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Managing Spent Nuclear Fuel

Strategy Alternatives and Policy Implications

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Summary

Nuclear power provides an alternative to coal and natural gas–fired electric power generation that emits far fewer greenhouse gases. As such, increasing nuclear power generation is one approach to reducing emissions of greenhouse gases. However, while nuclear power provides about 20 percent of electricity generated in the United States, no construction of nuclear power plants has begun since 1977. One of the major impediments to increasing nuclear power is the decades-long impasse over how to deal with spent nuclear fuel.

Until 2009, national policy for the management of spent fuel was guided by the path laid out in the 1982 Nuclear Waste Policy Act (NWPA), as amended: Under this act, utilities producing spent nuclear fuel have the option to transfer ownership of the spent fuel to the federal government, which will ultimately dispose of it in a permanent geological repository. The repository would isolate the spent fuel from the environment until it no longer poses a safety or health risk. The federal government was required to be able to take title to the spent fuel in 1998, when the repository was to have been licensed and ready to receive the spent fuel and other wastes from defense activities. In 1987, the NWPA was amended to require that the U.S. Department of Energy (DOE) consider only Yucca Mountain, Nevada, as a candidate for the nation's first repository, eliminating consideration of other candidate sites and provisions for selecting a second repository site, as envisioned in the 1982 NWPA.

To date, all commercial spent fuel remains at nuclear power plants and, despite more than 20 years of effort, the Yucca Mountain repository has not been built or licensed. Several utilities have filed lawsuits against the federal government claiming compensation for costs to store spent fuel after the 1998 deadline. In 2009, the administration eliminated funding for Yucca Mountain, and DOE subsequently filed a motion to withdraw its license application with the Nuclear Regulatory Commission. The cessation of efforts to pursue the Yucca Mountain repository indicates the need for a major policy review. In January 2010, the U.S. Secretary of Energy established the Blue Ribbon Commission on America's Nuclear Future to provide recommendations for managing spent nuclear fuel and other nuclear wastes.

If nuclear power is to be sustainable and accepted by the public, the nation must agree upon a solution to the spent–nuclear fuel problem that convincingly meets safety

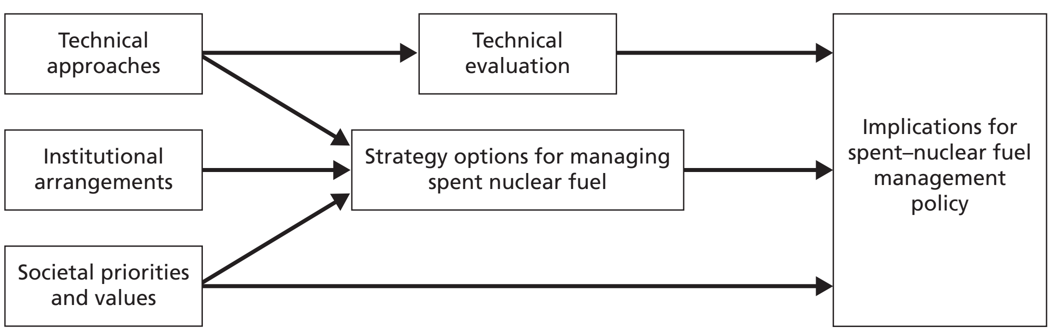
and environmental standards. What are the alternatives for safely managing, storing, and disposing of spent nuclear fuel, and how can they be characterized in a way that provides a better understanding of the trade-offs and policy implications of the alternatives?

There is an international consensus that no existing or currently conceived future technology can eliminate the need for one or more geological repositories for long-lived radionuclides. Permanent geological disposal does not need to occur immediately, however, and technical options exist that can buy time for an incremental approach to repository development and possibly also change the characteristics of the waste.

The objective of this monograph is to review the current status of the main technical and institutional elements of spent–nuclear fuel management and to identify the implications for the development of spent-fuel management policy. We examine policy implications in the context of a range of possible strategic approaches. While the strategies considered span much of the range of options currently being considered, we do not comprehensively evaluate all policy options nor attempt to recommend a particular policy approach. Due to the limited time available for this research, we chose to focus on commercial spent fuel exclusively and not to deal with the additional question of the disposition of defense nuclear waste.

The approach we follow is summarized in Figure S.1. Analysis of the key technical approaches and institutional arrangements associated with spent–nuclear fuel management, along with consideration of societal preferences, leads to a set of strategy options. The strategy options are then compared in the context of the technical evaluation and societal preferences to elucidate implications for spent–nuclear fuel management policy.

Figure S.1
Summary of Analytical Approach



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Technical Approaches to Spent–Nuclear Fuel Management

We examine four categories of technical approaches that comprise the essential approaches of any long-term strategy for spent–nuclear fuel management:

- surface storage technologies at existing nuclear plant sites (on-site storage)
- centralized interim storage away from plant sites
- advanced fuel cycles with spent-fuel recycling
- permanent disposal in a deep geological repository.

Any strategy for managing spent nuclear fuel will be built around combinations of these options, and all strategies must ultimately include permanent geological disposal.

To better understand these approaches, we consider them first as stand-alone technologies. We apply five criteria that cover many of the key concerns about nuclear power voiced in public debates and in the academic literature: safety, security, technical obstacles, public acceptance, and cost. Focusing initially on impacts over the next 20 to 30 years, we summarize the results of our evaluation of each approach in Table S.1. The evaluations are necessarily qualitative, and there is considerable uncertainty tied to them. The intention is to identify major distinctions between the approaches for each criterion when these technologies are viewed in isolation and relative to ultimate disposition of spent fuel or its derivatives in a geological repository.

In the case of advanced fuel cycles, we also examined the potential impacts on capacity requirements and environmental risk for a geological repository and uranium resource requirements.

Table S.1
Evaluation of Technical Approaches to Managing Spent Nuclear Fuel

Criterion	Continued On-Site Storage	Centralized Interim Storage	Advanced Fuel Cycle	Permanent Geological Disposal
Safety risk	Low	Low	Uncertain	Low
Security risk	Low	Low	Uncertain, potentially low	Low
Technical obstacles	Low	Low	High	Moderate
Public acceptance challenges	Moderate in general, but higher at decommissioned sites	Low near nuclear power plants, but likely to be higher near interim storage sites	High at site-specific level and likely high unless permanent geological disposal resolved	High at site-specific level, but much lower nationally
Cost	Low	Low	High	Moderate

Important findings from our analysis of technical approaches are as follows:

- In most cases, there is no pressing urgency to remove spent fuel from nuclear power plant sites—on-site storage is safe, secure, and low cost, and space limitations are generally minimal. An exception is "stranded fuel" at decommissioned reactor sites, where removing the spent fuel would allow redevelopment of the site.
- Centralized interim storage is anticipated to be similarly safe, secure, technically straightforward, and low cost.
- Advanced fuel-cycle technologies are in the early research stage, and implementation will require several decades of substantial funding before they could become viable at a commercial scale.
- Some advanced fuel-cycle configurations have the potential to significantly reduce geological repository capacity requirements (though this gain will be partially reduced by an increase in radioactive process wastes) but will have little benefit in terms of reducing a repository's long-term safety and environmental risk.
- Technical obstacles to developing a permanent geological repository that meets current regulatory requirements are likely to be surmountable; however, past experience shows that public acceptance and trust in the organizations charged with implementing a technological solution might be more challenging.

Institutional Issues

We evaluate the capacity and performance of the current institutional framework beyond the simple question of success or failure in siting a repository with the aim of establishing a baseline against which to consider the value of change. We employ two categories of factors for this evaluation:

- organizational competence and capacity
- performance of decision processes.

In the context of the national policy of siting a permanent repository, our assessment indicates that DOE, the Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC) have largely performed as Congress directed them to—albeit at a much slower pace than originally anticipated, incurring vastly higher costs, and with some large procedural and technical errors. What mattered more in terms of outcomes were (1) the collapse of the original NWPA consensus for an eastern and western repository and the consequent sole focus on Yucca Mountain; (2) poorly aligned incentives and institutional conflicts of interest that led to a loss of public confidence and gridlock; and (3) the overarching policy under which these agencies labored of driving toward repository siting at the expense of a more comprehensive plan for aboveground, long-term storage and a more incremental approach to repository development.

Moving forward, changes in the institutional framework need to be carefully considered in the context of national policy on management of spent fuel. However, according to our analysis, two major institutional changes merit closer examination to determine whether they would facilitate whatever course of action Congress and the administration choose to pursue, including maintaining the status quo:

- reconsideration of ownership of spent fuel and financing of expanded on-site storage facilities in the absence of a permanent geological repository
- reassessment of organizational responsibilities for managing spent-fuel resources.

All spent-fuel management strategies require utilities to maintain and expand on-site storage for an extended duration. As such, the government's liability for failing to take possession of spent fuel at operating and decommissioned plants will continue to mount unless some change in policy or practice is made. The federal government cannot unilaterally change the terms of the contracts with the utilities with regard to waste acceptance. However, changes in the NWPA could be implemented that would offer utilities an alternative approach to funding long-term on-site storage and, at the same time, would relieve the government of the obligation to take title to the spent fuel immediately. Under an arrangement with strict NRC regulation, the government would place the funds required for long-term storage into separate interest-bearing escrow accounts for each power plant. Utilities would continue to own the waste, but they would also gain control of the funding and have incentives to manage waste storage efficiently, including transport from decommissioned to still-operating plants. Changing this one area of the law would provide the government and industry with significantly more flexibility and potential cost savings than presently exists, and remove a significant impediment to strategies that require more time for research, development, and implementation.

These changes in funding and managing on-site storage might be necessary but still insufficient to fully resolve the waste acceptance issues. For this approach to be feasible, the public and the industry are likely to still need credible assurances in law that progress will be made toward the federal government taking ownership and possession of spent fuel over the next several decades through dedicated funding and transparent, sustainable, and competent organization and management. To further mitigate the effects of eroded public trust and of poorly aligned incentives within the existing framework, it is likely that any new spent-fuel management strategy will have more credibility if it is managed by a new organization outside of DOE. Such an organization could take several forms: public, private, or a public-private hybrid like, for example, a public corporation.

Policy Implications

The recent termination of funding and DOE's effort to withdraw its license application for Yucca Mountain reflect the realization that spent–nuclear fuel management policy in the United States needs to be reexamined. For moving forward, we consider four policy strategies built from combinations of the technical approaches. Each strategy would ultimately lead to the siting and licensing of a permanent repository, but the strategies differ on when and how that goal would be reached. In Table S.2, we identify these strategies by their key near-term (five to ten years) actions related to storage, fuel recycling, and disposal.

Each strategy differs in its focus and concentration of resources in the near term. In any strategy, on-site storage will continue for at least the next decade, and, in some strategies, it might continue for many decades. Although it is impossible to predict timescales with confidence, past experience and the current state of technology suggest that licensing Yucca Mountain or a centralized interim storage facility would take at least a decade, a new permanent geological repository would take two or more decades, and implementing advanced fuel cycles would take many decades. Moreover, even after the capacity for centralized storage, disposal, or recycling becomes available, it will take decades to complete the shipment of spent fuel currently stored at nuclear power plant sites.

The proposed strategies are not intended to represent a comprehensive menu of options but rather were chosen to span a range of approaches and to elucidate some important policy implications of different approaches. To help inform policy deliberations, each strategy is examined in terms of the societal priorities for spent-fuel man-

Table S.2
Strategies for Spent–Nuclear Fuel Management

	Near-Term Actions Related to		
Strategy	**Storage**	**Recycling**	**Disposal**
Expeditiously proceed with Yucca Mountain	Maintain on-site storage until Yucca Mountain available	Maintain current level of advanced fuel-cycle research	Open Yucca Mountain
Develop centralized interim storage in conjunction with permanent geological disposal	Develop centralized storage facilities	Maintain current level of advanced fuel-cycle research	Pursue alternative sites
Pursue advanced fuel cycles	Continue expansion of on-site storage or develop centralized storage facilities	Aggressively expand advanced fuel-cycle development efforts	Do not commit to any particular time plan or site
Maintain extended on-site storage	Continue expansion of on-site storage	Maintain current level of advanced fuel-cycle research	Do not commit to any particular time plan or site

agement that would need to prevail in order for it to be favored, the implications for the welfare of future generations, and the implications for the future of nuclear power in the United States.

Spent-Fuel Management Priorities That Would Favor Different Strategies

The different policy alternatives can have widely differing implications in terms of societal priorities for spent–nuclear fuel management. If the view that we are obligated to provide the capability to dispose of spent fuel as quickly as possible prevails as a top priority, because we believe either that disposal should not be left for the future or that we need to demonstrate the feasibility of the entire fuel cycle before undertaking further development of nuclear power, then proceeding with Yucca Mountain is the best choice. This strategy would also fulfill the federal government's obligation to take possession of spent fuel and pave the way for the expansion of nuclear power. If the main priority is more oriented toward enabling the expansion of nuclear power and a premium is placed on confidence in the decision process related to repository development and performance, then the staged strategy that combines centralized interim storage and siting a new permanent geological repository would be more attractive. Strong support for a very large increase in nuclear power, which could ultimately place a premium on repository capacity and uranium resources, would favor recycling spent fuel with an advanced fuel cycle. Finally, if the prevailing view is that uncertainty regarding repository performance, safety, security, cost, or public and political acceptance of nuclear power looms large enough, then continued on-site storage might be appropriate.

Implications for Future Generations

The strategy alternatives have widely differing implications in terms of trade-offs of responsibilities between current and future generations. A clear distinction is that the different strategies reach different states in terms of progress toward final disposition of spent fuel. Proceeding with Yucca Mountain or the staged storage-repository strategy provides a solution for final disposal in the relatively near term. Depending on the details of the technology chosen, pursuing advanced fuel cycles could leave future generations with significantly decreased repository capacity requirements. However, a substantial investment over an extended duration and with a highly uncertain outcome would be needed to realize those benefits, and other waste products generated from the processes might require deep geological disposal as well. Continued on-site storage leaves the entire burden of disposal for the future.

A related distinction is the level of uncertainty left for future generations. The Yucca Mountain and storage-repository strategies leave the least uncertainty. Pursuing the advanced fuel-cycle alternative would provide future generations with more information on the viability, safety, and security of this approach. But if this is done at the expense of pursuing centralized storage or a permanent repository, future generations will have less information than might be desirable to implement these moreconventional and more-likely options. Also, given the different potential approaches and objectives of advanced fuel-cycle technologies, it is not a given that this strategy would ultimately provide large benefits in terms of reducing repository requirements. Maintaining continued surface storage prolongs the existing uncertainty about how best to manage spent nuclear fuel.

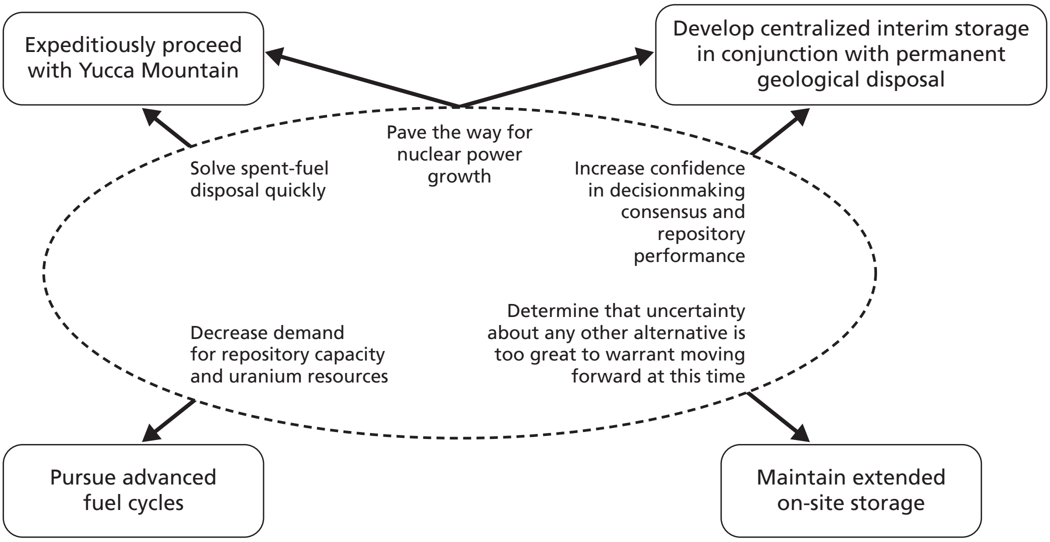
Implications for the Future of Nuclear Power

Expeditiously proceeding with the licensing of a repository at Yucca Mountain and the storage-repository strategies would have the greatest positive impact on the future of nuclear power because they would most swiftly allow the federal government to fulfill its contractual obligation to take possession of spent nuclear fuel now owned by the utilities. This would remove impediments to growth based on spent-fuel concerns. The advanced fuel-cycle strategy could help clear the way for new nuclear power plant development if it included mechanisms to improve the terms for ownership and financing of continued surface storage of spent fuel. Finally, in prolonging the indecision about spent-fuel management policy and potentially complicating new reactor licensing, continued on-site storage does nothing to facilitate growth in nuclear power and might have a negative impact by complicating the ability to license new reactors.

Distinguishing the Strategies

The selection of policy alternatives ultimately depends primarily on societal preferences about the disposition of spent fuel, the growth of nuclear power, and intergenerational trade-offs. This analysis highlights the implications of each strategy in the context of these societal preferences. The findings do not perfectly distinguish the different strategies according to unique societal preferences—some priorities are consistent with multiple strategies, and some strategies are consistent with multiple priorities—but they help restrict the range of combinations. The association between the strategies and several possible priorities is shown in Figure S.2. Aggressively pursuing advanced fuel cycles is attractive primarily if constraints on repository capacity or uranium resources are important. Maintaining extended on-site storage is attractive only if all other options are deemed unacceptable. Proceeding with Yucca Mountain or the centralized storage–geological disposal strategies is most attractive when facilitating the growth of nuclear power and not leaving spent-fuel disposal for future generations are the top priorities; choosing between them depends on how important it is to increase confidence in decision consensus and repository performance. Choosing a strategy thus entails assessing these preferences among stakeholders: it might be difficult to achieve a consensus. It is likely that no single strategy will satisfy all stakeholders in all three dimensions that we examine. However, in bringing the multitude of technical and institutional considerations together in the form of a limited set of preferences, we hope this analysis will contribute to consensus building and help guide that decisionmaking process.

Figure S.2
Association Between Strategies and Possible Societal Priorities



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