A REPORT OF THE CSIS PROLIFERATION PREVENTION PROGRAM

U.S. Spent Nuclear Fuel

A MARKET-BASED SOLUTION

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ISBN 978-0-89206-645-2

Acknowledgments

CSIS and the authors are most grateful for the financial support of the John D. and Catherine T. MacArthur Foundation. Charles D. Ferguson thanks Harold "Gerry" Lenfest and the Lenfest Foundation for support.

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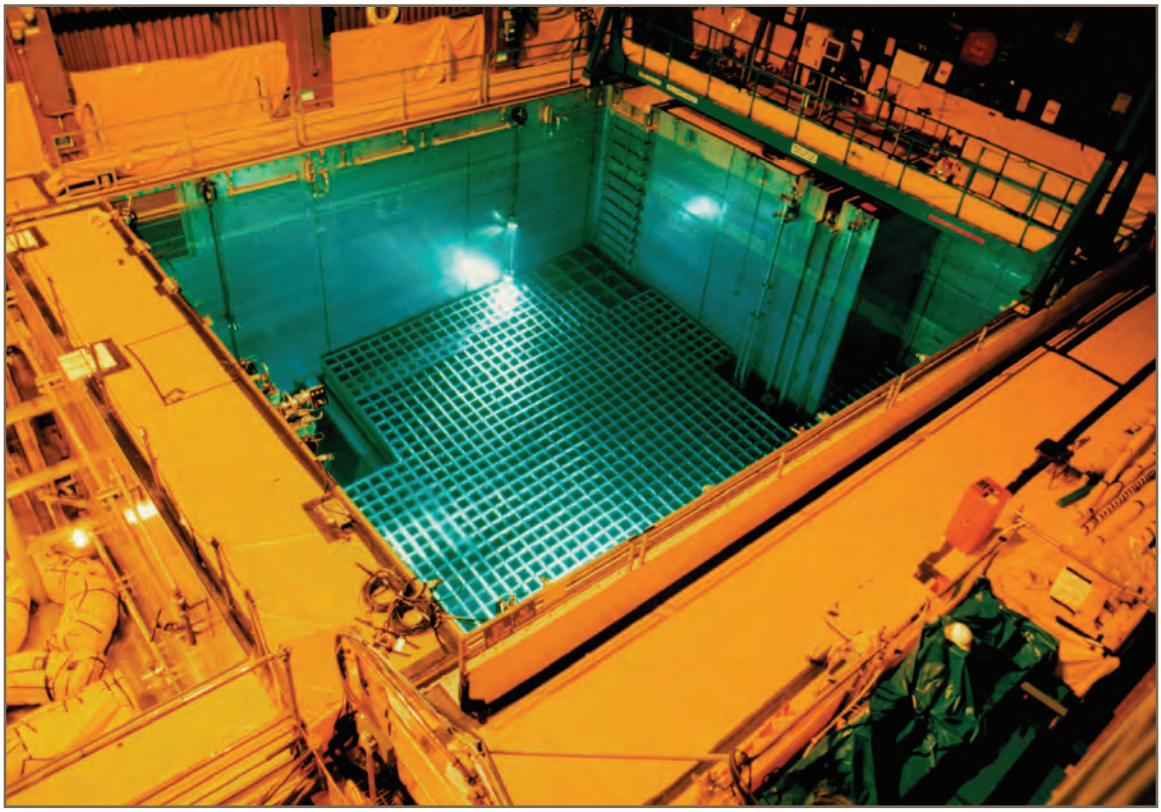


Source: Nuclear Regulatory Commission (NRC), http://www.nrc.gov/reading-rm/photo-gallery/index.cfm?text=spent+fuel+pool&cat=.

EXECUTIVE SUMMARY

The central planning approach to U.S. spent nuclear fuel management has been a glaring and unsuccessful exception to the trend toward a market-driven energy sector. This report envisions a market-driven approach, which would include eight components:

1. Phase out utilities' payments to the federal government for spent fuel management in favor of payments into escrow funds.
2. Reassess the radioisotope containment criteria for spent fuel repositories (i.e., the "million-year" benchmark).
3. Do not require prompt deep burial of all spent fuel.
4. Provide federal support for preparation of licenses for away-from-reactor spent fuel storage facilities.
5. Remove nontechnical restrictions on maximum volumes and site license durations for away-from-reactor spent fuel management facilities.
6. Treat all states equally in voluntary licensing processes, including Nevada.
7. Allow the private sector options to: keep spent fuel at reactor sites; ship it to another of their reactor sites in the same state; ship it to a reactor site of another company in the same state and transfer the escrow fund balance to that company; or ship it out of state. Shipments out of state could be to a spent fuel storage facility that might or might not be located at a licensed deep underground repository, to a repository for prompt emplacement, or to a reprocessing facility if one is available.
8. Allow states to import foreign spent fuel, to the extent consistent with U.S. nonproliferation policy and U.S. facilities' capacity to handle domestic spent nuclear fuel.

As with reactor decommissioning, payments to the federal treasury for spent fuel management can eventually be replaced by payments into escrow funds associated with each nuclear fuel dry storage cask. When spent fuel is shipped across state lines, the recipient state could require payment in excess of a federally determined minimum adequate to ensure the safe and secure future management of the spent fuel. By freeing up the remainder of the escrow fund balance, this approach would provide an incentive for shipping fuel off of reactor sites.

Consistent with federal requirements on safety, security, and sound financial management, this approach should provide current and future generations with the flexibility needed to take advantage of technological improvements, adapt to varying levels of spent nuclear fuel, and make decisions about the fate of spent nuclear fuel decades in advance. Fundamentally, this approach would convert spent nuclear fuel from a liability into an asset.

U.S. SPENT NUCLEAR FUEL
A MARKET-BASED SOLUTION

I. Fifty Years and Counting

During half a century of U.S. nuclear electric power plant operations, three so far unsuccessful approaches to dealing with spent nuclear fuel have been adopted. The first approach was to recover plutonium to feed breeder reactors that would make more plutonium than they consumed. The idea was to provide a nearly unlimited supply of nuclear fuel. The second approach was to fairly promptly bury spent fuel deep underground without reprocessing. The third approach was to repeatedly reuse spent fuel in order to burn out plutonium and its decay products. One of these decay products, americium-241, limits spent fuel packing density in a deep underground repository if it is to be sealed before many centuries have elapsed. The idea was to decrease the repository area needed for each nuclear reactor by as much as a factor of 10. In each case, the federal government was operating under the assumption that it could forecast for all time to come what the appropriate solution would be.

The breeding approach fell victim to discoveries of large quantities of uranium that could be economically fabricated into reactor fuel. The prompt burial approach failed to provide a flexible enough incentive to enlist the cooperation of states to host underground repositories. The deep burn approach assumed that the private sector would build a large fleet of commercially viable liquid-sodium-cooled reactors once the government funded prototype development. This hasn't happened. A common flaw was that none of these approaches had the flexibility to respond to changing economic and political conditions over the several decades that they would have taken to implement.

In other energy markets, the United States has moved toward letting market forces dominate, subject to regulations relevant to safety, security, and environmental impact. This approach applies even to nuclear reactor decommissioning, for which escrow funds are set aside to insure adequate financing of private-sector decommissioning operations. The advantage of a suitably framed market-driven approach is that it can respond to technological, economic, and public policy evolution as reflected in evolving costs of various options. For spent nuclear fuel management, there are three options: reprocessing, placement in a repository designed for permanent disposal, and retrievable storage pending a decision between the other two options. Given the impossibility of accurately forecasting the optimal solution decades or even centuries ahead of time, a market mechanism is needed that can dynamically reallocate spent fuel. Under current law in the United States, there is no such market mechanism for spent nuclear fuel producers. Instead, producers irreversibly pay to the federal government a fixed rate of $0.001 per kilowatt hour of nuclear electric power (mil/kWhe) generated. They then sue the government for the costs of managing spent fuel that the government so far has failed to take from them.

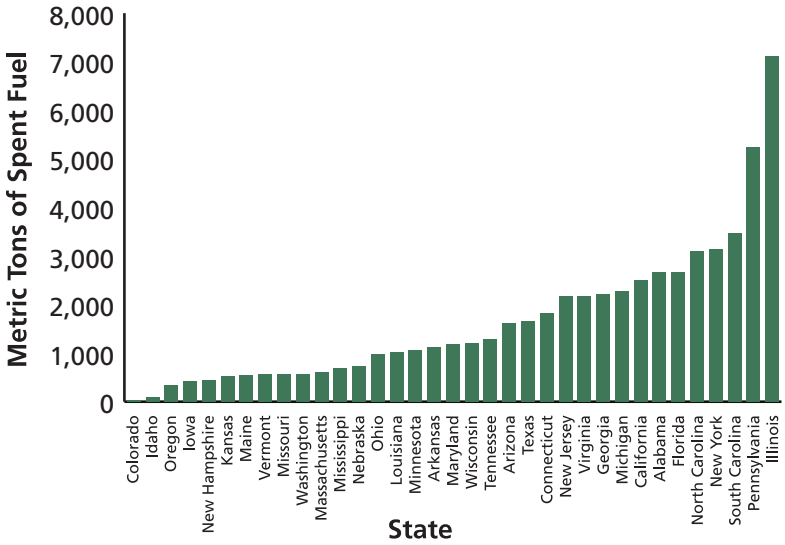
There are international as well as domestic consequences of having a dysfunctional system for handling spent U.S. reactor fuel. As the world's largest national nuclear energy market, the United

States has the opportunity not only to demonstrate safe, secure, and economically and politically viable spent nuclear management, but also to serve as a source of technology and exports in that field. U.S. influence on other countries' fuel cycle choices varies considerably from case to case but has been complicated by reversals in policies regarding reprocessing. The U.S. approach domestically and internationally has lacked continuity.

II. Creating a Market Mechanism

The spent nuclear fuel currently held in 35 U.S. states (listed in Graph below) has negative value to the nuclear industry. It is true that the cost of storing spent fuel in casks at reactor sites can be recovered by suing the federal government. However, there are 10 states that restrict new nuclear plant construction pending an overall solution for spent nuclear fuel management (cf. appendix A). In some other states, utilities feel that their inability to assure local communities that spent nuclear fuel will be removed is an impediment to nuclear power plant construction. This concern is likely only to deepen after the crisis at the Fukushima Daiichi nuclear power plants, which demonstrated some of the vulnerabilities of spent nuclear fuel pools.

Spent Nuclear Fuel (in metric tons of heavy metal) in Commercial Storage by State



Note: Idaho is holding used fuel from Three Mile Island, Unit 2. Data are rounded up to the nearest 10 tons.

Source: ACI Nuclear Energy Solutions and U.S. Department of Energy (updated May 2010).

On the other hand, a suitable site for the long-term management of spent nuclear fuel is currently not a useful asset anywhere. The state of Nevada was offered compensation for welcoming the Yucca Mountain repository on the order of a fraction of a percent of the total project cost, a return that was as unacceptable to the state as it would be almost anywhere in the private sector. South Carolina might welcome a spent fuel reprocessing facility, but it is neither keen to put up the cost of its construction nor serve as a permanent home for the radioactive fission products to be separated from spent nuclear fuel. Elected and appointed officials of Utah have so far successfully opposed the construction within its borders of a facility licensed for 20 years for interim storage of spent fuel. That facility would in any case have neither the capacity nor the longevity to provide a long-term option, even for reactor discharges to date, without both increasing its capacity and extending its license.

To transform spent nuclear fuel from a liability into an asset, the net value of accepting such fuel has to at least match the cost associated with the liability of leaving it where it is. The net value of accepting spent nuclear fuel within a state is a balance between the economic benefits to the immediate community, the perceived liability within and outside of that community for living near a waste management site or transportation routes, and the compensation provided for taking in the spent fuel. Local communities other than Indian tribes derive their legal authority from their state and have to negotiate a political compromise with their state. States also have an interest in decisions about spent nuclear fuel management on Indian tribe land within their state boundaries.

The state hosting a spent nuclear fuel management facility thus has an important role in determining the charge for taking in spent nuclear fuel. To respond to conditions that evolve over decades, there must also be flexibility in setting how such charges evolve over time. Two options include charges for the quantity of heavy metal (with atomic weights near that of uranium [e.g., in metric tons]) or the fission power produced using the spent fuel. Both reactor operators and the federal government could also have the possibility of reserving prospective waste management capacity in a host state at any point in the search, licensing, construction, or operations process for a facility. If this applies to reactor operators, it would be for any spent fuel they must dispose of, either because they have been relieved of the responsibility of paying a sum such as a mil/kWhe to the federal government, or because they have negotiated compensation from that government.

It is likely that states wanting to host spent fuel management facilities will contract out some or all of the stages for preparation, construction, and operation to a concern that is either fully privately operated or in which the state has a direct financial interest. Regardless, states are likely to require a regulatory oversight role, consistent with whatever federal government regulations are in place to ensure long-term safety, security, financial stability, and limitations on environmental impact.

III. Level the Playing Field

If current legislation can be revised to make the acceptance of spent nuclear fuel for long-term management attractive, who would be interested? Current legislation requires that Nevada be the first state to host a permanent repository. Current legislation also restricts the capacity of any monitored retrievable storage (MRS) facility that the federal government constructs. In order to create a level playing field for interested states, a more comprehensive approach is needed that neither forces a single state to take a facility it does not want nor puts any state in a politically defined privileged position.

Current requirements for geological repositories distort markets in several ways. Most important is the requirement for prompt burial, starting with the oldest spent fuel. One problem with this is that the liability cost associated with spent fuel storage at reactor sites depends on whether the reactor site is still operating and on other factors such as whether continued on-site storage adversely affects prospects for new reactor construction. An even more serious problem is that prompt burial considerably increases the time-discounted cost and uncertainty associated with repository design and operation. It can be considerably less expensive to allow for extensive decay of strontium-90 (half life 29 years) and cesium-137 (half life 30 years) before placing spent fuel in a repository.

In a more market-driven environment, a repository operation would have flexibility to store fuel before emplacement, provided that requirements for ensuring the adequate financing, safety, security, and the eventual availability of repository space were met. Within this context, entities initially responsible for spent nuclear fuel management would have the option of leaving spent fuel at reactor sites even until site decommissioning if desired, transferring spent fuel to a licensed facility set up for storage alone, transferring spent fuel to a licensed repository site, or transferring spent fuel to any extant prospective reprocessing facility that is also licensed for spent fuel storage. This would apply equally whether the spent fuel was from U.S. defense programs, commercial spent fuel for which the federal government is still responsible, or commercial spent fuel for which private-sector institutions become responsible. For any option where spent fuel is shipped to another state, the recipient state would set charges, with resulting funds to be managed in accordance with federal regulations ensuring long-term financial viability within a uniform national regulatory framework.

Even within a more market-driven environment, it would be necessary to restrict the use of funds required by states for accepting spent nuclear fuel. This is already the case for reactor decommissioning for which escrow funds are required to be set aside. Given the much longer half lives of the dominant radioisotopes in spent nuclear fuel compared to other reactor components, a more conservative investment strategy would be needed than is currently allowed for decommissioning funds. For example, a minimum amount could be required to be invested in inflation-indexed U.S. treasury securities. The outstanding potential liability depends on the location of the spent fuel. The minimum amount escrowed per unit of spent nuclear fuel should depend on whether the spent fuel is in a stand-alone storage facility, in decay storage at a repository with adequate capacity, or actually placed in a repository.

IV. Radioisotope Containment Requirements

The current regulatory framework assumes that spent nuclear fuel will promptly and permanently be placed in a deep underground repository, and it puts limits on the release and transport of radioisotopes in groundwater for a million years. Late in the Yucca Mountain site design and license preparation process, the 1 million-year requirement was imposed by the Environmental Protection Agency after a legally mandated National Academy of Sciences study. That study examined only the exposure to a hypothetical string of individuals with current human physiology and medical care who drink untreated well water at a single site just outside of an exclusion boundary enforced over the entire million years. The conclusion was that the cumulative radiation exposure over the million years exceeded that over the 10 thousand years for which exposure standards had already been developed. Excluded from the study were the larger cumulative population doses from global exposures to airborne radiocarbon releases from spent fuel. Also excluded from the study was any accounting for the possibility that nuclear materials in well-contained nuclear waste packages might be exhumed and used to construct weapons.

The combination of the long time frames for constraints on groundwater radioisotopes and the prompt and permanent burial assumptions complicated and potentially compromised license approval for the Yucca Mountain site for two reasons. The assumption of prompt and permanent burial yielded a design to place titanium-palladium alloy drip shields above the storage casks after about a century in order to protect the post-closure casks from corrosion. However, there is ques-

tionable confidence that this can be done after such a long time in the resulting temperature and radiation field. Moreover, questions have also been raised about whether the groundwater transport analysis for the Yucca Mountain site had adequate quality control.

Coincidentally, since the legislation launching the repository site licensing process was passed, the annual total radiation exposure to the U.S. population has increased millions of times more than the nominally expected exposures to the above-mentioned hypothetical individuals. This is primarily due to medical diagnostics and procedures to which the ALARA (as low as reasonably achievable) standards used in the nuclear industry are not uniformly or even generally applied. This observation suggests that reassessment of restrictions on possible long-term release of radioisotopes from spent nuclear fuel might be in order if establishing a level playing field for a more market-driven approach is desirable. The impact of such a reassessment is still unclear, but it is quite possible that something closer to a 10 thousand-year than a 1 million-year time horizon will be considered suitable if and when the controversy over the particular features and politics of the Yucca Mountain site lie in the past.

V. Actions toward a Market-Driven System

Eight actions to help create a more market-driven spent fuel management system would include:

(1) Phase out the mil: A core element of creating a more market-driven spent fuel management system is replacing payments of a mil/kWhe to the federal government by an appropriate level of payments into utility escrow funds. This amount should be adequate to provide for the disposition of all spent fuel stored on-site in dry casks. This can be applied to all new reactor licenses submitted after a date certain, but allowing potentially for license applications that would be significantly perturbed by such a change to be submitted and processed beforehand. Other reactor operations could be given the opportunity to cease such payments to the federal government in favor of payments into escrow funds and retaining title to future spent nuclear fuel discharges until they are moved away from sites owned by the holder of the escrow fund. This should be legally possible as long as payments to utilities for this purpose do not come from the Nuclear Waste Fund (cf. appendix B). A federal government official would be empowered and given guidelines to negotiate transfers of federal funds into escrow funds in exchange for release of the federal government obligation to expeditiously take title of spent fuel. Escrow funds would be held in inflation-indexed U.S. treasury securities except to the extent that it can be demonstrated that a portion can prudently be approved for investment with potentially higher but more uncertain yields.

(2) Reassess containment criteria: The procedure that led to a million-year horizon on limits on the appearance of spent nuclear fuel radioisotopes in groundwater was meant to provide reassurance. The net effect was instead to reinforce the idea that such materials are so extraordinarily hazardous that far more stringent criteria need to be applied to them than to either other sources of radiation exposure or other toxic materials not required to be so durably isolated. While it is true that fissile materials in spent nuclear fuel can be extraordinarily hazardous if fabricated into nuclear explosives, the plan for installing drip shields in Yucca Mountain made it more, rather than less, likely that fissile materials would remain more readily recoverable after fission product decay made them more accessible. The next step is to review and revise the containment criteria. Such a reassessment could examine changes in public attitudes, different options for exclusion boundaries or buying water rights in perpetuity, likely evolution in technology for water purifica-

tion and medical treatment, and comparative costs and hazards associated with other toxic materials. The next step toward market-driven spent fuel management in any case allows future generations to reassess containment criteria as the knowledge base evolves.

(3) Do not require prompt deep burial of all spent fuel: To build confidence in the availability of comprehensive spent fuel management, it is necessary that specific locations for a large amount of repository space be identified with the cooperation of host states. It is also necessary that some spent fuel be stored therein. However, it is neither technologically nor economically optimal that all spent fuel that is now in dry casks be promptly and permanently placed in deep underground repository space. Instead, trial emplacements for an extended period of time that allow studying the emplaced material and its surrounds, the decay of fission isotopes in additional material to be emplaced later, and the possibility of future technological improvement that could lower costs could be useful. In this context, states could be given the option of seeking a license initially for retrievable storage, later for permission to proceed to irretrievable emplacement, and possibly even later for permanent closure following abandonment of convective cooling. With more than one repository sited, not all would necessarily have the same type of license. Some could be for prompt permanent burial and others initially for retrievable emplacement. Of course, this is more likely to be a successful approach if the public views spent nuclear fuel as an asset rather than a liability.

Dry Storage Casks

Source: Holtec International, http://www.holtecinternational.com/.

(4) Provide federal support for license preparation: States are unlikely to be very interested in repository site licensing in a market-oriented system if all potential customers have the option of leaving spent fuel at production sites or at off-site interim but long-term storage facilities. Without some guaranteed customers for spent fuel management services, there would be little incentive for states to proceed. However, the federal government has agreements with current host states to remove high-level radioactive materials that were produced during defense programs. The space that was to be reserved for this at Yucca Mountain is equivalent to 7,000 metric tons of heavy metal (mostly uranium) of original reactor loading in commercial spent nuclear fuel. The federal government may also not manage to negotiate private-sector responsibility for some of the spent fuel for which mil/kWhe payments to it have already been made. The federal government can thus be a guaranteed customer for repository space and also pay states for costs of competing to obtain repository site licenses. The federal government can also require that minimum amounts of material actually be emplaced in a repository in order to build confidence in methods used for doing so.

(5) Remove restrictions on maximum volumes and site license durations: Current law restricts the capacity of a first deep repository to 70,000 metric tons of heavy metal. The capacity of monitored retrievable storage commissioned by the federal government is also limited. These restrictions are not needed in a market-driven management system and should be rescinded.

(6) Change the treatment of Nevada: In current law, Nevada is both designated for the first repository siting attempt and precluded from having a repository should that attempt fail. In a market-oriented approach, these restrictions are not necessary. Nevada can be given the option of not having the Yucca Mountain site opened, cooperating with submission of revised application, or proposing a different site.

(7) Give the private sector options, subject to state utility commission requirements: In a market-driven spent fuel management system, as allowed by state utility commissions, private-sector spent nuclear fuel producers would have several options. They could keep spent fuel at reactor sites, ship it to another of their reactor sites in the same state, ship it to a reactor site of another company in the same state and transfer the escrow fund balance to that company, or ship it out of state. Shipments out of state could be to a spent fuel storage facility that might or might not be located at a licensed deep underground repository, to a repository for prompt emplacement, or to a reprocessing facility if one is available. Subject to a minimum required by federal regulation to ensure adequate financing for long-term safe and secure management and any additional fund transfers required by the importing state, any surplus escrow funds would be retained within the state. State utility commissions would have the ability to regulate the distribution of such funds, require that spent fuel be moved off of reactor sites expeditiously if one or more destinations are available, and prohibit new reactor construction in the absence of such availability. Whether state utility commissions require use of alternatives more expensive than the minimum cost approach follows ultimately from the state political process that determines their composition and powers. The Federal Energy Regulatory Commission retains the ability to regulate interstate commerce in electrical energy. However, for the federal government otherwise to usurp states' abilities to prevent the indefinite accumulation of spent nuclear fuel in state would likely raise political opposition that could ultimately complicate spent nuclear fuel management.

(8) Allow states to import foreign fuel: Such imports would have to meet federal standards for contents, packaging, and transportation, and may be limited to amounts that do not compromise the capacity of U.S. facilities to handle domestic spent fuel. The federal government may then enter into international agreements for receipt of such fuel, and the U.S. Congress may determine that it is in the national security interest to pay some of the resulting costs. The federal government may then also enter into agreements guaranteeing fuel cycle services that include spent fuel management, in order to limit the proliferation of enrichment or reprocessing technology. The federal government may also support spent fuel imports to minimize the global distribution of fissile materials, especially in well-aged, low burnup fuel. (Some spent fuel from initial and final reactor operations has a plutonium composition particularly useful for nuclear explosives, and plutonium from such low burnup material becomes easier to purify as the strontium-90 and cesium-137 in it decays.) However, if there is a net financial gain from importing foreign spent fuel without the need for federal support, letting this benefit accrue to the importing state would both be consistent with the treatment of interstate shipments within the United States and provide an incentive for states to cooperate with the pursuit of international security goals.

VI. Timing and Consequences

Turning over the responsibility for managing all commercial spent nuclear fuel to the private sector immediately would likely trigger lengthy legal action and therefore could be counterproductive. Using the process described here, it could be several decades before the federal government disentangles itself from the obligation to take title to spent fuel from commercial nuclear power plants licensed before the start of the marketization process. Most urgent is the licensing of sites to which spent fuel can be shipped from most of the states where it was produced. Potential host states need to have adequate financial incentives, but this is insufficient for expeditious licensing. The federal government also needs to work promptly through the legislative and regulatory changes needed for the eight components of a marketization approach outlined here. The most successful and least costly path (for exporting states) would probably entail licensing of multiple spent fuel storage and repository sites. The balance between additional site licensing costs and the increased competition and lower transportation costs for having more than one site licensed will depend on the flexibility of licensing approaches and the results of any review of radioisotope containment requirements. The optimal number of licenses can be determined once the outlines of implementing legislation and regulations become clearer. Ultimately, however, the market should determine the number of repositories.

A market-driven approach to spent nuclear fuel management along the lines suggested here would turn good prospective spent fuel management sites into assets, not perceived liabilities. This could help achieve a goal that has eluded the United States for half a century and is an essential step toward ensuring that national spent fuel management capabilities will be adequate not only for the products of existing U.S. nuclear reactors, but also for any future expansion of the commercial reactor fleet. In the context of federal regulations on safety, security, financial stability, and environmental impact, it would allow for an appropriate distribution of spent fuel at reactor sites, at off-site storage facilities, at underground repositories, and at any spent fuel reprocessing facilities that might become economically viable. This flexibility would provide an opportunity to minimize costs directly associated with spent fuel management operations. As is currently the case with other technological and organizational improvements in the electricity sector, the distribution of the resulting savings amongst electricity customers and state residents and taxpayers at large would be up to the individual states to decide. Above and beyond the direct costs associated with spent fuel management facilities, there would be charges for shipping spent fuel out of producing states into other states that host such facilities. However, these additional costs to exporting states would be balanced by funds transferred to host states, with otherwise no net impact on the country as a whole.

Implementing a market-driven approach along the lines suggested here would enhance the United States' ability as a nuclear supplier to influence other countries' nuclear fuel cycle choices. It would give the United States an option for providing an integrated package of nuclear fuel supply and take-back that reduces incentives for other countries to set up their own facilities for uranium enrichment, spent fuel reprocessing, or both. The United States would be better positioned to help secure forms of spent fuel abroad that pose proliferation risks. Some countries may want to cooperate with the United States in this way simply to reduce their nuclear fuel cycle costs, with benefits also to U.S. industry and in the form of funds paid to U.S. states that import spent nuclear fuel. Other countries may want to cooperate with the United States in pursuit of regional security and nuclear nonproliferation goals. The resulting flexibility will give the United States an addition-

al tool to support nonproliferation initiatives.

Central to implementing a market-driven system is the provision of adequate incentives for states and communities to cooperate with site licensing. This means being prepared to provide financial incentives that are a substantial fraction of overall project costs, not just a few percent or less, to states hosting long-term spent fuel management facilities. One pitfall that must be avoided is to start down the road of a voluntary siting process and then fall back upon a forced process. Such an approach could very substantially increase both costs and delays. For pursuing a voluntary siting process for marketized spent nuclear fuel management, in the words of a well known albeit fictional personage: "Do, or do not. There is no try."

Entrance to the Onkalo Permanent Repository in Finland

Source: Posiva Oy, http://www.posiva.fi/ http://www.posiva.fi/files/106/onkolo5.jpg.

Appendix A. State Restrictions on Nuclear Power Plant Construction

Since a November 2006 review on state restrictions on nuclear power plant construction, there have been several failed attempts to reduce the restrictions. That review (Lovell 2006) listed the following examples of those restrictions.

> …Several states require only that the federal government has identified and approved "a demonstrated (or demonstrable) technology or means for the disposal of high-level radioactive waste" (California, Connecticut, Illinois, and Kentucky).
>
> A number of states require findings that a disposal facility exists and is accepting waste (Massachusetts, Maine, Oregon, West Virginia, and Wisconsin). Oregon requires a finding that "an adequate repository for the disposal of [spent fuel] has been licensed"; it specifies that the facility be for "the terminal disposition [of the waste] with or without provision for retrieval for reprocessing." Maine requires further that such facilities are "in full conformity with the technology" approved by the federal government. West Virginia requires that the facility has been in operation for 24 months. Wisconsin is the only state of those discussed in this Memo to allow consideration of facilities outside of the United States.
>
> Two states do not refer to federal approval or operation of a facility, but require findings of a more descriptive nature. Montana requires a finding that, among other things, "the radioactive materials from such nuclear facilities can be contained with no reasonable chance…of intentional or unintentional escape or diversion into the natural environment…" by any cause, including acts of God. New Jersey requires a finding than "the proposed method for disposal of radioactive waste material to be produced or generated by the facility will be safe, conforms to standards established by the Nuclear Regulatory Commission, and will effectively remove danger to life and the environment from such waste material."

Transuranic Waste Disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico

Source: Department of Energy (DOE), http://www.wipp.energy.gov/Photo_Gallery.htm.

Except for Montana and West Virginia, the above-mentioned states already have within their border spent fuel from commercial nuclear electric power plants. The Nuclear Energy Institute (2011) lists the amounts by state. Ewing et al. (2009) list the amounts of spent fuel at sites without operating nuclear reactors.

Lovell noted that Hawaii, Vermont, and Rhode Island, as well as California and Illinois also require the state legislature to ratify a decision to license a nuclear power plant. In addition to the

restrictions listed above, Massachusetts, Maine, Montana, and Oregon require approval of a licensing decision by voter referendum. Also, according to Parker and Holt (2007), "Kansas forbids cost recovery for 'excess' nuclear power capacity if no 'technology or means for disposal of high-level nuclear waste' is available." There are thus at least 15 states where public or legislators' opinions about the adequacy of provisions for spent nuclear fuel management have realized a mechanism for affecting licensing of new nuclear electric generating capacity, beyond that inherent in regulatory commission review of whether a new license is otherwise appropriate.

Appendix B. The Nuclear Waste Fund and Escrow Funds

The mil/kWhe has been paid into the restricted use Nuclear Waste Fund instead of as a simple tax. This restriction has been interpreted as allowing utilities legal recourse to restrict how appropriations from the Nuclear Waste Fund are used. For example, in July 2000 the U.S. Department of Energy (DOE) reached an agreement with the utility PECO concerning DOE's failure to meet a deadline for taking responsibility for spent nuclear fuel management (Holt 2008).

> The agreement allowed PECO to keep up to $80 million in nuclear waste fee revenues during the subsequent 10 years. However, other utilities sued DOE to block the settlement, contending that nuclear waste fees may be used only for the DOE waste program and not as compensation for missing the disposal deadline. The U.S. Court of Appeals for the 11th Circuit agreed, ruling September 24, 2002, that any compensation would have to come from general revenues or other sources than the waste fund.

The PECO case pertained only to offering one utility a different option for future payments into the Nuclear Waste Fund than available to other utilities. The law could be changed to offer all utilities the same treatment after some future date, with an option for no further payments to the federal government. If so, it could well be necessary to provide assurance that either the existing Nuclear Waste Fund balance or a commitment to additional federal support would be adequate for the federal government to meet its responsibility to take title to all previously discharged spent fuel, and perhaps also to all future spent fuel discharges from reactors within the period of their existing operating licenses. It could then be necessary for any payments into escrow funds in exchange for relief of the federal government responsibility to take charge of spent fuel that is subject to such restrictions to come from sources other than the Nuclear Waste Fund.

The difference in timing between earlier payments into escrow funds out of other federal revenues versus later payments out of the Nuclear Waste Fund for federal management of spent fuel could have nominal formal impact on the size of the federal deficit. This is because payments into the Nuclear Waste Fund are normally accounted as federal revenues without subtracting out an associated liability. Whether a larger or smaller nominal federal deficit would result depends on how much the approach suggested here would reduce the overall costs of spent fuel management. In any case, whether to allow the use of the escrow fund approach for previous spent fuel discharges in view of potential impacts on the nominal federal deficit is a political decision that if properly handled need not be constrained by technological or legal impediments.

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ISBN 978-0-89206-645-2
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