonium	Pu-239	24,110	57	Weapons usable
Plutonium	Pu-238	88	1	Minor
Americium	Am-241	432		Burial density
Fission product		$t_{1/2}$ (year)	#/fission	Impact
Strontium	Sr-90	29	0.06	Convective cooling
Cesium	Cs-137	30	0.06	Convective cooling
Technetium	Tc-99	213,000	0.06	Groundwater

Sources: Lawrence Berkeley Laboratory, "Fission Product Yields," 1998, http://isotopes.lbl.gov/fission.html; David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (New York: Oxford University Press, 1996).

Note: $t_{1/2}$ is the half life of the isotope for radioactive decay. #/fission is the average number of each isotope produced per fission event. Plutonium fractions are for a typical pressurized water reactor with a comparatively low burnup of 33 GW-days-thermal per metric ton. Yields per fission are for U-235 in a water-moderated reactor, after decay of short-lived precursors.

twenty-first century. A key challenge in implementing Plan C is to burn out the isotope plutonium-240 and others derived from it by neutron capture and intervening radioactive decay. Selected properties of some of these isotopes, called transuranic actinides, are summarized in Table 2.1. The approach preferred by the former administration required about three rounds of reprocessing and fuel burning in reactors cooled by liquid sodium. However, Congress has since declined to appropriate the funds needed to proceed with Plan C. On April 15, 2009, a DOE spokesperson said the United States would no longer pursue Plan C as its near-term domestic approach in connection with the Global Nuclear Energy Partnership of countries cooperating on investigating options for spent nuclear fuel management (NEI 2009). Plan E, elimination, is supported by a coalition of nongovernmental organizations. However, since the end of the Cold War—a period that has seen concerns about carbon emissions from cheaper methods of electricity production grow—support among the general public for eliminating nuclear power has waned (Jones 2009). Thus in actual practice, the United States appears to be left, for the foreseeable future at least, with Plan D.

TABLE 2.2 Commercial Spent Fuel at Sites without Operating Reactors

State	No. of sites running	Plant shut down	Type	MTHM
Illinois	6	Zion 1 and 2	Pool	1,019
Maine	0	Maine Yankee	Dry	542
Connecticut	1	Haddam Neck	Dry	412
Oregon	0	Trojan	Dry	359
California	2	Rancho Seco	Dry	228
California		Humboldt Bay	Dry	29
Massachusetts	1	Yankee Rowe	Dry	127
Michigan	3	Big Rock Point	Dry	58
Wisconsin	2	La Crosse	Pool	38
Total (of unrounded numbers)				2,813

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

Note: MTHM = metric tons of heavy metal.

Storage Options

Within the overall umbrella of a Plan D, there are several possible options for locations of dry cask storage:

- Operating reactor sites where the spent fuel was produced
- Reactor sites where the spent fuel was produced but the reactor has been shut down
- Reactor sites with the same owner/operator in the same state
- Reactor sites with a different owner/operator in the same state
- Reactor sites with the same owner/operator in a different state
- Reactor sites with a different owner/operator in a different state
- Away-from-reactor storage but not at a site licensed for deep burial or reprocessing
- A site licensed for deep burial
- A site licensed for reprocessing.

Storage at Reactor Sites

These options are listed roughly in the order of their legal complexity. The NWPA allows explicitly for the first three options. Moving spent fuel "stranded" at a site without an operating reactor to an active reactor site operated by the same utility is relatively straightforward. (Table 2.2 summarizes the inoperative reactor sites that hold stranded spent fuel, and Appendix C presents a complete state-by-state summary of spent fuel holdings and payments to the Nuclear Waste Fund.) There is precedence for moving spent fuel between reactors of the same utility. However, utilities generally have little incentive to do so as long as the Department of Energy remains legally obligated to take title to the spent fuel. In a few cases, such as Rancho Seco in central California and La Crosse in Wisconsin, moving stranded fuel to an operating reactor site in the same state would require shipping it to a different owner. Two states—Oregon, and Maine—have stranded fuel but no operating commercial nuclear power reactor. The U.S. Department of Energy is also directly responsible for management of some spent nuclear fuel, as summarized in Table 2.3. This management includes a relatively small amount of spent fuel from the Fort St. Vrain gas-cooled electricity production reactor in Colorado where the spent fuel was still on-site in 2008, but this fuel was scheduled to be moved to Idaho.

Concerning Oregon, the Trojan reactor vessel was shipped upriver to the Hanford site, but the spent fuel remains in Oregon. The Maine Yankee spent fuel could, in principle, be shipped to the Savannah River site without going overland through any other states, but there are no plans to do that. Nor are there any plans to ship the Trojan or Maine Yankee spent fuel to an operating commercial nuclear power reactor site in a neighboring state. Currently, the NWPA explicitly allows only "the transshipment of spent nuclear fuel to another civilian reactor within the same utility system" [Title I, Subtitle B, Sec. 134 (a)].

QUESTION 1. Should the NWPA be revised to explicitly allow transshipment of fuel from one utility's reactor site to another utility's reactor site within the same state?

Away-from-Reactor Storage

The NWPA allows for the possibility that the Department of Energy would establish a centralized monitored retrievable storage (MRS) facility. However, the heavy metal content of such storage is limited to 10,000 metric tons until a geological repository first accepts shipments and to 15,000 metric tons thereafter [Title I, Subtitle C, Sec. 148 (d)]. The NWPA does not prohibit larger capacity in a private interim spent fuel storage facility, but the issue of a twenty-year license for a facility that could be expanded to a capacity of 44,000 metric tons of such storage in Utah has not led to facility construction (IHS 2006).

QUESTION 2. In Subtitle C of Title I of the NWPA, should the capacity limits for a government MRS facility be changed, or are they adequate to allow longer-term storage in a private facility?

TABLE 2.3 Spent Nuclear Fuel Held by U.S. Department of Energy

Facility	Amount (MTHM)
Hanford, Washington	2,132
Idaho National Laboratory	273
Savannah River, South Carolina	67
West Valley, New York	27
Idaho Nuclear Reactors Facility (INRF)	20
Fort St. Vrain, Colorado	15
Others	1

Source: John Ahearne, et al. *End Points for Spent Nuclear Fuel and High-Level Radioactive Waste in Russia and the United States* (Washington, D.C.: National Academies Press, 2003), http://www.nap.edu/catalog.php?record_id=10667.

Note: Amounts are in metric tons of heavy metal (MTHM), where heavy metal includes uranium and elements with higher atomic numbers. The entry for INRF is rounded up from the reported 19.5 MTHM content. "Others" includes 0.67, Oak Ridge National Laboratory, Tennessee; 0.29, Sandia, New Mexico; 0.14, Argonne National Laboratory, Illinois; and 0.06, Brookhaven, New York. The maximum number of high-level waste cannisters allowed is 13,000 at the Hanford and Idaho facilities, 9,100 at Savannah River, and 275 at New York.

Retrievable Storage at Repository and Reprocessing Sites

A proposal to build 21,000 metric tons of spent fuel aging pads on the surface at Yucca Mountain exemplifies how the cost of retrievable storage might be reduced even at a site licensed for deep burial. Although the state of Nevada has objected to the proposal (Tetreault 2006), it is not clear whether there are any legal limits on surface storage at a facility licensed for deep burial. In Illinois, the private G. E. Morris spent nuclear fuel storage site, adjacent to the Dresden nuclear power plant, is an example of a facility that was designed for reprocessing but in effect became a retrievable spent fuel storage facility when plans for reprocessing were abandoned (see Appendix C for the amount of spent fuel stored at the Morris site). Despite this history, the NWPA does not currently require licensed reprocessing facilities to be designed for long-term storage of all spent fuel intake and reprocessing products, even if reprocessing or disposition of reprocessed materials does not proceed as originally planned (for example, as in Title IV, Sec. 406). The proposal for surface aging of spent fuel at Yucca Mountain and the situation at the Morris storage site illustrate the possibility of licensing one or both deep burial and reprocessing facilities for interim (less than 50 years), medium-term (50–100 years), or long-term (more than 100 years) retrievable storage without actually committing to deep burial or reprocessing until it becomes clear which of the two options is preferable.

QUESTION 3A. Should licenses for reprocessing facilities be required to include provisions for long-term management of spent fuel and reprocessed materials, and, if so, should any limits be put on their intake of spent nuclear fuel?

QUESTION 3B. Should licenses for geologic repositories be explicitly allowed provisions for long-term management of spent fuel before deep burial, and, if so, should any limits be put on their intake of spent nuclear fuel?

Benefits Provisions

Apparently, the NWPA does not include sufficient incentives to encourage a state to volunteer to accept spent nuclear fuel from outside the state for long-term management. Annual benefits payments to a state or Indian tribe while a federal government MRS or repository is open are $10 million and $20 million, respectively, plus $5 million and $10 million prior to opening [Title I, Subtitle F, Sec. 171 (a) (1)]. There is no provision for adjusting these payments for inflation. Thus, based on 3 percent annual inflation, the net value in 2007 of the benefits payments to Nevada for opening Yucca Mountain for a hundred years starting in 2020 was less than 0.5 percent of the total estimated inflation-adjusted lifetime cost of just over $96 billion (Reuters 2008). By comparison, the balance of the petroleum-related Alaska Permanent Fund in 2007 was about $40 billion, despite having paid out about $15 billion in face value dollars since 1982. If a geologically suitable nuclear waste repository and geologic petroleum reservoirs are both viewed as valuable national energy resources, then the difference in the benefits to the states' residents at large under the current NWPA is striking.

For reasons related to the information summarized in Table 2.4, the situation in the United States contrasts in several ways with that in Finland and Sweden—the two countries that have made the most progress toward deep burial of spent nuclear fuel. Each seeking less than a tenth of the capacity of Yucca Mountain, these countries chose a more expensive copper outer shell for waste canisters (in Sweden the shell is about two inches thick). Because copper is stable over geologic time in the reducing environments in these countries' prospective repositories, they have more confidence in the long-term isolation of radioactivity. Moreover, even at the lower end of the range of thermal conductivity for crystalline rock, the packing density limit for a given closure time is higher than for the type of volcanic tuff at Yucca Mountain. Particularly important is that, unlike in Nevada, the Finnish and Swedish sites under consideration are in locations where the regional population has already become accustomed to the presence of the nuclear industry. Sweden is also planning much larger near-term benefits payments per unit of repository capacity than specified in the United States in the NWPA (*World Nuclear News* 2009). The $240 million allocated by Sweden for enlisting regional community support is, however, still less than 0.3 percent of the total estimated overall cost of Yucca Mountain. With their approaches, both Sweden and Finland have encountered little regional resistance and scientific controversy over their repository plans when compared with the U.S. debate over Yucca Mountain.

QUESTION 4A. Should the benefits allowed for states or Indian tribes in Subtitle F of Title I of the NWPA be revised, and, if so, how?

QUESTION 4B. Should such a revision no longer single out Nevada as the only host for the first geologic repository?

Waste Management Payments

The NWPA mandates that a fee of 1 mill ($0.001) per kilowatt-hour ($1/MWhe) be paid to the U.S. Treasury to relieve the "person" that generated spent fuel from obligation for long-term management [Title III, Sec. 302 (a) (3)]. Unlike reactor decommissioning funds which go into escrow, the $1/MWhe effectively vanishes except for a promise, so far not kept, that the federal government will take over spent fuel management. According to the January 2009 issue of *Nuclear News,* "The DOE currently has an $11-billion liability associated with its delay in accepting spent fuel from utilities, as was made a contractual obligation under the NWPA. (The current liability assumes that the operation

TABLE 2.4 Finnish, Swedish, and U.S. Repositories

Country	Capacity (MTHM)	Above water table?	Oxidizing?	Envelope	Rock	Near reactors?	Earliest start
Finland	6,500	No	Reducing	Copper	Crystalline	Yes	2020
Sweden	9,300	No	Reducing	Copper	Crystalline	Yes	2017
USA	70,000	Yes	Oxidizing	Nickel alloy	Volcanic	No	2020

Sources: International Atomic Energy Agency, "Geological Disposal ofRadioactive Waste: Technological Implications for Retrievability," Technical Report NW-T-1.19, 2009; Norbert Rampe, "Permanent Undergound Repositories for Radioactive Waste," *Progress in Nuclear Energy* 49 (2007): 365; Robert Vandenbosch and Sussane Vandenbosch, "The Revised Radiation Protection Standards for the Yucca Mountain Nuclear Waste Repository," *APS Physics and Society* (2009), http://www.aps.org/units/fps/newsletters/200901/vandenbosch.cfm.

Note: MTHM = metric tons of heavy metals. Current U.S. requirements as set by the Environmental Protection Agency and federal law place limits on exposures to a single individual from unreprocessed spent nuclear fuel as a result of releases into groundwater. Those limits are 100 millirem per year (that is, less than minimum background exposure) for a million years and 15 millirem per year for the first 10,000 years. The Waste Isolation Pilot Plant (WIPP) in New Mexico is a salt formation licensed to start taking transuranic defense wastes and isolate them for 10,000 years. WIPP is not licensed to accept unreprocessed spent nuclear fuel.

of the Yucca Mountain repository would begin in 2020.)" (ANS 2009).

Without any change to the status quo, total legal fees associated with a continuing stream of lawsuits over DOE take-title obligations may cost billions of dollars.

QUESTION 5A. Should some or all of the charges for long-term waste management be administered under Nuclear Regulatory Commission guidelines in a manner that does not require annual congressional appropriations?

QUESTION 5B. If so, should this approach apply (1) only to new reactor licenses issued after some specified date, (2) also to existing reactors with license extensions issued after a certain date, (3) to all reactors for fuel discharged after a certain date, (4) retroactively, for reactor site owners willing to accept compensating disbursements from the Nuclear Waste Fund, or (5) retroactively, after disbursements from the Nuclear Waste Fund?

QUESTION 5C. Should there, in any case, be provision for possibly adjusting the charge rate from the currently specified face value of $1/MWhe when inflation has substantially eroded the purchasing power of these payments?

QUESTION 5D. Should the reactor owners recover any escrow funds not deemed necessary for long-term management of spent fuel after it is moved to a long-term management facility?

Construction of an underground repository for spent nuclear fuel in Finland (source: Posiva Oy, http://www.posiva.fi/).

3 | Conclusions

It now seems likely that much of U.S. commercial spent fuel will be stored extensively at operating reactor sites. Indeed, often spent fuel may remain at the site of the reactor that produced it as long as that reactor is operating. If so, then removal of the spent fuel becomes part of the overall decommissioning process (for information on the decommissioning of U.S. nuclear power reactors, see USNRC 2008). To ensure that funds for decommissioning are available to reactor owners without requiring legislative appropriations that may or may not be forthcoming when needed, decommissioning funds are set aside in interest-earning escrow accounts. Funds for spent fuel management are currently handled differently from reactor decommissioning funds—a historical legacy of Plans A and B. Plan A considered spent fuel to be a short-term financial asset to be harvested to meet the national goal of establishing a fleet of breeder reactors. Plan B assumed that spent fuel would be shipped out for national management from reactor sites shortly after removal from wet pool storage. Under these plans, the removal of spent fuel from reactor sites was to be handled very differently from reactor decommissioning and was thus at the time considered suitable for a different funding mechanism. This is the historical basis of a situation in which utilities are suing the federal government on a case-by-case basis for access to funds for spent fuel management rather than tapping escrow funds subject to government regulation, which occurs in nuclear power plant decommissioning.

A central conclusion of the March workshop was that the U.S. government should move toward placing spent fuel management charges in escrow funds attached to each commercial electricity production reactor. To avoid an ever-accumulating federal liability, it is particularly important that the shift to escrow fund accumulation is applied to new reactor licenses at the earliest date that avoids disrupting plans already in progress. Such an approach would also be applied to extending operating licenses for nuclear reactors. However, if the initial construction and operating license is issued before this requirement on future license extensions is implemented, then the question arises of whether such a requirement places an undue burden on the licensee. For spent fuel already discharged from reactors, the approach described in Appendix B includes trying to buy out the federal government's obligation to take title to other spent fuel by making transfers into escrow funds. For future spent fuel discharges from reactors with operating licenses and license extensions already approved or well in progress, either optional or compulsory shifts to the escrow fund approach could be used.

Subject to safety regulations, there is a financial incentive for reactor decommissioning to proceed efficiently so that unused escrow fund balances can be recovered. Applying the same principle to spent fuel management funds would give reactor owners an incentive to consolidate spent fuel from inoperative reactor sites with that at sites with operating reactors. The NWPA explicitly allows movements between reactor sites of the same utility, and it has survived a legal challenge when applied to movement of spent fuel within the borders of a state (Thomas Cochran, National Resources Defense Council, personal communication, June 8, 2008). In a few cases, operating reactors with different owners are in the same state that has a shutdown reactor with spent fuel still on a site that has no operating reactors. The consensus was that it is desirable to explicitly allow transfers within a state, even when a different owner is involved.

There are also cases in which a shutdown reactor in one state previously supplied power to a neighboring state. In some such cases, security could be improved while incurring minimal shipping distances for spent fuel if that fuel is moved from a shutdown reactor site in one state to an operating reactor site in an adjacent state. Because operating reactor sites need a full security apparatus to protect fuel in a critical assembly in reactor cores and in wet pools that cannot be drained, the additional cost of securing dry cask storage at such sites is less than it is for maintaining security of dry casks at inoperative reactor sites. Such shipments to neighboring states also minimize the financial and political costs of transporting spent fuel across state lines, requiring only an arrangement between sites in two states and generally minimizing shipping distances. The NWPA makes no distinction between shipments of spent fuel within and between states within one utility, which could be relevant because a number of utilities now operate nuclear reactors in more than one state. Under an escrow fund arrangement, utility ratepayers would eventually benefit from a utility reducing spent fuel management costs through consolidation of spent fuel away from sites that have no operating reactors. Such a strategy might ameliorate resistance from the states to such consolidations, which may also be appropriate from an equity point of view for reactors that historically have supplied consumers in a neighboring state with electricity. It does not appear that any other changes to the NWPA are needed to allow for such possibilities. However, explicitly allowing transfers across state lines between utilities might be more controversial, because it would allow convey greater latitude for nationwide shipments between reactor sites.

Three options were considered at the March workshop for preparing for the transfer of spent fuel away from reactor sites: (1) continuing management by the Department of Energy; (2) setting up a highly regulated corporation for this purpose; or (3) leaving it up to potential host states. On the one hand, it seemed unlikely that Congress would be willing to turn over escrow funds to a government agency if those funds would be accessed outside of the regular appropriations process. On the other hand, it could be problematic to leave it up to the potential host states to take the risk of qualifying a spent fuel management facility in the hope of tapping escrow funds once fuel is shipped to it from other states. This approach might be especially problematic for licensing an underground facility designed to store radioactive materials for thousands of years. The consensus was therefore that Congress should consider setting up a highly regulated corporation to tap escrow funds to prepare for out-of-state shipments of spent fuel.

Within the limited workshop time available, it was not possible to map out the parameters of a new corporation that would deal with longer-term spent fuel management. However, it was possible to contemplate a range of approaches. Under a more extreme approach, such a corporation could take over all of DOE's responsibilities currently funded by annual appropriations from the Nuclear Waste Fund. Under a more minimalist approach, such a corporation would simply be responsible for assigning escrow funds for the preparation of license applications as requested by one or more states volunteering to host a nuclear waste management site. Determining which approach would be most appropriate depends on the mechanism adopted for longer-term management of escrow funds.

The specific approach outlined in Appendix B for long-term management of escrow funds envisions the establishment of a permanent fund for each long-term spent fuel management facility. The balance accumulated in each permanent fund would be determined by the applicable operational requirements of the Nuclear Regulatory Commission and of the Environmental Protection Agency, federal financial stability requirements, *and spent fuel emplacement charges set by the host state*. The required permanent fund balance per unit of spent fuel could be different for a facility designed to hold spent fuel until a decision is made between reprocessing and prompt deep burial and for a facility that would accept radioactive material to be emplaced for permanent burial. The permanent fund balance in each case would have to be large enough to provide for permanent management. Permanent funds would earn interest released to the host state and would retain at a minimum the original principal to sustain interest earnings and insure against unanticipated additional costs. Some of the interest earned on a permanent fund could be reinvested in it, subject to government regulations, if the funds required the meet the costs associated with eventual permanent disposal have to be protected against inflation. Once a long-term spent fuel management facility is established, any additional escrow funds not needed for that purpose would be released to the original owner of the spent fuel.

The logic of the permanent fund approach mirrors that of the permanent funds maintained by Alaska for dealing with revenues from fossil fuel extraction. Similar approaches have been used successfully by Norway and the Canadian province of Alberta. Like the oil resources of Alaska, a suitable long-term spent nuclear fuel management site is in effect a valuable natural energy resource. And as in the extraction of Alaskan oil, the long-term local environmental consequences are borne by the state. Earnings from permanent funds can compensate a state or province for any consequences arising from the pursuit of the national interest (or, in Norway, the mutual interests of a country and its neighboring international trading partners).

More widely, adoption of a permanent fund approach provides a strong incentive for one or more states to cooperate on licensing long-term spent fuel management facilities. Such cooperation could, in turn, open up an opportunity to embrace the least complicated approach to shaping the role of the highly regulated corporation given the task of overseeing the application of escrow funds to preparations for licensing such facilities. Under this approach, the purview of such a corporation would be to assign escrow funds to the designee of a state volunteering to license such a facility. The expenditures for license and site preparation would flow through that designee. This approach would minimize the cost and activities of the oversight corporation. In particular, this approach could help avoid the large expenditures associated with licensing a site over the initial objections of a host state, only to find that fierce resistance precluded efficient utilization of such a site.

For the strategy outlined here, three types of facilities pertinent to longer-term management are of interest: (1) facilities designed for permanent isolation of radioactive materials, (2) spent fuel reprocessing facilities, and (3) facilities designed to secure spent fuel for a long period of time pending a decision between reprocessing and permanent isolation. It was the consensus of workshop participants that at present they could not forecast energy economics well enough to know with a high degree of confidence whether all nuclear reactor discharges will eventually be reprocessed for one or more cycles. There is thus the possibility that all three types of facilities of interest here will be constructed.

There was no consensus on how that part of nuclear fuel cycle research not related to individual facilities licensing should be funded. Some workshop participants felt that the spent fuel management charges should fund such research. Others were concerned that such an arrangement might be an ongoing drain on funds available for escrow without necessarily producing a solution that is actually implemented, and that any such funds should instead be appropriated in the usual way for federal support of research and development.

As for spent fuel reprocessing, there was a consensus that any license for a reprocessing facility should be accompanied by a license for long-term storage of accepted spent fuel and of the reprocessing product streams. Experience has shown that there is no guarantee that a reprocessing facility will operate as planned or that fissile or other radioactive materials from process streams will be moved off-site as anticipated. With adoption of the other recommendations made here, this approach will place reprocessing facilities and nuclear electric power reactors at the same level in that both will be expected to manage high-grade radioactive wastes on-site until overall site decommissioning. This parallel approach avoids a situation in which a reprocessing facility becomes a de facto long-term radioactive waste management facility even though it had never been licensed for such a purpose.

Another possibility is that spent fuel shipped to a facility for permanent isolation will not be successfully emplaced as originally planned. The prospects for successful operation of a deep underground isolation facility to contain fission products could be substantially enhanced by allowing before emplacement the decay for well over two half-lives of strontium-90 and cesium-137.[1] Even if the existing Yucca Mountain license application were approved, it might be desirable to revise procedures at the approved repository site to allow explicitly for this period of aging of most or all spent fuel before emplacement.

The push for prompt emplacement of spent fuel inside Yucca Mountain was driven by two considerations. First, the federal obligation to take title promptly to spent fuel was an imperative for prompt shipment to the facility. Second, there was a concern that, otherwise, Nevada would be forced to host a long-term spent fuel aging facility without the assurance that permanent isolation would actually be accomplished. The changes suggested here would relieve both of these concerns. The obligation of the federal government to take title promptly to spent fuel could be eliminated. If Nevada or any other state taking in spent fuel from out of state were compensated by transfers to a permanent fund that the state had considerable latitude to determine, the question of forcing a "bait and switch" conversion from deep burial to a long-term aging facility would become moot. In such a new environment, the technological benefits of extensive aging of spent fuel that is passively convectively cooled would no longer be trumped by political imperatives that would lead to a more costly and technologically uncertain approach.

[1] The half-lives of these and other isotopes particularly important for medium- to long-term spent nuclear fuel management are listed in Table 2.1. Entries in the last column of the table indicate that not allowing for prior aging of Sr-90 and Cs-137 initially forces active convective cooling of an underground repository with the configuration of Yucca Mountain. Moreover, if such a repository is sealed as anticipated after 300 years, then the packing density limit is limited by decay heat from Am-241.

The considerations just outlined also suggest revamping how government-operated monitored retrievable storage facilities and private fuel storage facilities are viewed. Within the context described here, such facilities are not necessarily limited to short- and medium-term operations with tightly limited capacities; they also could include facilities for longer-term aging designed to simplify eventual reprocessing or permanent isolation. Future generations would therefore make the decisions on how many rounds of reprocessing, if any, will be undertaken before permanent isolation of the remaining radioactive materials. It is quite possible that, benefitting from a much larger knowledge base, future generations will periodically examine spent fuel aging facilities and determine whether reprocessing, permanent isolation, or further aging is appropriate. Licensing requirements for such facilities should thus be consistent with this possibility.

It is also possible that future generations will develop and extensively deploy nuclear fuel cycle technology in the United States that favors maximizing utilization of all plutonium isotopes. Such an approach could require reprocessing spent fuel at a time after reactor discharge that is less than the 14.4-year half-life for plutonium-241 decay, leading to formation of americium-241. Until such technology is widely deployed in the United States, however, most spent fuel from U.S. reactors will be aged well beyond the half-life of plutonium-241 before the time, if ever, the spent fuel is reprocessed. If properly encased, the longer such fuel is left to decay, the more easily it can be handled for any purpose.

No one can predict with confidence what future generations will decide about spent nuclear fuel management. Even if 63,000 metric tons of heavy metal and associated fission products from commercial reactors were buried over the next few decades in a Yucca Mountain facility designed to isolate them for a million years, it could well be that over the next few centuries this facility would become an economically attractive source of fissile materials, which are then dug up again. However, suppose the previous presidential administration had successfully initiated construction of reprocessing facilities and liquid sodium–cooled reactors aimed at burning out the americium-241 that limits spent fuel emplacement densities in the approach adopted for the Yucca Mountain site license application. By the time (perhaps even in the next century) such a system of actinide burning would have approached equilibrium operation, it might have long been abandoned by future generations as uneconomic.

What this generation can do is to preserve future generations' options for spent nuclear fuel management by setting up the flexible institutional framework recommended here. At the same time, the immediate problems generated by the previous dysfunctional approaches could be avoided. One potentially useful component of a flexible institutional framework is allowing for the possibility that facilities intended to take in spent nuclear fuel from out of state are licensed but are used below capacity, or even not at all. For example, the approach outlined in Appendix B could be configured so that a state is allowed to require payments into a permanent fund that will long exceed the cost of dry cask storage of spent fuel at reactor sites.

At a U.S. Senate Energy and Natural Resources Committee hearing on March 5, 2009, DOE secretary Steven Chu responded affirmatively to a question of whether a DOE spokesperson had said that he and the president "have been emphatic that nuclear waste storage at Yucca Mountain is not an option" (U.S. Senate Energy and Natural Resources Committee 2009). Even if the process mandated in existing legislation leads to licensing the Yucca Mountain facility or the process is effectively revived by a future federal administration, the approach outlined here would give Nevada the option of requiring large enough payments into a permanent fund that no utility would actually ship spent fuel to Yucca Mountain in the foreseeable future. Nevada could then choose to negotiate with the federal government a trial program to take predominantly shorter-lived defense waste fission products—for example, if high-level waste vitrification at the Hanford site is completed by 2028, as the state of Washington was promised in 2003 (Washington State Department of Ecology et al. 2003). Alternatively, Nevada could simply hold Yucca Mountain inoperative as a future revenue source.

Similar considerations apply to other sites that might take in spent nuclear fuel from out of state. One option is for federal legislation to constrain the state offering to receive spent fuel to an upper limit on required payments to a permanent fund that is low enough to eventually attract shipments of spent nuclear fuel from out of the state, but high enough to make such shipments economically unattractive in the near term. Such an approach may satisfy legal requirements for the existence of a long-term spent fuel solution, but without forcing states to take in spent fuel on terms they currently find unacceptable.

Although the approach outlined here may be an attractive solution to the spent nuclear fuel management conundrum, the thorny question of how to time its implementation remains. One pivotal point is determining the date on which reactor operating licenses would begin to require that payments for spent fuel management go to escrow funds instead of to the U.S. Treasury, thereby relieving the federal government of the obligation to take title promptly after spent fuel is discharged from wet pool storage. Until that date, the federal government would continue to accrue liability for taking title to spent fuel discharged from all commercial nuclear electricity production reactors. Once such a date and the corresponding implementation procedures are established, the federal government could start formulating arrangements for sending other new spent fuel management charges to escrow funds rather than to the federal Treasury. Concomitantly, Congress could approve appropriations as needed to allow escrow funds to be set up for previously discharged spent fuel insofar as arrangements with owners can be made, thereby relieving the government of liability for taking title to such spent fuel.

A second pivotal point is when a corporation might be established to manage escrow funds beyond those needed to set up and maintain dry cask storage of spent nuclear fuel at reactor sites. Setting up such a corporation is more complicated than simply enacting the kinds of legislative changes outlined in Appendix B. There is, however, no need to establish such a corporation coincidentally with enacting such legislative changes. Escrow funds can continue to accumulate while the appropriate configuration and mandate for such a corporation are being considered. In the meantime, with adequate appropriations the Department of Energy will have the option of pursuing the licensing of one or more new facilities for spent nuclear fuel management, aided by a better understanding of the context in which such facilities would be operating.

In summary, this chapter has described the broad-based consensus reached at the March 2009 workshop on the outlines of a revised U.S. approach to the management of spent nuclear fuel. This approach addresses the immediate problem of regularizing ongoing dry cask storage at reactor sites and lays out a suitably flexible foundation for choosing appropriate solutions for eventual shipments of spent nuclear fuel out of the state in which it was generated. Chapter 4 presents more detailed answers to the ten questions posed in Chapter 2.

4 | Answers to the Questions Posed

The following answers to the questions posed in Chapter 2 flow from the conclusions described in Chapter 3.

QUESTION 1. Should the NWPA be revised to explicitly allow transshipment of fuel from one utility's reactor site to another utility's reactor site within the same state?

Consolidation of spent fuel at active reactor sites in close proximity could reduce costs while minimizing transportation distances and the political difficulty of moving spent fuel between states. Thus if amending legislation would resolve any legal question about whether shipments to any active reactor site within a state are allowed, it would be advantageous to do so.

QUESTION 2. In Subtitle C of Title I of the NWPA, should the capacity limits for a government MRS facility be changed, or are they adequate to allow longer-term storage in a private facility?

Using the approach suggested here, there would be no need in the near term to use escrow funds to create a monitored retrievable storage facility with a capacity greater than the current limit of 10,000 metric tons of heavy metal, because the process of storing and consolidating spent fuel at operating commercial reactor sites within the states where it was generated would be regularized. Moreover, nuclear reactor discharges from defense programs and reprocessed radioactive materials that are neither suitable for emplacement in the Waste Isolation Pilot Plant in New Mexico nor programmed for near-term fabrication into reactor fuels will likely be stored for aging at existing government facilities if the Yucca Mountain facility fails to take such materials. The Department of Energy may want to consolidate these materials at fewer sites and consider following a permanent fund approach if doing so requires changing previous understandings with states about where such materials are already stored or their new location. Absent a long-term storage option other than at the locations listed in Table 2.3 that are currently holding high-level defense wastes, the federal government may have to pay damages pursuant to the existing agreements with states where such wastes remain. The adoption of a permanent fund approach to consolidating at least some defense wastes and fewer sites is one possible way in which the federal government could deal with this problem.

Far less than 10,000 metric tons of spent fuel are stranded at shutdown reactor sites in states without operating commercial reactors that produce electric power, and that is likely to remain the situation for decades to come. Thus the potentially controversial question of whether the current MRS capacity limits for storage of fuel to which the federal government is obligated to take title does not have to be addressed for quite some time. However, it might be useful to clarify that escrow funds could be used to transfer spent fuel to a private fuel storage facility, which would then require an associated permanent fund balance adequate to support the eventual transfer of radioactive materials to longer-term isolation.

QUESTION 3A. Should licenses for reprocessing facilities be required to include provisions for long-term management of spent fuel and reprocessed materials, and, if so, should any limits be put on their intake of spent nuclear fuel?

If licenses for reprocessing facilities are not required to include fully preapproved and funded provisions for long-term management of spent fuel and reprocessed materials, then there is a danger that spent nuclear fuel or reprocessing streams material derived from it may become stranded at a facility not adequately licensed to manage either over the long term. An advantage of combining a spent fuel aging facility and reprocessing facility if a reprocessing facility is indeed ever built is that such a facility could alleviate the need for multiple transfers of spent fuel destined for reprocessing. If this approach is taken, then the aging facility should be licensed for at least full lifetime reprocessing capacity, which could be quite large if reprocessing is carried out at such a facility without a defined sunset horizon.

QUESTION 3B. Should licenses for geologic repositories be explicitly allowed provisions for long-term management of spent fuel before deep burial, and, if so, should any limits be put on their intake of spent nuclear fuel?

The longer spent fuel is aged, the easier it is to pack at high density in an underground repository that will not be convectively cooled well beyond the 432-year half-life of americium-241. Unless licenses for spent fuel repositories allow aging before emplacement of the full capacity of the repository, an additional cost burden may be created. Depending on progress toward licensing another repository or reprocessing facility and on its expected location, it may or may not be desirable to also allow the aging at one repository of spent fuel that is destined for eventual shipment elsewhere.

QUESTION 4A. Should the benefits allowed for states or Indian tribes in Subtitle F of Title I of the NWPA be revised, and, if so, how?

The current disparity between the benefits to states of contributing to national energy supplies through fossil fuels versus nuclear fuel cycle services has generated fierce, and to date effective, political opposition to siting spent nuclear fuel management facilities. Thus the benefits provisions of the NWPA may have to be revised for pragmatic reasons, despite different views of what is appropriate from an equity perspective. States with facilities designed for final disposal of radioactive materials from spent nuclear fuel, whether from out of state or from their own nuclear reactors, might be allowed to require payments into a permanent fund. If a maximum payment rate is specified, the maximum should be high enough to allow a host state to delay imports of spent nuclear fuel until one or more rounds of reactor decommissioning make emplacement for permanent isolation substantially more cost-effective than is presently the case. This approach will allow time for the host states to take advantage of a growing knowledge base and to gain distance from the current political impasse when making decisions. If attempts are made to bypass the interests of a state by making agreements with an Indian tribe, or if an Indian tribe is substantially affected by a proposed spent fuel management site, an agreement between the state and the tribe would be needed before proceeding.

QUESTION 4B. Should such a revision no longer single out Nevada as the only host for the first geologic repository?

If the recommendations made here are adopted, Nevada would be treated no differently than any other state. The submission of the Yucca Mountain site application to the Nuclear Regulatory Commission has, in any case, made many of the provisions of the NWPA specific to Nevada already obsolete.

QUESTION 5A. Should some or all of the charge for long-term waste management be administered under Nuclear Regulatory Commission guidelines in a manner that does not require annual congressional appropriations?

The establishment of escrow funds for as much spent nuclear fuel as possible should be pursued expeditiously if the advantages of the approach outlined here are to be realized. Suitably regulated, this approach will produce the financial incentives that have been lacking for the efficient management of spent nuclear fuel. Reviews by the Environmental Protection Agency and federal regulation of escrow fund management will be needed as well.

QUESTION 5B. If so, should this approach apply (1) only to new reactor licenses issued after some specified date, (2) also to existing reactors with license extensions issued after a certain date, (3) to all reactors for fuel discharged after a certain date, (4) retroactively, for reactor site owners willing to accept compensating disbursements from the Nuclear Waste Fund, or (5) retroactively, after disbursements from the Nuclear Waste Fund?

Gathering escrow funds for the management of fuel discharged from nuclear reactors in the future would begin as soon as possible without delaying the progress of license applications submitted by a deadline established close to the enactment of this requirement. By the time such a requirement is in place, there would probably be a limited number of applications for extending the operating licenses of reactors in operation as of 2010. However, applying such a provision to as many future operating license extensions as possible could also be considered, particularly for reactors not yet in service. This approach will at least ensure that federal liability for spent nuclear fuel management will not continue to accumulate beyond mid-century. The legal implications of shifting to escrow funds for all commercial spent fuel discharges produced after some earlier future date should be examined to determine whether such a step is practical. The federal government could negotiate a plan for shifting spent nuclear fuel payments and the nominal accumulated interest into escrow funds in order to avoid continuing contested legal actions. Requiring such retroactive adjustments could be legally complex and would likely be considered only as a last resort.

QUESTION 5C. Should there, in any case, be provision for possibly adjusting the charge rate from the currently specified face value of $1/MWhe when inflation has substantially eroded the purchasing power of these payments?

The approach suggested here should be far less expensive than either prompt deep burial or near-term reprocessing. As long as inflation-adjusted interest rates remain positive on average, escrow fund balances for spent fuel stored in dry casks at reactor sites will continue to grow. Meanwhile, the inventories of strontium-90 and cesisum-137 that are the most troublesome for about a century after discharge from wet pool storage will continue to decay. The current $1/MWhe charge would thus remain adequate in the face of inflation for much longer than it otherwise would. However, if the intention is to provide a durable long-term solution, it would be useful to set up a more robust mechanism than in the current NWPA for reviewing the adequacy of this charge and raising it periodically in face value terms once it is determined to be inadequate. Congress would, of course, retain the ability to review any such adjustments and to enact modifications.

QUESTION 5D. Should the reactor owners recover any escrow funds not deemed necessary for long-term management of spent fuel after it is moved to a long-term management facility?

As just noted, the $1/MWhe charge for newly discharged spent fuel should be more than adequate for a long time if the approach outlined here is adopted. Allowing utilities to recover escrow fund balances in excess of what is needed for longer-term management should be a useful incentive for moving to such management when it is economically favorable.

A technician watches the placement of defense-related transuranic radioactive waste at the Department of Energy's Waste Isolation Pilot Plant (source: US Dept. of Energy, http://www.wipp.energy.gov/).

Appendix A |Contributors to Workshops

JUNE 6, 2008, WORKSHOP

American Association for the Advancement of Science Center for Science, Technology, and Security Policy (CSTSP), Washington, D.C.

The following people contributed to the CSTSP workshop by either attending or participating in email correspondence exchanges about the materials discussed. The June 6 workshop did not forge a consensus, and the conclusions drawn in this report should not be construed as being either consistent or inconsistent with the views of the contributors. Rather, each contributor provided valuable background information that was relayed to the workshop held on March 16, 2009.

Robert Alvarez, Institute for Policy Studies
Thomas Cochran, National Resources Defense Council
Steve Fetter, University of Maryland
Victor Gilinsky, formerly at the U.S. Nuclear Regulatory Commission
Allison McFarlane, George Mason University
Ivan Oelrich, Federation of American Scientists
Clifford E. Singer, University of Illinois at Urbana-Champaign
Henry Sokolski, Nonproliferation Education Center
Benn Tannenbaum, AAAS Center for Science, Technology, and Security Policy
Leonor Tomero, Center for Arms Control and Nonproliferation, Council for a Livable World
Frank von Hippel, Princeton University

MARCH 16, 2009, WORKSHOP

University of Illinois at Urbana-Champaign Program in Arms Control, Disarmament, and International Security

Daniel B. Bullen is a senior managing engineer at Illinois Exponent Failure Analysis Associates. Prior to his involvement with Exponent, Bullen was an associate professor of mechanical engineering at Iowa State University. At Iowa State, he was the Nuclear Engineering Program coordinator and director of the UTR-10 Nuclear Reactor Laboratory. Bullen was also appointed to two terms as a member of the U.S. Nuclear Waste Technical Review Board.

Carlos Henry Castano is an assistant professor in the Department of Mining and Nuclear Engineering at the Missouri University of Science and Technology. His research areas include the study of alternative energy sources and their effects on the environment and the study of hydrogen in materials.

Rodney Ewing is the Donald R. Peacor Professor in the Department of Geological Sciences and professor in the Department of Nuclear Engineering and Radiological Sciences and in the Department of Materials Science and Engineering at the University of Michigan. He has published on environmental mineralogy, radioactive waste management, radiation effects, and electron microscopy.

Audeen Fentiman is a professor in the Department of Nuclear Engineering and associate dean of engineering for Graduate Education and Interdisciplinary Programs at Purdue University. Her research interests include radioactive waste management, nuclear fuel cycle, environmental risk assessment, and engineering education. She previously served as senior engineer in the Systems Engineering Department in the Office of Nuclear Waste Isolation.

Colin Flint is the director of the Program in Arms Control, Disarmament, and International Security and associate professor in the Department of Geography at the University of Illinois at Urbana-Champaign. His current research interests include the geographic elements of terrorism, war and peace, American hegemony, and the Arab world. Flint has served as president of the Political Geography Specialty Group within the Association of American Geographers and has served on the editorial boards of *Political Geography* and *Professional Geographer*.

Carolyn Heising is a professor in the Department of Industrial and Manufacturing Systems Engineering at Iowa State University–Ames. Heising is a leading scholar on nuclear power plant safety, condition monitoring, and predictive maintenance. She is also a co-principal investigator on the ISU NSF ADVANCE grant that aims to advance the careers of women in the fields of science, technology, engineering, and mathematics. Heising previously served as chair of the Women in Academia committee of the Society of Women Engineers.

William Martin is the chair of and professor in the Department Nuclear Engineering and Radiological Sciences at the University of Michigan at Ann Arbor. His research interests include the development of numerical methods for solving the Botlzmann transport equation, development of computational methods for the solution of neutron transport problems, and reactor core analysis and thermal hydraulics. He was made a Fellow of the American Nuclear Society in 1995.

Matthew Rosenstein is the associate director of the Program in Arms Control, Disarmament, and International Security (ACDIS) at the University of Illinois at Urbana-Champaign. His areas of expertise include regional security and politics and militancy in South Asia and Russian culture and society. Rosenstein is editor of the ACDIS *Occasional Paper* series and the journal *Swords and Ploughshares*.

William R. Roy is a senior geochemist at the Illinois State Geological Survey and adjunct professor in the Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois at Urbana-Champaign. His research interests include geochemistry and soil chemistry, carbon sequestration, and radioactive waste management. Roy has served on the editorial boards of the *Journal of Environmental Quality* and S*oil Science Society of America Journal*.

Clifford E. Singer is a professor in the Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois at Urbana-Champaign. In 2008 Singer published *Energy and International War: From Babylon to Baghdad and Beyond*. He is former director of the Program in Arms Control, Disarmament, and International Security at the University of Illinois at Urbana-Champaign and is currently a co-director of the College of Engineering's Initiative on Energy and Sustainability Engineering. Singer has also served as chair of the Champaign County Intergovernmental Solid Waste Disposal Association.

James F. Stubbins is department head and professor in the Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois at Urbana-Champaign. In 2004 Stubbins was named International Scientist of the Year by the International Biographical Centre and in 2007 became a fellow of the American Nuclear Society. His research interests include irradiation damage and effects, mechanical properties, high-temperature corrosion and stress corrosion cracking, and electron microscopy.

Rusi P. Taleyarkhan is a professor of nuclear engineering at Purdue University. His research interests include nano- to macro-scale applications of nuclear science, acoustic inertial confinement fusion energy, advanced energetic materials, and propulsion.

Robert V. Tompson Jr. is an associate professor in the Department of Nuclear Engineering in the Nuclear Science and Engineering Institute at the University of Missouri at Columbia. His research interests include rarefied gas dynamics, aerosol mechanics, materials science and engineering, laser applications, biomedical engineering, and health physics.

Paul P. H. Wilson is an associate professor in the Department of Engineering Physics at the University of Wisconsin–Madison. He is also a faculty member in the Computational Nuclear Engineering Research Group (CNERG) at the University of Wisconsin–Madison. CNERG focuses on nuclear energy systems and fuel cycle concepts. Wilson was a Euratom Fellow at the Institute for Neutron Physics and Reactor Engineering at the Karlsruhe Research Center in Germany.

Appendix B | Revising Spent Nuclear Fuel Legislation

Plan D for U.S. spent fuel produced at U.S. nuclear reactors would normally consist of keeping the fuel on-site until the entire site is decommissioned.[2] After decommission, the spent fuel would either be sent to another storage site, reprocessed to recover the remaining usable fuel, or buried under the assumption that it will probably never be reprocessed. The document that makes up this appendix is a first attempt at an "existence proof" of the possibility of amending the Nuclear Waste Policy Act of 1982 (NWPA) as amended to implement this plan. The goal is not to provide either complete or optimal legislative language, but rather to illustrate the outcome of a paragraph-by-paragraph examination of the NWPA to identify what aspects of the current legislation would have to be changed to actually implement a Plan D. Three possibilities for changes are identified—two major changes and one set of minor changes:

1. Establish a permanent fund, similar to the Alaska Permanent Fund for fossil fuel revenues, associated with each geologic repository and any monitored retrievable storage facility that takes in spent nuclear fuel from out of state. Subject to Nuclear Regulatory Commission (NRC) regulations, each state housing such a facility would have unrestricted access to interest earnings on the associated permanent fund in excess of those required to complete the construction and to ensure safe and secure operation of the facility.
2. Establish an escrow fund associated with the spent fuel from each nuclear reactor. After the Yucca Mountain site application is either approved or abandoned, funds from the Nuclear Waste Fund would be allocated to escrow funds as needed to relieve the U.S. government of the responsibility of taking title to spent nuclear fuel so that it can avoid losing more lawsuits over the take title issue. Further payments would be made into each escrow fund instead of into the Nuclear Waste Fund. When spent fuel is shipped to a monitored retrievable storage facility or depository, funds not required to be paid from the relevant escrow fund to the relevant permanent fund would be available without restriction to the party relinquishing title to the spent nuclear fuel. Until that time, that party would retain title to the spent fuel and could withdraw from the escrow fund the monies needed for management of dry cask storage as approved by the NRC.
3. Remove various provisions of the NWPA of 1982 requiring DOE to promptly take title to spent nuclear fuel and move it to Yucca Mountain. Instead, a market-driven system would allow each reactor owner to make economically optimal decisions about storage of removals from spent fuel storage ponds on-site in dry casks. Dry cask storage may be available at other reactor sites in the same state, at an out-of-state site in case no nuclear power reactors are operating in the state, or at a repository. Spent nuclear fuel could not be shipped to a reprocessing facility until it is first placed in a licensed monitored retrievable storage facility on the same site so that spent fuel or high-level reprocessing wastes are not stranded at a reprocessing facility that failed to operate as expected.

The intention here is to outline a system that could resolve the U.S. spent nuclear fuel management dilemma for the rest of the century without congressional involvement. The changes described here would also provide the basis for a market-driven system for managing spent nuclear fuel in the longer term, with the federal government reverting to its role of regulating the system to ensure safety, security, and financial responsibility. States would be allowed to require payments into their permanent funds up to a specified maximum per unit quantity of spent fuel, thereby applying their own views of the balance between the diseconomies and benefits of hosting a nuclear waste facility.

Overview

The starting point for this analysis is the NWPA of 1982, including amendments through 2004 aimed at limiting options for storage of spent nuclear fuel other than at the Yucca Mountain site. Three problems with this approach have emerged: regulatory, political, and temporal. The regulatory problem is a mismatch between the underground oxidizing atmosphere of the Yucca Mountain site and what evolved into limits on release of radioactive materials for a million years. It is much harder to qualify containment materials for oxidizing than reducing environments, but amendments to the NWPA of 1982 restricted the initial

[2] Plan A was to recover plutonium from spent fuel for use in breeder reactors. Plan B, adopted during the Carter administration, was to promptly bury spent fuel at Yucca Mountain and then in a second deep repository. And Plan C was to repeatedly burn plutonium and heavier elements in liquid sodium–cooled reactors without breeding.

Appendix B was provided on March 3, 2009, by Clifford E. Singer (csinger@uiuc.edu), Department of Nuclear, Plasma, and Radiological Engineering and Department of Political Science, University of Illinois at Urbana-Champaign.

search for a repository site to Yucca Mountain. The political problem is that the payments to Nevada under the benefits agreement section of the NWPA are a minute fraction of the total cost of the project, a situation that has helped generate fierce opposition from Nevada and whatever allies it can find. The temporal problem is that U.S. generation of spent nuclear fuel is already at about the 70,000 metric ton limit on the quantity of shipments of heavy metal in spent fuel to Yucca Mountain before opening a second repository. Even without this legislative limit, significant physical limits would be imposed in this century on the Yucca Mountain storage capacity because of the limited size of the mountain ridge, its history of seismic activity, and the fact that its volcanic tuff rock has about half of the thermal conductivity of crystalline rock used, for example, in Finland. Resolving these difficulties would require amending the NWPA to halt putting "all of the eggs in the Yucca Mountain basket."

It is neither technically necessary nor politically feasible to site two repositories in the next few years or to try to force into Yucca Mountain all of the long-lived radioactive material from U.S. spent nuclear fuel generated in this century. From a technical point of view, spent nuclear fuel removed from storage pools at reactor sites can be stored most safely and economically for extended periods in dry casks where generated or at a nearby operating reactor site. If adopted by each state with operating nuclear reactors, this approach could minimize occupational exposures and transportation hazards and costs, as well as reduce political opposition to moving spent fuel great distances before the most troublesome fission products have largely decayed away. Because each operating reactor must, in any case, safely manage much more dangerous radioactive material in operating reactor cores and spent fuel storage pools, the additional cost of safely and securely storing dry cask materials on-site is minimal as long as spent fuel also remains on-site underwater in storage pools.

Until it becomes clear that states that currently have or will construct nuclear power reactors will shut them down and remove all spent fuel from storage pools, the Plan D approach of using dry casks on-site as the primary storage medium should be tenable, provided the NWPA is amended to make this approach feasible and give it the economic attractiveness it would have in a market-driven system. However, because considerable groundwork has been laid for eventual away-from-reactor storage, it may also be worth preserving options for siting away from reactor storage facilities for the longer-term management of spent nuclear fuel. The "straw man" amendments to the NWPA outlined here attempt to accomplish both of these feats.

Permanent Funds

Payments of 1 mill ($0.001) per kilowatt-hour ($1/MWhe) of nuclear electric power generation into the Nuclear Waste Fund specified by the NWPA are based on the idea that the federal government will successfully take over the management of spent nuclear fuel on a permanent basis. However, because Congress must appropriate annually any reimbursements of costs to be paid from the Nuclear Waste Fund, in effect payments into the NWPA simply vanish and reappear only when the political process deems it appropriate. As a result, there is neither an opportunity nor an incentive for the private sector or states to cooperate with federal plans for spent nuclear fuel management. The approach adopted here of a permanent fund associated with each spent fuel repository and managed retrievable storage facility would change this dynamic. The principal payments into the permanent fund would remain the basis of income for paying off the costs of construction and operation of such facilities. Interest earnings on the principal in excess of such costs would be available without restriction to the host state (subject to an agreement with any affected Indian tribe). This arrangement could provide a state with a substantial incentive to host such a facility and to have it managed efficiently subject to federal regulations on safety and security.

The NRC would set minimum payments per kilogram of heavy metal into a permanent fund. The amendments outlined here also specify a maximum payment in order to avoid a situation in which a state obtains a monopoly on long-term storage capacity and then exploits that monopoly with extremely high payment requirements during the extensive period of time required for another state to obtain a license for a competing facility. The value of the maximum payment per kilogram of heavy metal into a permanent fund would be set by Congress. In effect, this would involve negotiations between members of Congress from prospective host states and members from non-host states. Too low a value will elicit stiff resistance from prospective host states and reduce the longer-term prospects for successful facility siting. Too high a value will arouse resistance from prospective spent nuclear fuel shippers and also reduce the prospects for successful facility siting.

The idea of a permanent fund is based on an analogy with another energy source that has a potentially long-term environmental impact: Alaskan oil. Like Alaskan oil, the sites of long-term spent nuclear fuel management are in effect a national energy resource. And like the extraction of oil from permafrost areas, the establishment of long-term spent nuclear fuel management facilities requires careful management of environmental impacts. Just as residents of Alaska have decided to set up a permanent fund with earnings to compensate future generations of Alaskans for bearing the brunt of such environmental impacts, so too could the residents of a state hosting a spent nuclear fuel management facility. A "straw man" version of some of the language that could allow the establishment of such permanent funds appears in Box B.1.

Escrow Funds

The payments into permanent funds per kilogram of heavy metal require a funding source. Under the approach described here, the escrow funds associated with the spent nuclear fuel produced by each nuclear reactor serve as the source of these payments. Once an agreement is reached to relieve the federal government of its responsibility to expeditiously take title to spent nuclear fuel, escrow funds could also be used to meet the costs of dry cask storage at reactor sites without the need to petition the Department of Energy or sue the federal government. On a per kilogram of heavy metal basis, excess escrow funds would be available to the party shipping the fuel to a monitored retrievable storage facility or repository. Such an arrangement would provide financial incentives for utilities both to enter into agreements with the Department of Energy to retain title to spent nuclear fuel and to ship fuel to longer-term storage instead of keeping it at decommissioned reactor sites indefinitely.

The basic idea behind the escrow and permanent funds is to relegate the U.S. government to a regulatory role and get it out of the business of directly managing the funds required for spent nuclear fuel management. To ensure that this scenario does become a reality eventually, the straw man amendment language presented in Box B.2 specifies that there will be dates beyond which all new reactor licensees and all reactor owners seeking operating license extensions will have escrow fund agreements with the federal government. Each such license would then require a viable physical and fiscal management plan that allows the option of storing spent nuclear fuel from each reactor at the reactor site at least until all the fuel from that reactor is removed from storage pools. For replacements for the current U.S. reactor fleet, this arrangement should provide a safe and economically attractive spent fuel management strategy beyond the end of this century. Because interest would accrue on the escrow funds, barring long-term real negative returns to investment, the escrow funds should remain sufficient indefinitely to provide the required eventual payments into the permanent funds.

Upon establishment of each escrow fund, payments previously made to the Nuclear Waste Fund would be redirected to the escrow fund. Because the intention here is to relieve Congress indefinitely of the need to address spent nuclear fuel management if it so chooses, provision is made for eventual inflation adjustment of the 1 mill per kilowatt-hour. However, in the near term increasing this level of payment is unlikely to be necessary, because the approach adopted here will be considerably less expensive than prompt "permanent" burial or reprocessing after accounting for the interest earnings on the escrow funds. Thus the date at which inflation adjusting will begin is left open for negotiation. The provision in the existing NWPA for an annual review of the payment level and adjustment by Congress is left intact, but Congress is not expected to ever act on this provision. The maximum for required payments to a permanent fund per kilogram of heavy metal upon shipments to monitored retrievable storage or a repository would also be adjusted for inflation; otherwise Congress would eventually have to intervene to adjust this limit.

To encourage the federal government to exit from direct financial control of spent nuclear fuel management sooner

BOX B.1 Permanent Funds

Straw man amendments to the Nuclear Waste Policy Act

Sec. 176.

(a) In general.

(1) The Secretary may enter into a benefits agreement with a State concerning a repository or a monitored retrievable storage facility for the acceptance of high-level radioactive waste or spent nuclear fuel in that State that requires the establishment of a State Spent Nuclear Fuel Management Permanent Fund.

(2) Any affected Indian Tribe must be a party to any benefits agreement that requires the establishment of a Permanent Fund.

(3) There shall be a separate Permanent Fund for each licensed repository and each licensed monitored retrievable storage facility.

(4) Payments to each Permanent Fund shall be per kilogram of heavy metal entering into a State and shall be due no later than the time of entry.

(A) The maximum payment into a Permanent Fund per kilogram of heavy metal required under the laws of a State shall be (insert number) on (insert date), adjusted annually each year thereafter by (insert inflation adjustment description).

(B) A schedule for the minimum payment into a Permanent Fund per kilogram of heavy metal shall be approved by the Commission upon facility licensing, taking into consideration costs of—

(i) Facility construction and debt service

(ii) Facility operation and administration

(iii) Facility closure or decommissioning

(iv) Site monitoring after closure or decommissioning

(5) Each Permanent Fund shall maintain a balance equal to the total of per kilogram payments it receives, except that the per kilogram payments for amounts of heavy metal received shall be made to the recipient thereof for each kilogram of heavy metal removed from the State.

(6) Each Permanent Fund shall be invested in obligations of the United States having maturities determined by the Secretary of the Treasury to be appropriate to the needs of the Permanent Fund.

(7) Except as required under paragraph (4)(B), the interest earnings on each State Spent Nuclear Fuel Management Permanent Fund shall be available without restriction for use by the corresponding State in a manner compatible with any agreement between such State and an affected Indian Tribe.

rather than later, the straw man amendments listed in Box B.2 require the secretary of energy to offer to enter into agreements to distribute the balance of the Nuclear Waste Fund to escrow funds, except the small portion needed to provide for management of high-level radioactive waste from commercial reactor fuel already reprocessed. Because the Yucca Mountain site application process has already been submitted to the NRC and because its review must proceed until Congress intervenes, this requirement about the secretary of energy does not come into force until the Yucca Mountain site is either licensed or withdrawn from consideration. In any case, several years of preparation would likely be necessary to undertake the needed financial arrangements. The escrow funds and permanent funds must be invested in obligations of the United States. Until (in the distant future) spent fuel is shipped to facilities covered by the permanent funds, the escrow funds will not be used except for management of dry cask storage, which

BOX B.2 Escrow Funds

Straw man amendments to the Nuclear Waste Policy Act

Sec. 307.

(a) Contracts.

(1) In the performance of his functions under this Act [42 U.S.C. 10101 et seq.], the Secretary is authorized to enter into contracts with each person who generates or holds title to spent nuclear fuel, of domestic origin, for such person to retain title to such high-level radioactive waste or spent nuclear fuel, thereby relieving the Secretary of obligation to take title under section 302 [42 U.S.C. (insert number)].

(2) Within one year of the licensing of the Yucca Mountain site or its removal from consideration, whichever shall come sooner, the Secretary shall offer contracts that transfer to persons holding title to high-level radioactive waste or spent fuel the balance of the Nuclear Waste Fund, less any portion thereof that the Secretary deems necessary to provide for the management of high-level radioactive waste not contained in spent nuclear fuel.

(A) The funds distributed under this section shall be divided in proportion to the kilograms of heavy metal in spent nuclear fuel to which each person holds title.

(B) Each person receiving funds distributed as designated in this section shall deposit such funds in an Escrow Fund, with Escrow Funds principal balance and interest earnings to be used only for the purposes listed in paragraph (5) of this section.

(3) There shall be a separate Escrow Fund for each nuclear power plant.

(4) From the time of the first payment of each Escrow Fund, payments specified under section 302 [42 U.S.C. (insert number)] in connection with each nuclear power plant shall be paid into its Escrow Fund rather than to the Nuclear Waste Fund.

(5) Per kilowatt-hour payments into each Escrow Fund shall be at the rate of 1 mill per kilowatt-hour until (insert date) and adjusted each year thereafter (insert inflation adjuster description) unless otherwise determined following the procedure specified in section 302, paragraph (4) [42 U.S.C. (insert number)].

(6) Each Escrow Fund shall be invested in obligations of the United States having maturities determined by the Secretary of the Treasury to be appropriate to the needs of the Escrow Fund.

(b) Escrow Fund use.

(1) The Escrow Fund for each power plant may be used, as approved by the Commission, for—

(A) costs of dry cask storage at the power plant where spent nuclear fuel was produced, and for transportation, treating, or packaging of spent nuclear fuel or high-level radioactive waste to be disposed of in a repository or to be stored in a monitored retrievable storage site.

(B) payments to the Escrow Fund associated with another power plant owned by the same person, or another power plant owned by another person within the same State, upon the transfer of associated spent nuclear fuel to such power plant.

(C) payments to a Permanent Fund on a per kilogram of heavy metal basis upon shipment of spent nuclear fuel to a repository or monitored retrievable storage site.

(2) Upon shipment of spent nuclear fuel to a repository or monitored retrievable storage site, the balance of the Escrow Fund associated with each quantity of nuclear fuel shall be available for use by the corresponding power plant owner, without restriction.

(c) Escrow Fund required

(1) Each application for a commercial nuclear reactor operating license submitted (insert reference to licensing legislation) after (insert date) shall require an Escrow Fund contract for spent fuel to be produced by that reactor and an operation and decommissioning plan that allows for storage of all spent fuel at the power plant site at least until all spent nuclear fuel produced by the plant has been removed from cooling ponds.

(2) Each application for a commercial nuclear reactor operating license extension (insert reference to licensing legislation) submitted after (insert date) shall require an Escrow Fund contract for spent fuel to be produced by that reactor and an operation and decommissioning plan that allows for storage of all spent fuel at the power plant site at least until all spent nuclear fuel produced by the plant has been removed from cooling pools.

is already the subject of lawsuits by the utilities against the federal government on a case-by-case basis. The primary economic effect will be to relieve Congress from making annual appropriations for spent fuel management, resulting in considerable net cost savings.

Other Changes

Box B.3 lists other possible revisions of the NWPA aimed at regularizing the process of longer-term dry cask storage. The text to be deleted is in square brackets, and the text to be added is in italics. The revision to section 111 notes the change in the federal government's role from providing for to regulating management of spent nuclear fuel. The revisions to section 134 explicitly allow moving spent nuclear fuel within state boundaries even when it is transferred between reactor sites of different utilities.

Box B.4 lists possible revisions of the NWPA aimed at reducing restrictions on monitored retrievable storage. These revisions reduce restrictions on when and where such facilities can be constructed and on how much spent nuclear fuel they may take in. The changes in sections 141 and 145could allow monitored retrievable storage to continue over an extended period of time until it became economically preferable to move spent fuel to a geologic repository in order to reduce the costs of ensuring safety and security under federal regulations. The extent to which it is seen as desirable over the long run to force the pace of repository siting can be adjusted by filling in smaller, equal, or larger limits in section 148 on monitored retrievable storage holdings allowed before a repository is sited. In recognition of the different points of view on this question, the limits on monitored retrievable storage capacity in section 141 are left open to negotiation. The changes in sections 141 and 145 are worded to retain the current understanding with the state of Nevada that no monitored retrievable storage facility will be placed there if the Yucca Mountain repository is licensed, a restriction that could also be removed if the new permanent fund arrangements make the removal of this restriction acceptable to Nevada.

The boldfacing of the numbers in section 148 (d) in Box B.4 highlights the possibility of changing limitations aimed at forcing earlier construction of a repository by limiting the amount of spent fuel that could be placed in monitored retrievable storage. However, such a change in limitations would be needed only if it is anticipated that the federal government will remain stuck with obligations to take title to and remove from reactor sites more than 15,000 metric tons of heavy metal in spent fuel because the secretary of energy is unable to negotiate enough transfers to escrow funds for older reactor discharges. The changes in section 170 (a) remove the implication that Nevada should necessarily be the first state in which a repository will be sited. The deletion of section 170 (e) frees up the siting of monitored retrievable storage facilities and repositories to adjust to market forces over the long term.

BOX B.3 Dry Cask Storage

Straw man amendments to the Nuclear Waste Policy Act

Sec. 111. FINDINGS AND PURPOSES

(a) Findings . . .

(4) while the Federal Government has the responsibility to ~~provide for~~ *regulate* the permanent disposal of high-level radioactive waste and such spent nuclear fuel as may be disposed of in order to protect the public health and safety and the environment, the costs of such disposal should be the responsibility of the generators and owners of such waste and spent fuel; . . .

Sec. 134. LICENSING OF FACILITY EXPANSIONS AND TRANSSHIPMENTS

(a) Oral argument. In any Commission hearing under section 189 of the Atomic Energy Act of 1954 [42 U.S.C. 2239] on an application for a license; or for an amendment to an existing license, filed after the date of the enactment of this Act [enacted Jan. 7, 1983], to expand the spent nuclear fuel storage capacity at the site of a civilian nuclear power reactor, through the use of high-density fuel storage racks, fuel rod compaction, the transshipment of spent nuclear fuel to another civilian nuclear power reactor within the same utility system *or to another utility system within the same State,* the construction of additional spent nuclear fuel pool capacity or dry storage capacity, or by other means, the Commission shall, at the request of any party, provide an opportunity for oral argument with respect to any matter which the Commission determines to be in controversy among the parties. . . .

Sec. 135. STORAGE OF SPENT NUCLEAR FUEL . . .

(b) Contracts.

(1) Subject to the capacity limitation established in subsections (a) (1) and (d) the Secretary shall offer to enter into, and may enter into, contracts under section 136 (a) [42 U.S.C. 10156(a)] with any person generating or owning spent nuclear fuel for purposes of providing storage capacity for such spent fuel under this section only if the Commission determines that— . . .

(B) such person is diligently pursuing licensed alternatives to the use of Federal storage capacity for the storage of spent nuclear fuel expected to be generated by such person in the future, including— . . .

(iv) transshipment to another civilian nuclear power reactor owned by such person or to another civilian power reactor within the same State and owned by a different person.

In Box B.4, the addition of paragraph (c) to section 406 closes a potential loophole by preventing spent fuel from again being stranded outside the permanent fund system at a prospective reprocessing site that does not in fact reprocess the received fuel. Nor would a reprocessing

BOX B.4 Monitored Retrievable Storage

Straw man amendments to the Nuclear Waste Policy Act

Sec. 141. MONITORED RETRIEVABLE STORAGE

(a) Findings. The Congress finds that— . . .

(5) disposal of high-level radioactive waste and spent nuclear fuel in a repository developed under this Act [42 U.S.C. 10101 et seq.] ~~should~~ *may* proceed regardless of any construction of a monitored retrievable storage facility pursuant to this section. . . .

(g) Limitation. No monitored retrievable storage facility developed pursuant to this section may be constructed in ~~any~~ *the* State *of Nevada* ~~in which~~ if there is located *in that State* any site approved for site characterization under section 112. . . .

Sec. 145. SITE SELECTION

(a) In general. The Secretary may select the site evaluated under section 144 [42 U.S.C. 10164] that the Secretary determines on the basis of available information to be the most suitable for a monitored retrievable storage facility that is an integral part of the system for the disposal of spent nuclear fuel and high-level radioactive waste established under this Act.

(b) Limitation. The Secretary may ~~not~~ select a site under subsection (a) ~~until~~ *before* the Secretary recommends to the President the approval of a site for development as a repository under section 141 (g) Limitation. No monitored retrievable storage facility authorized pursuant to section 142 (b) [42 U.S.C. 10162 (b)] may be constructed in the State of Nevada *until such time as the Secretary decides that there is in the State of Nevada no longer a candidate site under consideration for development as a repository*.

Sec. 148. CONSTRUCTION AUTHORIZATION . . .

(d) Licensing conditions. Any license issued by the commission for a monitored retrievable storage facility under this section shall provide that— . . .

(3) the quantity of spent nuclear fuel or high-level radioactive waste at the site of such facility at any one time may not exceed ~~10,000~~ ______ metric tons of heavy metal until a repository under this Act first accepts spent nuclear fuel or solidified high-level radioactive waste; and

(4) the quantity of spent nuclear fuel or high-level radioactive waste at the site of such facility at any one time may not exceed ~~15,000~~ ______ metric tons of heavy metal . . .

Sec. 170. BENEFITS AGREEMENTS

(a) In general.

(1) The Secretary may enter into a benefits agreement with ~~the~~ *a State* ~~of Nevada~~ or an Indian Tribe concerning a repository or with a State or an Indian tribe concerning a monitored retrievable storage facility for the acceptance of high-level radioactive waste or spent nuclear fuel in that State or on the reservation of that tribe, as appropriate. . . .

(e) . . .

Sec. 406. MONITORED RETRIEVABLE STORAGE . . .

(c) Reprocessing facilities. No spent fuel reprocessing facility shall be licensed for construction at a site that is not also licensed as a monitored retrievable storage facility with adequate capacity to store all spent nuclear fuel shipped to the facility but not yet reprocessed, and all high-level radioactive waste produced at the facility and not yet shipped to a repository.

[42 U.S.C. 10246]

facility again be allowed to reproduce separated high-level radioactive waste streams in the hope of shipping them off-site for permanent storage without alternative back-up by a previously approved monitored retrievable storage facility at the reprocessing site.

Implications and Implementation

Further amending the Nuclear Waste Policy Act of 1982 along the general lines just outlined would fundamentally transform the management of spent nuclear fuel in the United States. No longer would the federal government be the sole determinant of the fate of spent fuel removed from reactor sites—a role that it has long played with so little success. Instead, the government would play a role similar to the one it plays in the ongoing operation of nuclear reactors, which is primarily to regulate for safety and security. Nor would the federal government be forcing on a state its own view that the disadvantages of accepting large amounts of spent nuclear fuel from other states are minimal. Instead, setting a suitably large upper limit on payments into associated permanent funds would allow various candidate states for monitored retrievable storage facilities and repositories to compete in a more open marketplace by assigning their own market value to suitable candidate sites.

It is quite possible that many decades would pass before utilities build up large enough escrow funds that they are willing to pay enough to move spent nuclear fuel off-site to induce any state to host a monitoring retrievable storage facility or repository. However, the escrow funds would provide a reliable and fully adequate funding source for dry cask storage at reactor sites if necessary until the entire site is decommissioned. Also, additional flexibility is provided for moving spent nuclear fuel from one reactor site to another within states in order to avoid stranding spent fuel at decommissioned sites and the need for cross-country shipping.

It is also quite possible that these changes would result in the licensing and operation of a monitored retrievable storage facility long before a substantial amount of spent nuclear fuel is placed in a geologic repository. It is, however, not necessarily inappropriate that the trade-off between spent fuel emplacement in facilities that are and are not designed to be permanently sealed should be evaluated by future generations. One possibility is that the previous emphasis in the NWPA on relatively prompt deep underground burial will survive the current century and that monitored retrievable storage will prove fairly transient. Another possibility is that the major fission products or even the 432-year half-life americium-241 that dominates the planned Yucca Mountain packing density will be allowed to decay substantially in monitored retrievable storage before deep burial. A third possibility is that technological advances and changes in levels of concern about plutonium use will make spent fuel reprocessing commercially competitive with continuing retrievable storage, perhaps sometime in the twenty-second or twenty-third century. The current generation cannot forecast and certainly cannot foreordain what future generations will ultimately decide about such matters. But what can be done now is to set up a more orderly system for managing spent nuclear fuel and to lay down a legal and financial framework, should future generations decide to use it, for making such choices. It is this that the changes outlined here to the NWPA are designed to do.

This appendix has provided just a sketch of what a more complete set of amendments to the NWPA would look like after being set out in precise legal language and suitably cross-referenced. Later, revisions of administrative regulations would be needed as well—important issues but ones that are beyond the scope of this proposal. Although the overall undertaking is a substantial task, it is a far less formidable one than either trying to license promptly a second U.S. repository or forcing the radioactive material produced in U.S. nuclear reactors in this century to fit into Yucca Mountain. Ultimately, shuffling paper will prove easier than moving mountains.

Appendix C | Spent Nuclear Fuel Holdings from Commercial Power Plants by State

TABLE C.1 Spent Nuclear Fuel Holdings (MTHM) and Payments to Waste Fund

State	All	Dry	Morris, Ill.	M$NWF	M$Owing
Alabama	2,600	130		710	
Arizona	1,600	550		501	
Arkansas	1,100	610		178	
California	2,500	400	100	789	
Connecticut	1,800	510	30	349	474
Florida	2,600	75		736	
Georgia	2,200	410		649	
Illinois	6,930	460	140	1,685	1,004
Iowa	420	110		107	
Kansas	540	0		179	
Louisiana	1,000	70		307	
Maine	540	540		65	183
Maryland	1,100	560		340	
Massachusetts	620	130		155	
Michigan	2,300	420		495	422
Minnesota	1,000	360	200	374	
Mississippi	700	50		192	
Missouri	590	0		185	
NorthCarolina	3,100	392		792	
Nebraska	720	50	200	250	
NewHampshire	400	0		144	
NewJersey	2,200	220		567	172
NewYork	3,000	150		752	499
Ohio	1,000	30		284	32
Oregon	360	360		76	

State	All	Dry	Morris, Ill.	M$NWF	M$Owing
Pennsylvania	5,200	910		1,484	88
SouthCarolina	3,500	1,200		1,184	
Tennessee	1,300	200		434	
Texas	1,700	0		570	
Vermont	550	0		89	143
Virginia	2,200	120		665	
Washington	540	180		151	
Wisconsin	1,200	270		341	
Total (with Morris)	57,780	9,467	670	15,779	3,017

Source: U.S. Department of Energy, "Waste Locations by State," 2008, http://www.ocrwm.doe.gov/info_library/newsroom/photos/photos_natlmap.shtml.

Note: Entries in table are estimates for the end of 2007. Spent fuel amounts are in metric tons of heavy metal (MTHM), and payments are in millions of face value dollars. "All" indicates the total of wet pool storage and the dry cask storage listed under "Dry." These entries do not include amounts listed under "Morris" that were shipped to pool storage at Morris, Illinois, adjacent to the Dresden reactors site. Amounts for dry casks are as of April 30, 2008. "Total (with Morris)" indicates the sum of the entries listed under "All" and "Morris." "M$NWF" lists payments until March 31, 2008, to the Nuclear Waste Fund, including interest paid in lieu of the indicated principal payments listed under "M$Owing" owed from before April 7, 1983 (Judy England-Joseph, "Nuclear Waste Changes Needed in DOE User-Fee Assessments," General Accounting Office statement before the U.S. House subcommittee on Energy and Power, May 8, 1991).

Nuclear plants in the United States. Stars indicate sites without operating reactors currently storing spent fuel (source: Nuclear Energy Institute, http://www.nei.org/).

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