Spent Nuclear Fuel Management: How centralized interim storage can expand options and reduce costs

A study conducted for the Blue Ribbon Commission on America's Nuclear Future

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I. Executive Summary

Centralized interim storage of spent nuclear fuel is an old idea worthy of fresh consideration in light of the challenges facing the U.S. nuclear industry. A commitment to pursue centralized interim storage for spent nuclear fuel could prove invaluable in meeting challenges and lowering costs in the years ahead. A permanent repository, already decades behind schedule, is not imminent, leaving the Department of Energy (DOE) subject to legal claims that might lead to damages of billions of dollars. Meanwhile, a wave of reactor decommissionings looms on the horizon, which will drive a dramatic increase in the cost of storing and managing spent fuel at existing reactor sites. The spent fuel must be moved eventually. The technological and political hurdles in the transport, storage, management and ultimately, disposal of spent fuel are considerable, resulting in substantial uncertainties over the costs that will be incurred and the time it will take until the spent fuel reaches its final disposition. The U.S. nuclear industry is striving for a rebirth after decades without any new construction, but the lack of progress by DOE in accepting spent fuel adds an unwelcomed complexity to moving forward. On top of all this, spent fuel stored in pools played a major role in the accident at Fukushima Daiichi—and several times more spent fuel is stored at most U.S. reactors than were at the Japanese reactors. While the circumstances of that accident may be unique, the fundamental questions it raises about the reasonableness of our spent fuel program are valid. Simple questions, such as "Why have we allowed our spent fuel to be managed in this fashion?" are increasingly difficult to answer.

A step forward in managing spent fuel could be achieved by the development of a centralized interim storage facility. Such a facility would allow fuel to be moved away from reactor sites, as DOE would accept the fuel and consolidate it at one or more sites in the U.S. This would finally provide DOE with the means of meeting its long-overdue obligations to begin accepting the fuel under the so-called standard contracts it signed with nuclear utilities in the early 1980s. It is particularly to consider this option now as storage costs at operating reactors will increase dramatically as those reactors retire in the coming years, and actions are needed in the near future to limit the coming wave of increased costs that will ultimately be passed on to taxpayers. The consolidation of spent fuel under DOE control creates opportunities beyond merely holding fuel, as it can contribute to the overall spent fuel management program in several ways. Benefits could include added safety and added capabilities at a centralized location that would not be available at reactor sites across the nation. These might include spent fuel handling capabilities to get the fuel ready for the permanent repository. They might include capabilities to support reprocessing, if fuel management priorities move in that direction. Should the fuel storage systems eventually require modifications, it will be more efficient to implement them at one or two centralized sites rather than the 70 storage sites scattered across the nation where the spent fuel currently resides.

The purpose of this study is to assist decision makers in evaluating the centralized interim storage option. We explore the economics of centralized interim storage under a wide variety of circumstances. We look at how a commitment to move forward with centralized interim storage today could evolve over time. And, we evaluate the costs of reversing a commitment toward centralized storage if it turns out that such a decision is later considered a mistake. We have not conducted independent analysis of cost elements, drawing instead on the work of others, but we compare and contrast these other cost studies to gain an appreciation of the uncertainties. While we conduct many analyses, our purpose is not to provide a single value or estimate of the incremental costs/savings of centralized storage. Instead, we present analyses to inform decision makers of the nature of costs under a wide range of circumstances. We find that the risks and benefits of today's decision are asymmetric: a centralized interim storage facility could prove invaluable, but under other circumstances the downside is relatively modest—if the facility is not needed total expenditures can be limited.

The full deployment of a centralized interim storage option will cost billions of dollars. In one estimate the total costs are over $7 billion (non-discounted, 2009 dollars), assuming a centralized facility in 2020 and a repository in 2050. Whether this $7 billion expenditure lowers the total costs of spent fuel management depends on many factors, some of which will be unknown for decades. Cost savings would come primarily from saving the cost of storing fuel at individual reactors after the reactors have retired. Without centralized storage, at-reactor storage would be necessary until the repository is opened and the additional 45 years or so that is required to move spent fuel away from all of the reactors.

The economics of centralized interim storage have been studied for many years. Studies from the 1980s and 1990s are largely historical documents at this point, but still serve to highlight the long-term interest in removing fuel from operating reactors and providing centralized storage until a final repository is in operation. Several studies from recent years provide insights into the centralized storage option; these studies serve as a foundation for this report. All of these studies adopt an assumption that a commitment is made for the full deployment of the envisioned centralized storage option, without the ability to modify and evolve over time in response to developing circumstances. The conclusions reached in these studies are somewhat mixed. The results are particularly sensitive to assumptions made about ongoing costs of operations, including the cost of operating stand-alone storage facilities at individual reactor sites, the cost of operating the centralized facility, and the cost of shipping fuel over many decades. The degree of uncertainty over such issues is substantial, because spent fuel management involves actions taken at a scale that is unprecedented. Spent fuel has been shipped before, for example, but never at the scale needed to meet DOE's obligations. Even the time needed to site, design, license and build a centralized storage facility is highly uncertain, with the referenced studies offering assumptions that range from four to 33 years.

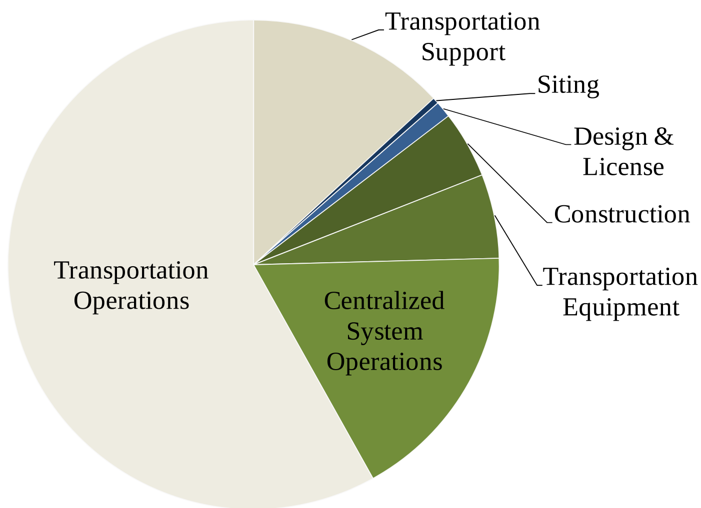
Analyses of the centralized storage option typically consider total costs over a long time horizon, both with and without the centralized interim storage. This approach, while routinely practiced and useful in many circumstances, has limitations. The attempt to develop a comparison of costs with and without centralized storage can even be counterproductive, because it masks the many uncertainties inherent in the analyses.

A more fundamental problem with such analyses is that they tend to treat this as a single decision that will be unchanged over time, so that the analysis fails to capture the value that comes from the ability to modify strategies over time. A decision today puts in motion a direction, but that direction can evolve over time in response to new developments. A decision to pursue centralized interim storage will result in concrete efforts to site, license and design a facility to meet the needs of the overall spent fuel management system. Whether that facility gets built depends on the outcomes of those efforts, the status of the permanent repository at the time a construction decision has to be made and other information that will be learned over time about costs and operating practices. Assuming the facility is built, it might be used in a variety of ways, such as for repackaging spent fuel for disposal, reprocessing spent fuel, or handling a variety of other issues involving the handling of spent fuel in coming decades. Thus, development of a centralized storage facility creates valuable options. Not pursuing centralized storage today, of course, does not preclude its development in the future; it delays the date at which these options become available and limits the benefits that can be realized. That is just one of the factors that complicate this analysis.

The value provided by a decision to pursue centralized interim storage comes from the flexibility it provides under evolving circumstances. If the final repository is greatly delayed, virtually all fuel might be moved away from reactor sites on an interim basis. If it is determined that the fuel canisters need to be opened, perhaps because a technical problem has arisen or because the canisters have reached the end of their design lives, it can be done at a centralized location at a much lower cost than at each individual site. If the repository moves forward quickly, it is relatively easy to scale back the operation of the centralized storage facility. Plans can also be adjusted if costs are substantially different than expected.

Decision makers should not assume they know with certainty how a centralized interim facility will be used in the decades ahead. Fortunately, today's decision concerns just a small part of the total cost of centralized storage and a very modest expenditure relative to the overall costs of spent fuel management. The only commitment that can be made at this time is for the tens of millions of dollars to site, license and design a facility. The decision on construction, full implementation of centralized storage and a variety of other capabilities such a facility could provide will be made in the future. Today, all that can be done is to give those future decision makers an option that they will not have until the first steps are taken.

Total Cost of Centralized Interim Storage



We do not attempt to calculate a single cost or net cost-saving figure for comparison and decision-making. Economics is just one element of the decision and a single figure tends to mask the complicated considerations, particularly those that do not readily lend themselves to economic quantification. Our analysis indicates that in some circumstances, centralized interim storage could produce cost savings of billions of dollars. From the perspective of non-quantifiable benefits, centralized interim storage appears to have substantial additional value. On the other hand, it does not appear that there are viable scenarios where the pursuit of centralized interim storage results in substantial increases in costs. Such outcomes would only occur if decision makers continue to pursue centralized interim storage when it because clear that it is far more costly than expected. It is not reasonable to assume that future decision makers continue to blindly implement the strategy in the face of unexpectedly high costs. Therefore, the downside of pursuing centralized storage is not as costly as might be expected from an analysis that assumes there is no opportunity to adjust strategies. The decision today concerns the tens of millions of dollars for siting, designing and permitting a facility; it has the potential to save billions under some circumstances, but the downside risk is largely limited to the direct spending necessary to develop the option.

Our analysis is intended to support the decision process, but not provide an all-encompassing, fully quantified basis for the decision itself. Decision makers need to set their sense of priorities and weigh issues of equity in their analysis. Some will conclude that the obligations of the US government in establishing the national waste management program are absolute. To them, with the permanent repository program far behind schedule and currently in disarray, centralized storage provides a means of compliance and should be pursued. Others will weigh additional factors.

History has shown that permitting and constructing such facilities is plagued by uncertainty. Actions taken to move forward and resolve those uncertainties will improve the ability to manage spent fuel in the future through the learning that should be expected in the process. If built and put in operation, actual performance will provide a trove of information about costs and operating complexities that are the subject of large uncertainties at present. Decisions about full deployment of centralized storage will inevitably be made at a future time, when far more is known about costs and implications. More will also be known about the perceived benefits of moving fuel from reactor sites and consolidating it in dedicated facilities. And, if we fail in the attempt to develop centralized facilities because of such problems as the inability to find a willing host site, that will be known as well.

Decisions regarding spent fuel management involve billions of dollars spread over many decades, if not centuries. As indicated in the pie-chart above, the substantial majority of those costs involve transportation, transportation support and operations. These costs are incurred as fuel is moved, and since the centralized facility allows for much earlier movement of spent fuel, this option moves forward in time massive costs that would have been incurred anyway when fuel is eventually moved. Significant questions concerning discount rates and intergenerational equity become very important in the economic analysis and in the decision more generally. The cost savings provided by centralized storage can change dramatically under different discount rate assumptions that are within the range some might consider appropriate for this analysis. Discount rates are not uncertain in the same manner as future costs, but instead are part of the criteria decision makers need to establish in evaluating the options. Some will consider issues of intergenerational equity to be of substantial importance. As today's generation is the beneficiary of the power that created the waste, it is only appropriate that future generations should not be unduly burdened with that power's costs. A portion of our analysis uses low intergenerational discount rates to assist in evaluation from this perspective. Others will approach this decision from the perspective of more typical business investment analysis. They would ask whether a decision to pursue centralized storage now will reduce DOE's expected cost of the overall spent fuel management program. To support this approach, we conduct analyses with a higher discount rate.

Our analysis is limited by the degree of uncertainty in critical areas. The largest such uncertainty is the start date of the permanent repository. Less notorious but similarly vexing uncertainties concern such things as the cost of transporting spent fuel. Spent fuel has been shipped before, but never with the scale of operations needed here. It is easy to lose sight of the fact that the transportation cost assumptions developed for analyses like ours will be used for movements that take place over 50 years or more and could stretch into the next century, involving transfers from some 70 different locations, many requiring specific infrastructure improvements and other complex issues. In reviewing the various studies it seems that there is no consensus on these costs, let alone agreement over how they might change over time. And it must be recognized that in most cases we are making billion dollar assumptions about the cost of moving fuel without even knowing the fuel's destination. For all of these reasons, caution is urged in using these transportation cost projections from these or other studies.

Our goal is to inform decision makers about the various considerations and implications of centralized storage. At the risk of oversimplification, their conclusions may rest on their philosophical outlooks. Pursuit of centralized storage now will appeal most to those frustrated by decades of inadequate progress, pessimistic about dramatic changes in the future, concerned about safety issues, lacking confidence about the ease with which any spent fuel program can be implemented or optimistic in the belief that the benefits that come from attacking the problem will outweigh the costs. On the other hand, a decision to defer commitment will likely appeal to those optimistic about progress on a repository, confident that a centralized facility could be built quickly at a later time and confident that spent fuel shipments at high annual volumes can be made when needed. We say "defer commitment" because no decision will preclude the opportunity for reconsideration in later years. Mixed in through all of this will be personal views on such technical issues as the appropriate discount rate to use and views concerning the degree of technological change over time.

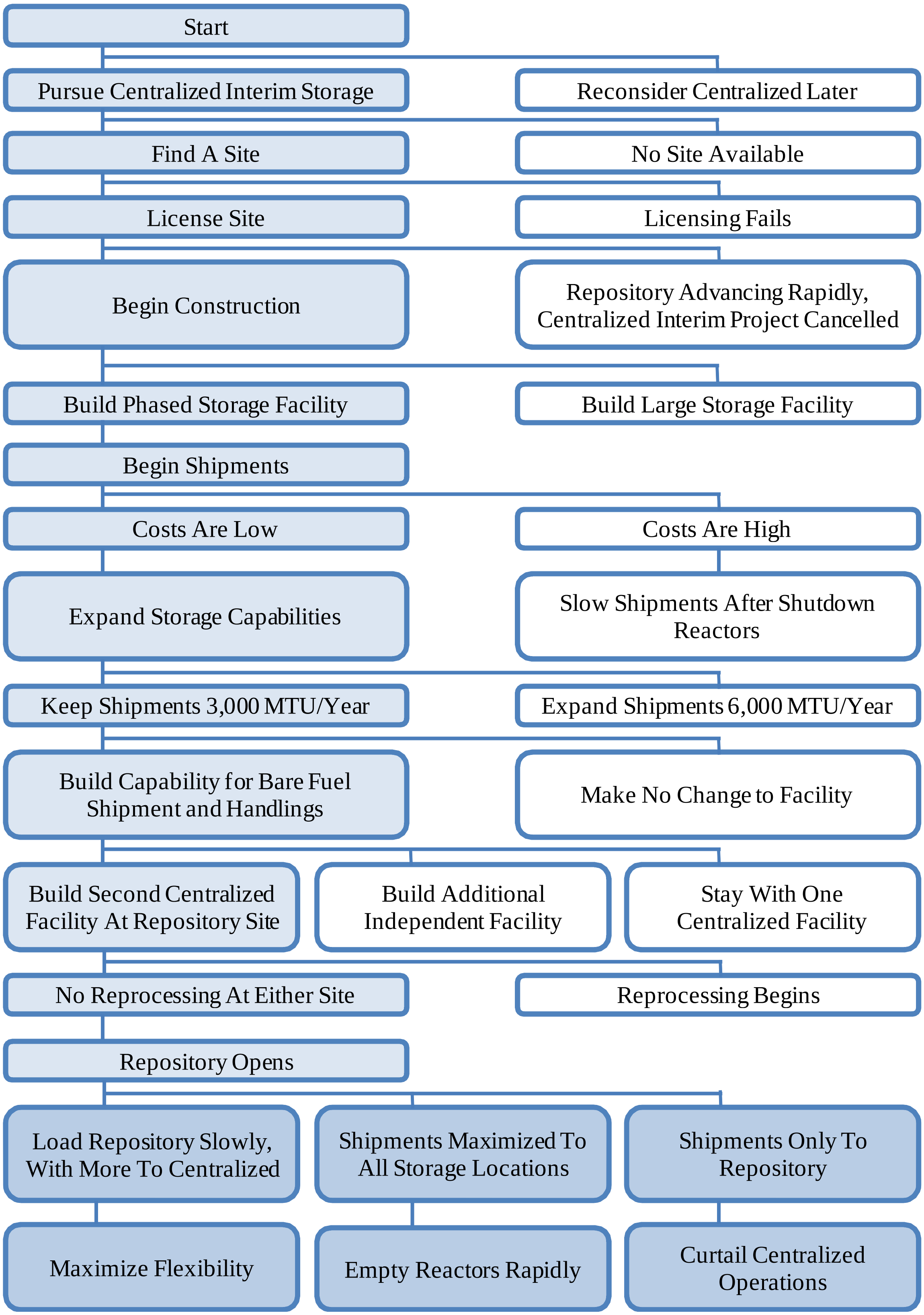
This is a complicated issue. We hope our analysis helps those facing this challenge.

II. A Conceptual Framework for Evaluating Centralized Interim Storage

Conventional decision analyses involve looking at the costs and benefits of a decision, in this case the adoption of centralized interim storage for spent nuclear fuel. Typically, such analyses include a cost comparison of the two options. Where there are uncertainties, they can be dealt with in various ways, such as by choosing conservative assumptions or by developing probability-weighted expected values. Such analyses can be helpful, and several studies have been completed that address spent fuel storage issues on this basis. The challenge with spent fuel management analyses is the wide range of uncertainties that exist across a very long timeframe. Some of these uncertainties relate to not knowing exactly what may be required in managing spent fuel and not knowing how future decision makers will modify the spent fuel program over time. Long term projections based on a single decision point are inadequate and potentially misleading.

This study adopts a different approach. The focus here is on the decision itself, and the implications of that decision on the ability to deal with the many uncertainties that lie ahead. Among other things, this approach recognizes that today's decision can be changed over time. A commitment to centralized interim storage can be reversed at a later time, just as a decision to not pursue it now can be changed in the future. Reversing a decision at a later time does not produce the same outcome, of course, as time lost cannot be regained. The partial decision tree that follows demonstrates the kinds of issues that are likely to arise over time following a decision to pursue centralized storage. It is not meant to be all-inclusive, but only indicative of the kinds of considerations that will arise based on following a single path of a decision and other developments over time. We discuss each of these issues and decisions in this report, as well as others.

One Possible Path For Spent Fuel Management

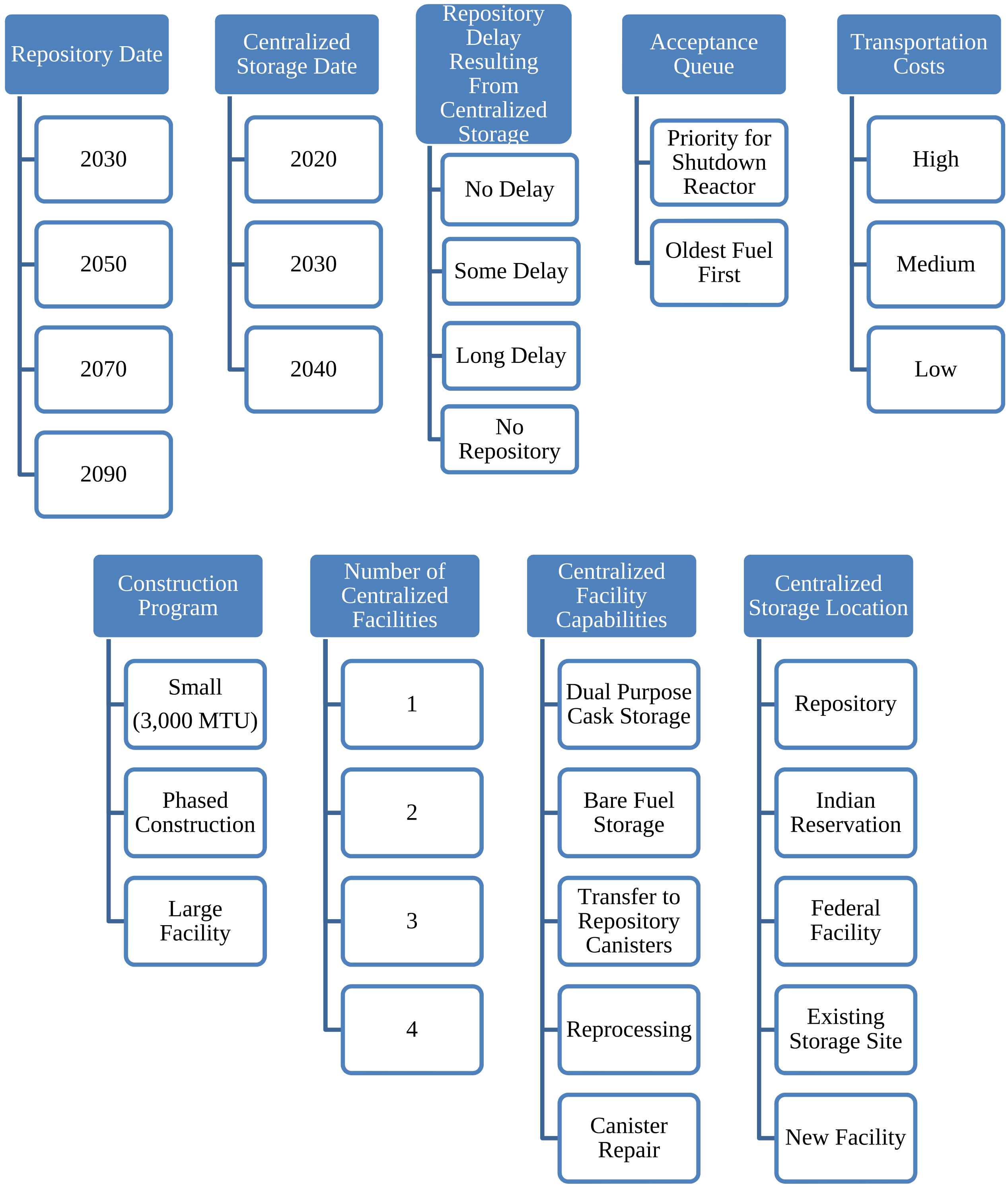


If the decision to proceed with centralized interim storage is made, however, there will be two important benefits. First, since development of this option will take time, the decision will move us closer to actually having such a facility. Second, in taking actions to develop a facility we will learn a great deal about what it will cost and how it will be configured. In this light, we can think of a decision toward centralized interim storage as the creation of an option, with today's decision being: Should policymakers work to move forward with the centralized interim storage option now, so that it can be deployed in the future?

A decision to pursue centralized interim storage now does not result in a permanent decision for spent fuel management for decades to come. Over time, decisions are reconsidered and other options will be explored. By analogy, this decision should not be viewed as the launch of an unguided missile that is destined to land on target 100 years in the future, without opportunity for a change in course. Instead, this decision should be viewed as the start of a journey headed to the same location, but with the expectation that there will be detours and quite possibly changes in the destination over time. The decision needs to be justified on the basis of the costs and benefits of taking the first steps, considering the range of possible outcomes over the long term, without necessarily knowing the exact outcome that is expected. We can also look at the decision as the purchasing of insurance. Do we want to spend money now to ensure we have a centralized storage facility in the future if we really need it?

The chart below identifies many of the uncertainties and decisions that will arise with centralized storage. While the decision tree presented above showed a single path based on a hypothetical set of decisions and outcomes, the graph below summarizes many of the issues that might arise. It is not a single path, but a summary of many of the uncertainties and choices that confound the decision analysis. All of these issues are discussed later in the report.

Centralized Interim Storage Uncertainties



The most obvious and largest uncertainty associated with spent fuel management is the timing of the permanent repository. Originally scheduled for 1998 and later designated to be built at Yucca Mountain in Nevada, the facility is long overdue and its location is uncertain. Evaluating centralized storage options would be much easier if the start date were known, but we may not know this for quite some time. Arguably, the start date may not be known until very close to the facility opening because, even with progress in construction, there is the potential for delay for political reasons. The uncertain status of the facility following nearly thirty years since the initial Act was passed in 1982 provides compelling evidence of the difficulties in predicting when the facility will come on line. Currently, some forecasts are for as early as around 2030, but others are less optimistic. A recent Government Accounting Office report considers the possibility of a hundred years, or many hundreds of years, before the facility starts operating. While the U.S. has a stated policy goal of moving the fuel to a permanent geological repository, it is conceivable that by default some form of interim storage may be used for a very long time. The date of the permanent repository bears heavily on analyses of the life-cycle costs of spent fuel management with and without centralized interim storage. Rather than picking a repository date and evaluating storage costs based on that assumption, our approach is to evaluate the implications of a range of repository dates on the interim storage decision. In short, given that the repository date cannot be known for certain, we look for the implications this uncertainty has on the centralized interim storage option. We also consider the possibility that construction of a centralized storage facility will take pressure off the construction of a permanent repository and allow some delay its implementation.

We use this approach in evaluating many critical uncertainties. Some uncertainty will only be resolved when we move forward. For example, while there are many uncertainties associated with trying to locate, license and build a centralized, interim storage facility, the one sure way to resolve these uncertainties is to go out and try to build one. As progress makes available better estimates of the cost of centralized storage, there is the potential to change course. Shipments to centralized storage facilities can be stopped if costs turn out to be too high. The design and nature of the centralized facility can also change over time, prior to construction and even after it commences operation.

One uncertainty that will be better understood over time even without progress on centralized interim storage is the cost of storing spent fuel at reactor sites after they have been otherwise decommissioned. We call this situation stranded storage, and the cost of stranded storage is the primary economic motivator in consolidating spent fuel locations because it costs almost as much to monitor fuel at a single reactor site as it would to monitor all spent fuel in the country if it were located in the same place. Some data on the cost of stranded storage is already available, but estimates going forward vary widely, with some estimates nearly twice the cost of others.

In several instances, we conduct sensitivity analyses to highlight the factors that have significant influence on the analyses. In our base case, we tend to adopt conservative assumptions that make centralized storage appear less favorable. In addition, there are other factors to consider that may not be easily quantified in our economic analyses. Those issues are discussed. Decisions need to be made on the basis of all important considerations, not just those economic considerations that can be quantified. Our focus is economic, but our attempt is to provide a framework for the consideration of all relevant factors.

The spent fuel management costs in this analysis will be borne by DOE as a result of either meeting the requirements of, or damages as a result of breach of, the standard contracts for spent nuclear fuel. The soonest reasonable date at which DOE might start picking up spent fuel is around 2020, a point at which it is virtually assured that all incremental costs associated with putting the fuel in dry casks will be borne by federal taxpayers through payments from the federal Judgment Fund for damages resulting from breach of the standard contract. The costs we analyze for spent fuel management will either come from the Judgment Fundo or from the money utilities have already paid under the standard contract. As a result, while we evaluate total costs of various options, it is likely that any of the cost savings from centralized storage will accrue almost entirely to taxpayers via DOE, and those that do not will benefit the utilities.

While we recognize legislation will be needed to support these actions, we do not deal explicitly with what changes will be needed. Passing new legislation is critical, and is assumed to occur as part of the process of implementation.

III. A Review of Other Studies of the Centralized Interim Storage Option

The potential for benefits from a centralized, interim storage facility have been recognized for almost as long as there have been efforts to build a permanent repository. Beginning in the mid-1980s, studies have evaluated the potential benefits centralized interim storage could provide.

1. "Comments of the Department of Energy's Mission Plan for the Civilian Radioactive Waste Management Program," Oceans and Environment Program, Office of Technology Assessment, September 13, 1985.
2. "Nuclear Waste: Is There A Need for Federal Interim Storage?" Monitored Retrievable Storage Review Commission, November 1, 1989.
3. "Disposal and Storage of Spent Nuclear Fuel – Finding the Right Balance," Nuclear Waste Technical Review Board, March 1996.
4. "Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites," Office of Civilian Radioactive Waste Management, U.S. Department of Energy, December 2008. (DOE 2008.)
5. "Cost Estimate for an Away-From-Reactor Generic Interim Storage Facility (GISF) for Spent Nuclear Fuel," Electric Power Research Institute, J. Kessler Project Manager, E. Supko Principal Investigator, May 2009. (EPRI 2009.)
6. "GNEP Deployment Studies, Final Business Plan Report, Revision 3, Integrated Used Fuel Management, A Strategy for the Disposition of the Nation's Used Commercial Nuclear Fuel," Alan Dobson, Energy Solutions, Shaw, Booz Allen Hamilton, September 30, 2009. (GNEP 2009.)
7. "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," Government Accountability Office, GAO-10-48, November 2010. (GAO 2009.)
8. "Key Issues Associated with Interim Storage of Used Nuclear Fuel," Andrew C. Kadak and Keith Yost, Advanced Nuclear Energy Systems, MIT, December 2010. (MIT 2010.)

Over a little more than the past two years, there have been five significant studies that address economic aspects of centralized interim storage options. Three of those studies involve evaluations of the cost of centralized interim storage relative to scenarios where the centralized facilities are not built (DOE 2008, GAO 2009 and MIT 2010) while the other two focus primarily on the cost of centralized storage itself (EPRI 2009 and GNEP 2009). All of these studies are premised on a number of assumptions regarding the timing of the permanent repository, the timing of an interim facility, numerous cost assumptions, and a variety of other factors. The DOE 2008 study concluded that a centralized facility for the currently shutdown reactors would increase total costs over the entirety of the repository program. The GAO 2009 report takes a Monte Carlo approach to evaluating the costs of spent fuel management with and without centralized storage under various scenarios and with consideration of a range of uncertainty for many critical assumptions. At the risk of oversimplification, the GAO 2009 study does not draw a firm conclusion whether centralized storage would lower total costs or not, as it finds a great deal of cost overlap between the two options. Finally, the MIT 2010 study provides analyses of the potential cost savings from centralized storage and concludes that consolidation of fuel currently held at the nine nuclear reactor sites where the power plants have been retired will produce cost savings.

The EPRI 2009 study focuses on the costs of an interim storage facility, but does not draw conclusions regarding the costs and benefits of an interim facility as part of an overall spent fuel management program. Similarly, the GNEP 2009 study focuses only on the cost of interim storage. The MIT 2010 study, I will note, also provides cost data for the Private Fuel Storage[1] initiative.

All of these studies contribute to an understanding of the centralized interim storage option. Each has different assumptions for the manner in which a centralized facility(ies) will be deployed over time. In DOE 2008, interim storage is provided for the roughly 2,800 MTU[2] currently stored at the nine sites whose reactors have been permanently shut down. EPRI 2009 considers centralized interim storage of 40,000 MTU, with alternate capacities of 20,000 MTU and 60,000 MTU considered. GNEP 2009 evaluates a 30,000 MTU facility. GAO 2009 considers 153,000 MTU at either one or two facilities and the MIT 2010 study evaluates 3,000 MTU and 40,000 MTU facilities.

Decision makers may find it difficult to draw conclusions from these studies. At a superficial level, they may appear to be contradictory, with the DOE 2008 study concluding that

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1 Private Fuel Storage is a private initiative by a consortium of utilities to develop an interim spent fuel storage facility.

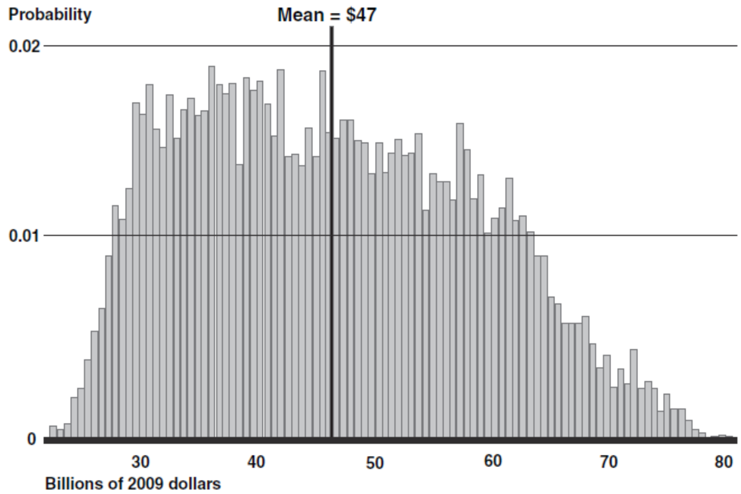
2 MTU stands for metric tons uranium. Some studies focus on metric tons heavy metal (MTHM), which is similar, and we treat as interchangeable to simplify the discussion.

interim storage would not save money, the MIT 2010 study supporting interim storage, and the GAO 2009 study indicating that the range of uncertainty over either alternative appears to overwhelm the analysis. Any study of spent fuel management inherently involves time scales measured in decades (if not centuries) and large uncertainties. The approaches taken to narrow the complexities vary in each study. Assumptions made and structural steps taken in the analyses can substantially influence the perceived conclusions. It is perhaps our strongest conclusion from reviewing these studies that for our purposes, an attempt to develop a single cost estimate for this decision would be inherently problematic and potentially counterproductive.

We draw on the five recent studies in this analysis. Further detail on each will help put them in perspective and provide useful background for our evaluation.

GAO 2009 Report. We rely on the GAO 2009 Report as the primary source of data for assumptions because the data it contains appears most robust and complete relative to our needs. Our analyses differ from GAO 2009 in several critical ways, based on our emphasis of supporting the decision process. The GAO 2009 report studies total costs over the long term for several scenarios. The cost of on-site versus centralized storage is compared under the assumption that a permanent repository opens in 2108. Monte Carlo techniques are used to address many uncertainties, but not the start date of the repository (2108) or the centralized storage facility (2028). The results are shown below. (Note that the x-axes are different, so care is needed in making comparisons.)

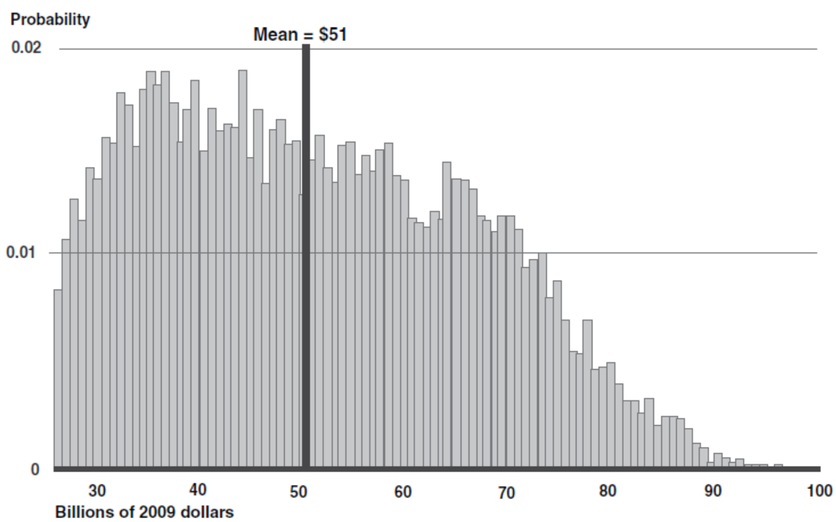
Figure 10: Total Cost Ranges for Centralized Storage for 100 Years with Final Disposition



Source: GAO analysis of expert and DOE provided data.

Note: The values on the horizontal axis of the figure are to provide a scale and do not correspond exactly to the ranges for total costs which are provided in table 8.

Figure 11: Total Cost Ranges for On-site Storage for 100 years with Final Disposition



Source: GAO analysis of expert and DOE provided data.

Note: The values on the horizontal axis of the figure are to provide a scale and do not correspond exactly to the ranges for total costs which are provided in table 8.

The results for both scenarios contain a great deal of overlap, with a mean savings of $4 billion (2009$) with centralized storage. This savings is small relative to the overall cost of the program (10%), and small relative to the range of possible outcomes (roughly $25 billion to $80 billion). While these results give the impression that centralized storage tends to reduce costs, care must be taken in interpreting these results. The analysis was designed around evaluating the potential costs of both options, not to assess the likelihood of savings from centralized storage. Uncertainties in assumptions concerning items such as transportation costs and discount rates produce considerable variation in the ultimate total cost of the program under either strategy, but it is difficult to infer from aggregate cost distributions whether such uncertainties could turn the $4 billion mean savings associated with centralized storage into a loss. For example, some uncertainties might affect both scenarios equally (such as the cost of the repository, although that uncertainty was not included in the study) while others might create differences (such as transportation costs, because fuel has to be moved twice with a centralized facility). And despite including a wide range of uncertainties, some important uncertainties were not studied (such as the potential for a repository before 100 years). The timing of storage facilities is particularly noteworthy as an uncertainty worthy of additional analysis. Lastly, the study does not consider a staged development process for the centralized storage facility that would allow future decisions to reflect circumstances that develop over time. If, for example, transportation costs are very high (driving up the relative cost of centralized storage when fuel has to be moved twice), future decision makers could modify the centralized storage option. They need not stay on a high-cost path.

DOE 2008 Report. The DOE 2008 study of interim storage only considers storing spent fuel from the nine shutdown sites where the fuel either already is in, or will soon be in, stranded storage. These sites are important, but they are only one element of the long-term spent fuel management issue. The study assumes the shipment of approximately 2,800 MTU of spent fuel from these sites to a centralized facility starting in 2015, and then shipment from the centralized facilities to the repository between 2025 and 2028, would have a cost of $743 million, and doing so would increase the total life cycle cost of the entire repository program by an unspecified amount. In reaching this conclusion, the analysis assumes shipments from the storage facility to the permanent repository start in 2025. There is no consideration of a delay, of storing other fuel at the centralized interim facility, of using the centralized facility to lower standard storage costs at other reactors or a host of other options. The study does not even expressly calculate the savings in stranded storage costs at the nine sites that would be shipping fuel to the centralized facility.

MIT 2010 Report. The third comprehensive study that considers the pros and cons of centralized interim storage is the MIT 2010 study. It concludes that actions should be taken to consolidate stranded spent fuel currently at decommissioned sites. The report further concludes that the consolidation of spent fuel from operating plants to a centralized facility is not economically justified at the current time since incremental storage costs at operating plants are low, but states that there will be a need for such consolidation by 2030 as additional reactors retire. While the MIT 2010 report does not deal with the option value of a centralized facility in quite the same way we do here, consideration is given to changing strategies over time in light of new developments. The report gives considerable attention to the implication of different storage location options, and to the potential effect spent fuel reprocessing would have on storage considerations.

The report does not present analyses of the cost of centralized storage as it relates to serving the currently operating reactors as they shut down, and does not consider when actions must begin and the rate at which spent fuel must be shipped to avoid substantial at-reactor stranded storage costs.

IV. The Coming Wave of Stranded Storage Costs at Shutdown Reactor Sites

In response to DOE's failure to begin accepting spent fuel in 1998, dry storage facilities have been constructed at most nuclear power stations in the country, with all 70 sites expected to have them by 2020. The spent fuel is safe, protected and adequately monitored, but the situation is far from ideal as there are large inefficiencies in the current system.

The cost of loading spent fuel in dual purpose spent fuel casks is substantial, but it is likely those costs will be incurred regardless of whether or not centralized storage is adopted.[3] These costs, therefore, do not play a major role in this analysis. The related cost that is very significant to our study is the cost of stranded storage. This is the cost of storing fuel at a reactor site after it would otherwise have been fully decommissioned. The increase in costs attributed to spent fuel management when the fuel goes from being stored at an operating site to stranded

[3] We consider the potential of shipping some fuel without being loaded in dual purposes casks later in this study.

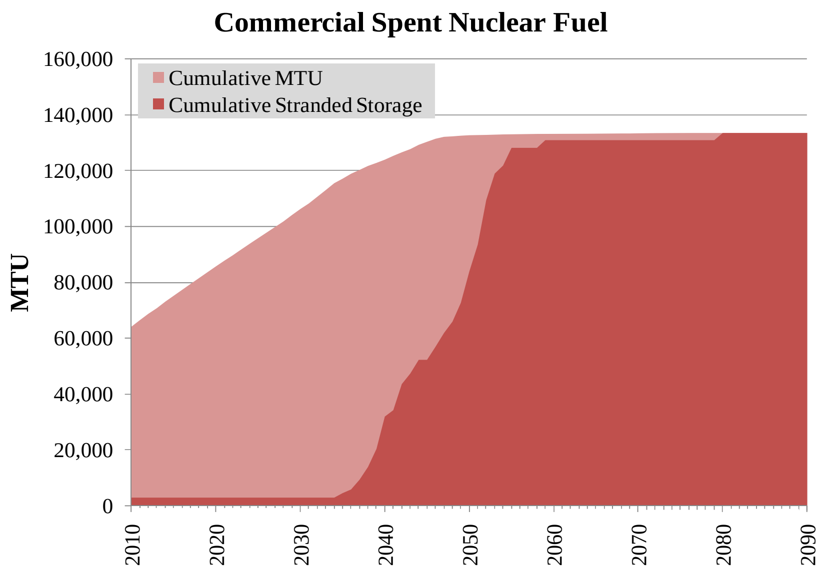
storage is significant. GAO 2009 estimates the stranded storage cost at $4.5 million per year at each site, which is much larger than the $200,000 yearly cost when a reactor is in operation. The reason for the increase has to do with the allocation of costs. During operations, a plant needs extensive security systems and operating staff. The incremental effort for those people and systems to monitor spent fuel in dry storage on the site is quite minor. For a shutdown plant that has otherwise been decommissioned, all costs associated with providing security and other support must be allocated entirely to the spent fuel, and that is why the cost increases so dramatically. In our analysis, we assume the plant is decommissioned over the six years following retirement and the operating license of the plant at that point is converted to one specifically for the storage of spent fuel: a Part 72 license per the Code of Federal Regulations. Stranded fuel already exists at nine different nuclear plant sites in the U.S.

Spent Fuel Currently In Stranded Storage at Shutdown Reactor Sites[4]

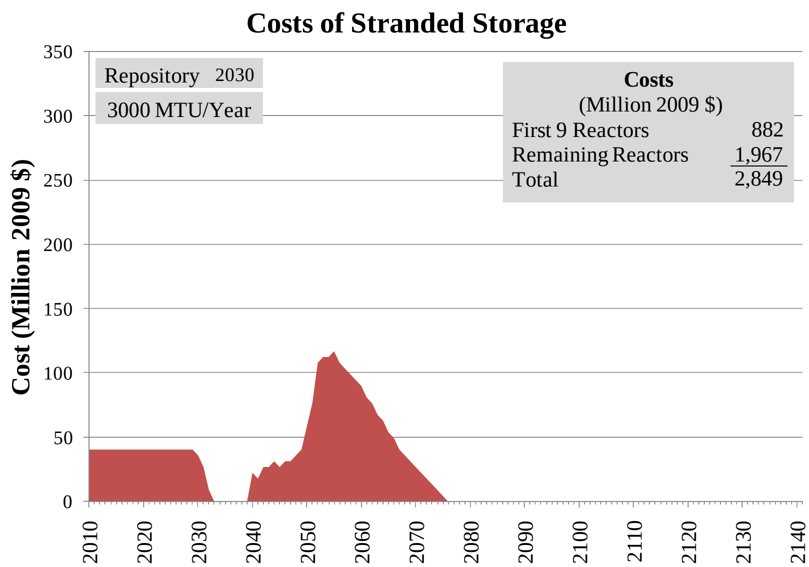
Reactor Name	State	Year of Shutdown	SNF (MTU)	On-Site Dry Storage Status
Humboldt Bay	**California**	1976	29	In Transition
LaCrosse	**Wisconsin**	1987	38	Planned
Rancho Seco	**California**	1989	228	In Storage
Yankee Rowe	**Massachusetts**	1991	127	In Storage
Trojan	**Oregon**	1992	359	In Storage
Haddam Neck	**Connecticut**	1996	412	In Storage
Maine Yankee	**Maine**	1997	542	In Storage
Big Rock Point	**Michigan**	1997	58	In Storage
Zion 1 & 2	**Illinois**	1998	1,019	Planned
Total:			2,813	

There is a coming wave of stranded fuel with the retirement of nuclear power plants beginning around 2030. Even if all operating plants obtain 60-year licenses, which is what we assume, this wave of retirements will be substantial. In fact, the wave of retirements is so large that it may not be possible to prevent a surge of stranded fuel costs unless fuel begins to be picked up before the retirements begin. To frame the issues in this analysis, we start with projections of spent fuel production.

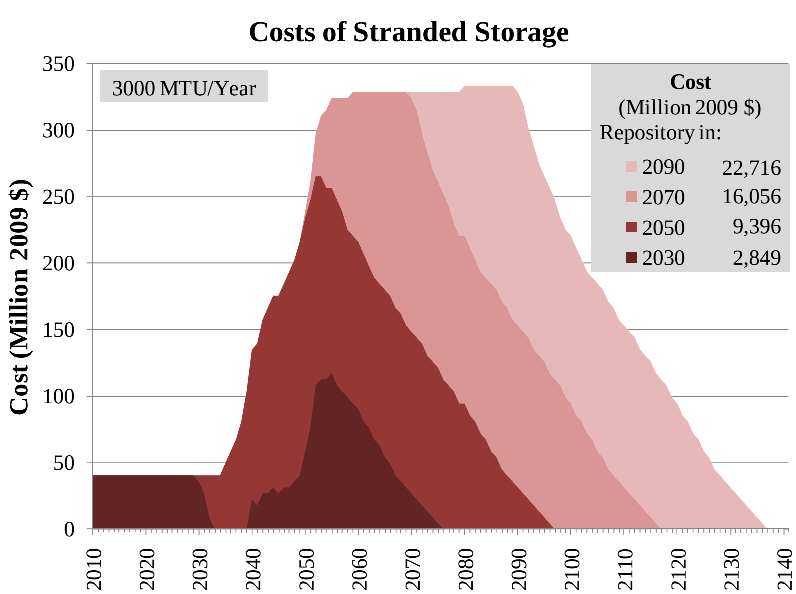
[4] Source: DOE 2008.



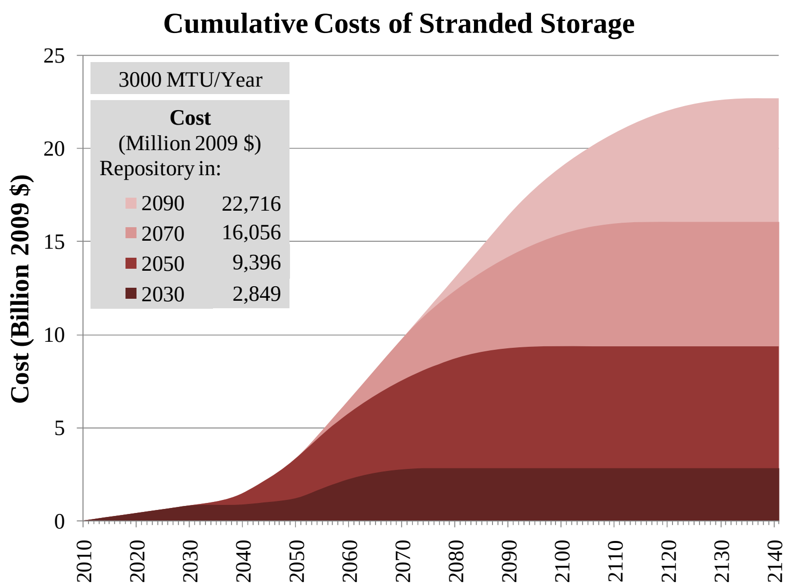
Stranded fuel storage costs start to increase substantially in the late 2030s, after the retired plants start to be decommissioned. The most optimistic projection for the start of the permanent repository is around 2030. This might lead to a mistaken conclusion that these stranded storage costs can be avoided if the repository can be built to come on line by then. Unfortunately, the wave is too large and steep. The figure below assumes a 2030 repository and fuel shipments that ramp up to 3,000 MTU/year in accordance with current planning assumptions. There are two areas of costs in the figure. The left summarizes the cost of maintaining fuel at the nine plants that are already shut down. Stranded fuel storage costs at these plants are already being incurred, and will continue to be incurred, until the fuel is picked up. The mountain of costs to the right, centered around 2050, results from plants retired after the repository opens. A 3,000 MTU acceptance rate schedule simply cannot keep up with the volume of spent fuel that needs to be managed. Or put another way, if we wait until 2030 to start accepting spent fuel, we have waited too long to avoid substantial costs. That mountain of costs totals around $2 billion in 2009 dollars.



The 2030 start date allows the fuel to be picked up from the reactors that are already shut down in a couple years. Additional fuel will be picked up from other sites, but by 2040 the rate of DOE acceptance will not be sufficient to keep up with rate at which fuel goes into the stranded storage configuration. A delay in the repository dramatically increases stranded storage costs. The figure below provides alternative analyses under assumptions of substantial delays in the repository start date. Billions upon billions of dollars are at risk if the fuel is kept at reactor sites around the country after the reactors are shut down.



The cumulative cost of stranded storage is shown below for a range of possible repository start dates. These costs continue to accumulate until substantially after the repository comes on line and fuel is being picked up from reactor sites.



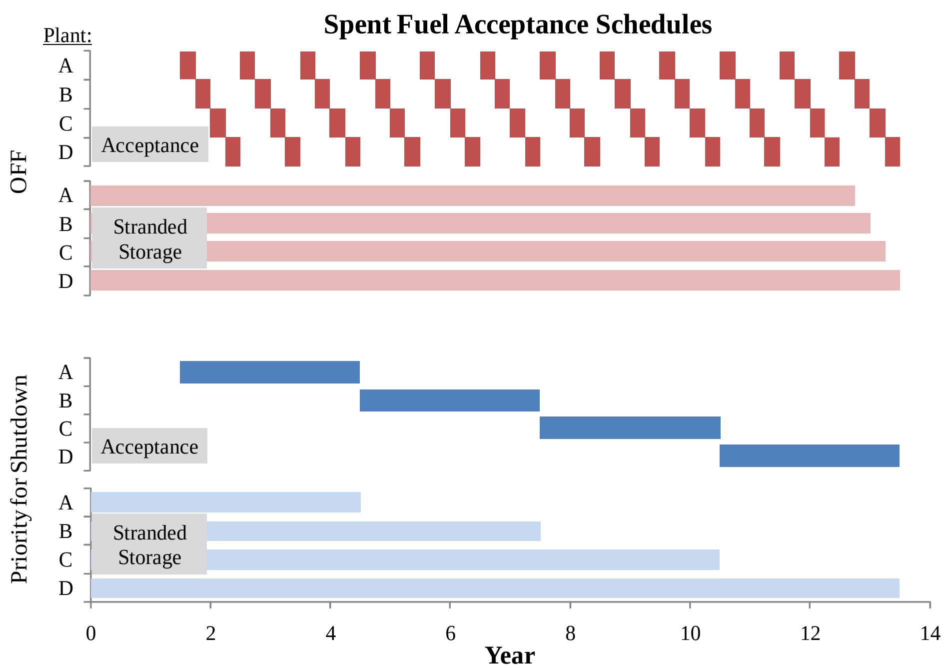
V. Priority to Shipments from Shutdown Reactors Produces Substantial Savings

The standard contract establishes priority for shipments based on an "oldest fuel first" (OFF) basis, but contains a provision for giving priority for shutdown reactors. Deviating from the OFF standard will be controversial, but the potential cost savings are overwhelming. We've adopted the priority-for-shutdown-reactors assumption because it produces such large savings. The savings are substantial regardless of whether shipments are to a centralized facility or a repository, although the later shipments begin, the less sense OFF makes.

Our analysis assumes spent fuel is shipped from the reactors in a manner where the 3,000 MTU/year of fuel pickup minimizes stranded storage costs. In reality, practical limitations would not allow such perfectly efficient shipments and this will likely increase storage costs. This would be true in both the centralized storage and repository-only scenarios, so the conclusions about priority apply in both cases.

The figure below provides a conceptual explanation of the difference between priorities based on OFF or shutdown reactors. Consider the simplistic schedule of 4 plants that have the same amount of spent fuel and enter stranded storage without any fuel having been picked up. To make the example simple, the plants all go into retirement in sequence (A, B, C and D) within a very short time frame.

Giving Priority to Shutdown Reactors Will Reduce Costs

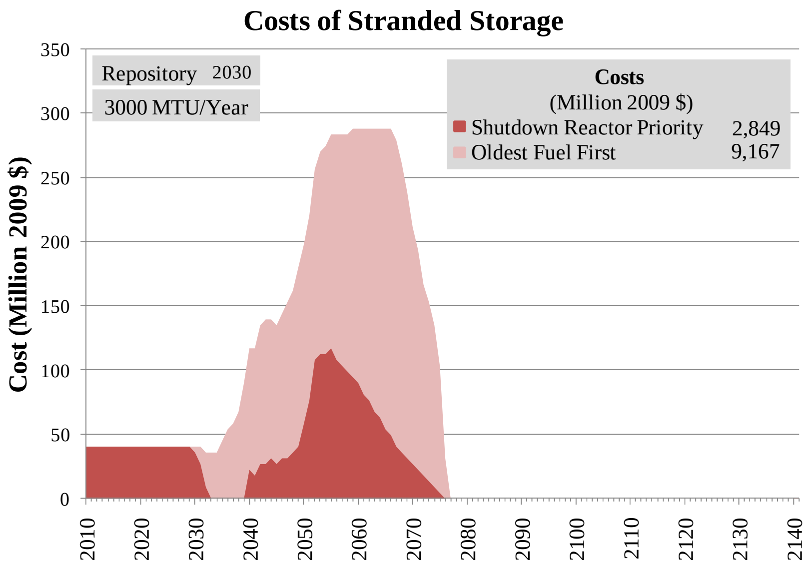


In the first case, which is shown in red, a small amount of fuel is picked up from each reactor each year; in the second case shown in blue, the four sites are emptied in sequence. Three points should be obvious from the figure. First, stranded storage costs are substantially reduced in the second approach. Second, while the last of the fuel is picked up earlier from some of the plants under the shutdown-priority schedule, no plant has its last fuel picked up at a later time than it would have under OFF. From the perspective of both stranded storage costs and freeing sites for potential reuse, the benefit does not accrue until all of the fuel is removed. Third, rather than having to manage fuel pickup intermittently over a very long period of time, individual campaigns are conducted at each plant, allowing for all of the fuel from a reactor to be picked up roughly at the same time. Together, shutdown-priority schedule offers substantial cost advantages, accelerates the complete emptying and closure of sites, and no utility or storage site host community is worse off than it would have been under OFF.

It is hard to imagine that fuel will be picked up on a strict OFF basis in any case. Visiting nearly every plant on a near-yearly basis is clearly a high cost alternative. On top of the logistical complexity, these shipments would be for low quantities, adding further inefficiencies. Instead, we consider it inevitable that fuel will be picked up in larger quantities from fewer sites each year. Thus, once a plant is slated for fuel pickup and the site starts shipping fuel, we expect those shipments to continue until substantial quantities are delivered. Under such a "campaign" scenario, there may be many years in between fuel pickups, but once those pickups are scheduled, a great deal of fuel will be accepted. The removal of all spent fuel from a site may require anywhere from one to a handful of campaigns. If priority is given to shutdown reactors, the fuel will probably be picked up in one campaign to minimize that plant's stranded storage costs.

Employing an OFF acceptance priority will dramatically increase stranded storage costs, as shown below. Stranded storage costs under the OFF strategy increase by $6.3 billion with a 2030 repository date, and cost increases of a similar magnitude would occur for any other starting date. This calculation does not even include the transportation efficiency benefits that come from conducting major campaigns at sites in a sequential manner.

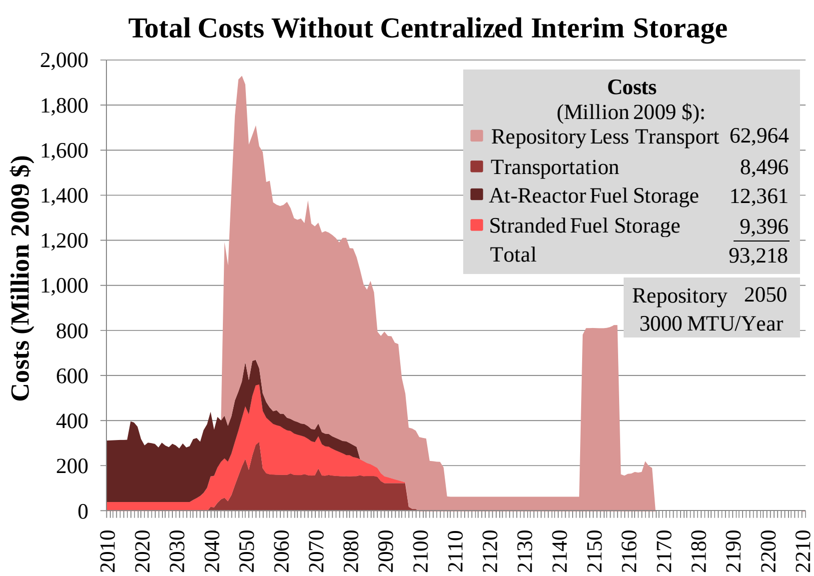
Substantial Savings Available by Giving Priority to Shutdown Reactors



We are aware of concerns that utilities not favored by the shutdown priority may be opposed to this approach, and this approach will be controversial. We offer several observations. First, while not offering a legal opinion, it is possible that the Standard Contract gives DOE this option based on language in the contract concerning a shutdown reactor priority. Second, DOE's acceptance of fuel will come decades later than the 1998 commitment and at a time where essentially all plants will have fuel in dry storage at their sites. The extent of such storage was not expected, of course, and utilities are suing DOE to recover these costs as damages. If a utility is "harmed" because it believes its fuel is accepted later than it would under the OFF priority, it will have incurred this "harm" in a situation where it is already eligible for damages. Since compensation is paid to make the utility whole for the actual costs incurred by the breach, it is entitled to full compensation covering the period until the fuel is taken away. Whether or not that fuel was delayed because of DOE's acceptance choices does not leave the utility worse off to the extent that it is already entitled to compensation resulting from the breach.

VI. Cost Implications of Centralized Interim Storage under Different Assumptions

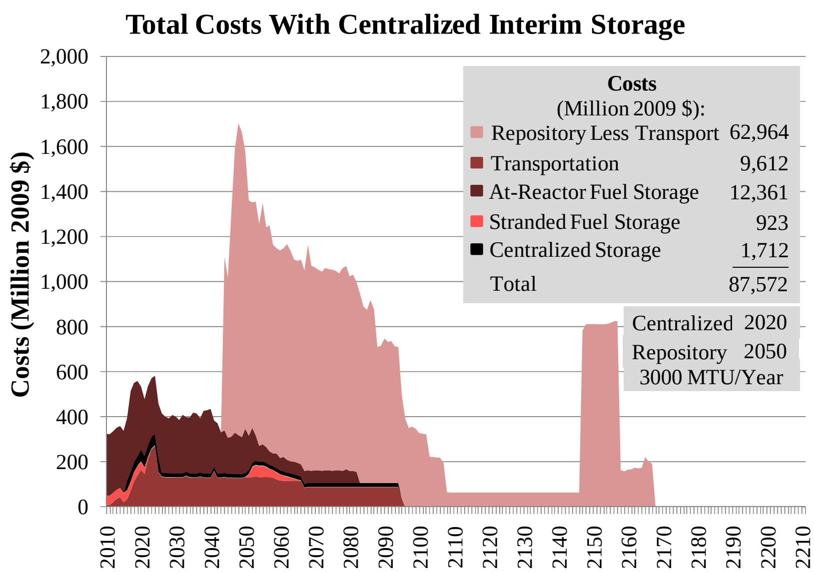
The stranded storage costs are significant, but are still only part of the overall costs of managing fuel. They are particularly relevant to an evaluation of centralized interim storage because they can be reduced or eliminated, but they must be put in perspective. The figure below provides a forecast of all costs associated with spent fuel management assuming a permanent repository that begins accepting fuel in 2050. The 2050 start date was selected for this figure because it represents a significant, but not unreasonable delay in the repository timeline and provides an example where the dynamics of certain cost elements become observable. In this analysis all operating reactors are assumed to have a 60-year life. Cost data for this analysis are based on best estimates from the GAO 2009 report, although with priority given to shutdown reactors for shipment, with corresponding adjustments made to transportation costs assumptions as discussed later in this report. The GAO analysis places special emphasis on the uncertainties of many of the assumptions, it should be noted, and conducted extensive Monte Carlo analysis using a range of values for many assumptions to deal with these issues. We focus on only best-estimate assumptions in order to understand the nature of the costs and sources of potential cost savings.



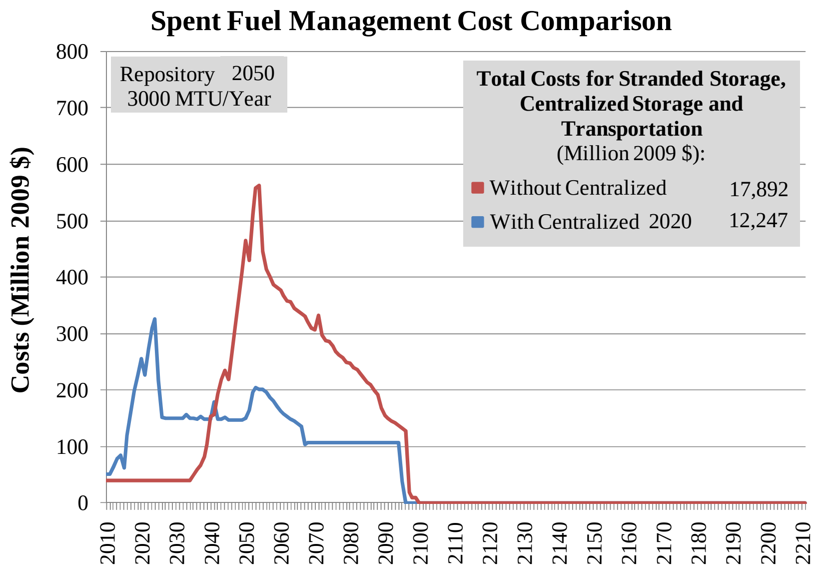
The total estimated cost of the program is $93.2 billion in 2009 dollars, without discounting. This cost is broken down into four major categories. The largest costs are associated with the repository, nearly $63 billion, which were derived from the Total System Life Cycle Cost analysis for Yucca Mountain. This includes construction, licensing, loading and eventually sealing off the repository. Most of the costs are incurred in the 2040-2110 time period. The repository is then monitored for an extended period until preparations for final closure begin around 2150. These preparations produce the large cost spike and involve installing drip shields (needed at Yucca Mountain, but may not be required elsewhere) and other steps, with final closure achieved around 2170. These repository costs are unchanged in the scenarios analyzed, although we do consider different start dates for the repository.

The next largest category of costs is labeled “At-Reactor Fuel Storage” and totals $12.4 billion. This includes the cost of loading spent fuel into dual purpose casks and placing it in at-reactor dry storage. These costs generally do not change even when different fuel management strategies are adopted. One exception to this assumption is if spent fuel it picked up from the pool by DOE without the use of dual purpose casks and we discuss that situation separately. The third largest cost is the stranded fuel storage cost which depends on the timing of shipment from the reactor site. Lastly, we break out the transportation costs. With a centralized interim facility, fuel will have to be moved twice and this incremental cost must be considered.

The next chart considers a centralized interim storage facility based on dry cask storage that begins operation in 2020. Overall, the total costs are over $5 billion lower in 2009 dollars, before discounting. One new cost category has been added and there are changes in two of the other cost categories. The new cost category is for the centralized facility. At a total cost of $1.7 billion, this cost category includes initial construction and operation for roughly 75 years. When the repository comes on line in 2050, there is still a substantial amount of fuel at the reactors. The analysis assumes that 3,000 MTU/year continue to ship, with movements from the reactors to the repository at that point. When all available fuel from reactors has shipped to the repository, the shipments begin to empty the centralized storage facility, which takes roughly 30 years. As indicated in the chart, the cost of the centralized facility itself is quite modest relative to the other costs. The stranded fuel storage costs drop substantially in this scenario, as would be expected. The transportation costs increase substantially, and it is these costs that are particularly important to evaluating the interim storage option. These costs are incurred at an earlier time (increasing costs in net present value terms) and are greater in absolute terms because fuel has to be shipped twice.



A centralized interim storage facility lowers total costs by over $5 billion, but this savings on a non-discounted, constant dollar basis masks the implications of a major shift in when the dollars are spent. The next chart demonstrates this issue. As noted above, the cost of the repository and the at-reactor spent fuel storage costs are the same in either scenario. The differences lie in the stranded spent fuel storage costs, the cost of centralized storage and the transportation costs. The chart below looks only at those cost categories. With centralized storage, almost all of these costs are associated with transportation. Without centralized storage, the mountain of costs is composed of both stranded spent fuel storage costs and transportation costs, in about equal measure.



Yearly cash flows for both scenarios can be discounted to develop net present values (NPV) for direct comparison. NPV analyses are particularly sensitive to the discount rate assumption when the time horizon is long and when the scenarios being compared have very different time-distribution of cash flows. These analyses are relatively extreme in both dimensions. The MIT 2010 report used a discount rate of 7% while no discounting was done in the DOE 2008 report. In GAO 2009, a variety of discount rate assumptions were embedded in the Monte Carlo analysis (GAO 2009 p. 64); the study developed a probability distribution of possible discount rates for each of five different time intervals.

A major challenge addressed with present value analysis is the wide variety of views among experts as to the appropriate discount rate. Finance theory suggests that the discount rate should reflect the risks of the project, to ensure that an evaluation of the project properly weighs the risks inherent in the effort. Such situations typically assume that there is the alternative of not undertaking the effort if it will not produce adequate returns. Here, the project will never produce a return and there is no choice but to deal with the fuel, so the basic premise underlying the typical selection of a discount rate is not present. A rate associated with the cost of capital might be considered. In this case it is the borrowing cost of the federal government, which is only moderately above inflation. There is another significant issue, however. Some challenge the underlying premise of substantial discounting when the effect is to push off costs and obligations from one generation to the next. Obviously, the first generation is better off if they never have to face the costs, yet saddling future generations with costs when they were not recipients of any of the benefits for which the costs were incurred seems inherently unfair. Based on such issues of fairness, some economists suggest very low discount rates in real terms.

These general issues are addressed in the GAO 2009 report by the use of probability distributions for discount rate assumptions. These distributions are based on published studies, and different ranges of discount rates were used for different time periods in the analyses. This treatment of the range of possible discount rates is a significant contributor to the wide distribution of NPVs presented in that GAO 2009 report and reproduced earlier in this study.

This issue is particularly important to decision makers. Investing in centralized storage in the near term has the potential to lower costs over the long term, and decision makers need to consider their perspective on intergenerational issues and the appropriate discount rate for their considerations. In our analyses we present results under different discount rate assumptions in order to provide decision makers the results they would need under whatever approach they may deem most appropriate. This presentation also serves to demonstrate the magnitude of the effect of different assumptions.

Since our calculations are based on constant 2009 dollars, simply summing those annual costs over the period of analysis equates to using a discount rate just equal to the rate of inflation, which is also known as a 0% real discount rate. We also provide analyses at 1% real and 4% real discount rates. These assumptions provide a reasonable range given the issues addressed above. The 1% real rate is very low, and reflects significant consideration of issues of intergenerational equity. The 4% real rate is significantly higher, roughly equal to the MIT 2010 rate of 7% if inflation is assumed to equal 3%, and higher than borrowing costs of the US government. As will be evident in the figures to be presented below, the discount rate assumption has an enormous effect on the NPV calculations.

The table below presents result for four different scenarios, which are among the many different scenarios considered in this analysis. These were selected to provide an indication of the extreme sensitivity of the analysis to different considerations. The first scenario is based on the assumptions included in the GAO report (including the OFF acceptance priority) except for our adoption of 2020 for the date the centralized interim facility opens and 2050 for the date of the permanent repository. Savings from this scenario are negative at both 1% and 4% discount rates, but as we discussed earlier, we do not feel this is an appropriate base case. The second scenario presents our base case. It assumes shutdown reactors (including those that are about to shutdown) are given priority in the shipment schedule to minimize stranded storage costs. The effect of this single assumption is substantial, with strong savings at 1%, although at 4% centralized storage increases costs by $742 million. In the third scenario, the cost of maintaining spent fuel at a reactor site that would otherwise have been decommissioned is increased from $4.5 million/year (GAO 2009) to $8 million/year (MIT 2010), and savings are achieved for all discount rates evaluated. And lastly, we also adopt certain transportation cost assumptions from the low end of the range within the MIT 2010 report. These assumptions substantially improve the calculated cost advantages of centralized interim storage.

Savings from Centralized Interim Storage
Assuming 2020 Centralized Facility, 2050 Repository

Scenario	NPV Savings (Million 2009 $) 0% Real Discount Rate	1% Real Discount Rate	4% Real Discount Rate
- GAO Assumptions, OFF	$2,414	-$799	-$2,506
Base Case: - Priority for Shutdown Reactors	$5,645	$2,308	-$742
- Priority for Shutdown Reactors - $8 Million/year Stranded Storage Cost	$12,236	$6,416	$424
- Priority for Shutdown Reactors - $8 Million/year Stranded Storage Cost - Low MIT 2010 Transportation Cost	$14,133	$8,225	$1,631

These NPVs mark the beginning of the analysis, not the end. In a decision with the complexity of this one, with the major uncertainties and possible changes over time, NPV calculations are informative, but no single calculation provides enough information for making a final decision, particularly since the cost impacts are only one part of all the factors that must be weighed and balanced in the decision process. In the material that follows, critical assumptions are explored, alternatives discussed and other analyses are performed.

VII. The Configuration of the Centralized Interim Facility Is Uncertain

There is a high degree of uncertainty over the configuration of a centralized interim storage facility. It is compounded by the degree to which options might be implemented, as what may appear to be an excellent choice in theory might turn out to be impractical. We explore these situations in this section. In our analyses, we choose a simple and relatively high-cost alternative. Specifically, we assume the construction of two independent, centralized, storage-only facilities capable of holding up to all of the spent fuel that may be produced from the existing fleet of nuclear power plants based on GAO 2009, at a cost of $218 million each. Lower cost and potentially better options may exist, as we discuss below, and to the extent they are ultimately adopted it will make the interim storage option more attractive. Cost savings would result, for example, from the use of a single centralized storage facility at the $302 million cost assumed in GAO 2009. The obstacles to better alternatives are generally not technological, but instead a result of permitting and process-related issues. It may be that the only way to know whether better options are available is to attempt to build them. Therefore, one advantage of pursuing the centralized storage option in some form is to find out whether better options could be implemented.

The most immediate need for centralized storage concerns the nine plants currently shut down and incurring stranded storage costs today. While actions may be needed today to minimize the cost wave of coming decades, these plants are incurring high storage costs today and their owners have made appeals for actions now. From an economic perspective, costs could be reduced if this spent fuel could be consolidated to a single facility. One of the primary conclusions of the MIT 2010 report was that there were substantial savings associated with consolidated storage of this spent fuel.

A facility for such a limited purpose could be quite small, as less than 3,000 MTU of spent fuel is associated with these plants. Economically, the sooner a facility is built and fuel shipped, the sooner the excessive cost of management at all of these sites could be saved. Success with a limited facility would prove that the centralized storage option could be implemented, both in building the facility and shipping the spent fuel. There are, after all, no known technical obstacles preventing consolidation at a centralized facility. On the other hand, there has not been any success, either. Commitment to a program for centralized storage for the stranded spent fuel at existing shutdown reactors would effectively create a pilot project that would lead to a better understanding of the centralized option and inform future decisions about expanding the centralized storage option.

A basic facility for storing spent fuel in dual purpose casks is a very simple facility. Once the general unloading capabilities are available, scale of the facility depends on the size of the parking lot for casks. And that parking lot can be expanded over time. Building a facility in stages, with additional capacity added over time, makes sense because it will delay substantial costs until the capacity is needed. If the need for a larger centralized facility never develops, cost savings will be realized. The permitting and licensing process, however, can provide for a much bigger facility and expansions can be made as needed. In this way the potential delays and added costs from multiple licensing processes can be avoided, and the construction costs can be deferred until needed.

Dry Cask Storage Facility for Spent Fuel

Source: DOE 2008, Connecticut Yankee's Facility

The various studies of interim storage assume that anywhere from one to four independent facilities would be necessary to hold all of the currently projected spent fuel. The GAO 2009 report assumes either one or two facilities will be built. The EPRI 2009 base case assumption was a facility that could accommodate approximately 25% of the projected spent fuel, although it considers moderately different sizes (20,000 MTU, 40,000 MTU and 60,000 MTU). The DOE 2008 study only considered a 2,813 MTU pilot project without consideration of further expansion. The license submission on behalf of Private Fuel Storage for a facility in Utah calls for a capacity of 40,000 MTU. The GNEP 2009 study assumes that three facilities will be built to hold all projected spent fuel, and that these facilities will be built in stages. Having reviewed these reports, we do not offer any insight into which of these alternatives might prove optimal, except to say that given the many uncertainties associated with putting a facility in operation, it may be best to focus on getting a single facility in service before worrying about a second or third facility. While transportation logistics could be optimized if one knew from the beginning the number of storage units that might be built, those costs and issues are not the biggest impediment to a centralized interim storage program. If the first storage facility is capable of substantial expansion as needed, decisions concerning additional sites could be made after shipments to the first facility have commenced and much more is known about the need for and operation of a centralized storage facility.

The specific location of the facility needs to meet technical requirements for geological stability, be in a relatively sparsely populated area, have access to rail (and possibly barge) transportation infrastructure and other technical issues beyond the scope of this review. The more challenging problem in siting a facility involves gaining local approvals and public acceptance. At the local level this might involve partnering with a local community or an Indian tribe to place the facility on a greenfield site, building it on federal property already involved with nuclear material, or adding to an existing storage facility at a nuclear power station. Each of these could have advantages. Another option would be locating the interim facility at the site where the permanent repository will eventually be built, which would provide major benefits in transportation logistics and cost savings when moving the spent fuel out of the interim facility if it is to be disposed of directly in the repository. That is complicated, however, because the location of the permanent repository is at this point uncertain. The GNEP 2009 report provides extensive discussion of steps that might be taken to get approvals for an interim storage location. There is no doubt that this will be a challenging process.

One option would be to select a site for the first centralized facility with primary consideration given to gaining acceptance and commencing operations, and then build a second interim facility at the repository location once it is known. The first facility could meet near-term needs and help to minimize stranded storage costs. The second facility could provide more cost-effective storage over the longer-term at the repository site. In this way, the benefits of centralized storage could begin relatively quickly, and the long-term cost-effectiveness of a location at the repository could be realized as soon as feasible.

The technology involved in interim storage will include parking areas for dual purpose dry fuel storage canisters, complete with concrete over-packs and other storage elements that are specific to the particular design. The facility would also need equipment for loading, unloading and moving equipment on site. The centralized storage facility could serve other purposes and have other capabilities. For example, it might be determined that the centralized storage location would be a good place to transfer fuel from the dual purpose canisters to whatever storage device is needed for permanent placement in the repository. Alternatively, it might be necessary to transfer fuel out of the dual purpose canisters due to unexpected effects from aging of the canisters or fuel, or because they had reached the end of their 100 year lives and needed to be replaced (as was assumed in one scenario in the GAO 2009 report).

A centralized facility might also open the possibility of skipping the transfer to dual purpose canisters in the first place. The GNEP 2009 report considered the possibility of loading fuel from the reactor pools directly in a shipment cask and then transferring them to a storage facility (dry or wet) at the centralized location. This approach may be able to produce additional savings and is discussed later in this report.

The MIT 2010 study considers the possibility of fuel reprocessing. This would require substantial investments and facilities, but if fuel has been shipped to a centralized location and the decision was made to reprocess the fuel, that centralized storage location could be a convenient location for reprocessing. All of these alternatives only become possible when we move past the theoretical and into a world where spent fuel has been consolidated.

Our analysis is structured around the concept of DOE ownership of the centralized storage facility, but the overall conclusions remain valid if the facility is in private hands. In essence, this assumes that a private facility could be owned and managed with roughly the same efficiency as a DOE facility. As a practical matter, many of DOE's most extensive facilities are managed by private firms, so even if DOE were to take the initiative in building the centralized storage unit, it might still be managed by a private firm. Thus, this analysis takes no position on the role of private companies in the ownership or operation of any of the spent fuel management facilities.

VIII. Transportation Costs Are Very Uncertain

Most planning for the permanent repository involves shipping spent fuel at a rate of 3,000 MTU/year, ramping up to that level in the first five years. If the repository begins accepting fuel at that rate, it will takes approximately 45 years for it to be filled, regardless of whether the fuel is coming from the reactor sites or a centralized facility. The total number of years during which fuel is being shipped is much higher when a centralized facility is used, of course, because the shipments start earlier and all of the spent fuel that is shipped to the storage facility has to be shipped again to the repository.

The GAO 2009 report assumes the same shipment cost whether shipping from the reactor to a centralized facility, from the reactor to the repository, or from the centralized facility to the repository. These are abstract assumptions, in the absence of certainty over the location of any facility, but it seems clear that the cost would be significantly lower when shipping from a centralized facility to the repository. With a centralized facility, all operations will be conducted at the same site, the transportation distance will probably be shorter than from most reactors and shipments would likely be more efficient in that they would involve more casks per train.

There are general categories of transportation costs. The first is the capital cost of rolling stock and infrastructure improvements (e.g., railroad spurs) needed for the program. Some of these costs are independent of the rate of shipment, but not all. Second, there are shipping costs associated with freight charges and other operating arrangements. Third, there may be additional transportation support expenditures.

In the first category, the GAO 2009 report assumed $400 million (± 10%) was needed for rolling stock, while transportation casks cost $4.5 million, for 3,000 MTU/year. MIT 2010 presented several sets of assumptions. In figures based on the EPRI 2009 study, transportation infrastructure costs (including transportation equipment) would total $365.8 million, for a 2,000 MTU/year, 40,000 MTU program. The MIT 2010 study also used figures from the Private Fuel Study initiative which formed the low end of the range of costs considered, and it had costs of $87.2 million for a 2,000 MTU/year shipment, 40,000 MTU program. We rely on the GAO 2009 report for most of our analysis, although we conducted sensitivity analyses based on the MIT 2010/Private Fuel Storage figures, scaled up to a facility sized for the entire spent fuel program. Differences of opinion over costs could result from different views on the number of rail cars holding spent fuel in each shipment, the used of dedicated trains (which was assumed in all of these figures), and the specific rail system improvements needed for the shipment's site. In general, these costs differences are not a source of the largest cost differences in this analysis.

The second category concerns operating costs. Separate costs for loading and for shipment are typically provided, along with shipment costs. The costs are reported in different ways in the various reports and will not be repeated here. The MIT 2010 report provides a range of costs where the High value is roughly four times higher than the Low. This is a huge range and the report recognizes that resolution of these uncertainties could affect the study's outcome. GAO 2009 assumes dollar-per-ton costs that are higher than the high-end of the range in the MIT 2010 report, yet assigns a range of uncertainty of only 10%. These variations illustrate the uncertainties over these costs and decision makers need to recognize that these costs may only become better known as progress is made in moving spent fuel.

It is the third category where assumptions are furthest apart. The GAO 2009 report assumes a cost of $2.5 billion will be associated with transportation system support, and this figure comes from the DOE report, "Analysis of the Total Life Cycle Cost of the Civilian Radioactive Waste Management Program." These costs are spread over all of the years of shipment, at roughly $50 million a year. This cost is for community support in states, municipalities and Indian reservations, and includes safety training, security plans, transportation operations management and stakeholder relations. Much of this is driven by the requirements of section 180(c) of the Nuclear Waste Policy Act Amendments of 1987. These costs are not included in either the EPRI 2009 or the GNEP 2009 studies. They also do not appear to be included in the MIT 2010 analysis. A cost of $2.5 billion is obviously significant and while the amount of spending may be uncertain, it appears that some costs of this sort will be incurred with the movement of substantial quantities of spent fuel.

Unless otherwise stated, in our analysis we rely on the GAO 2009 assumptions, with certain modifications to reflect two issues. First, while the GAO 2009 analysis assumes shipments based on oldest fuel first priorities that involve collections from most reactor sites in each year, we assume priority is given to shutdown reactors. This will greatly streamline all aspects of the fuel shipment process. Instead of shipments for a given reactor (and along a transportation path) being spread over many years, those shipments will be concentrated in a narrow window or two. Second, the second leg of the shipment from a centralized facility to the permanent repository will be much more efficient than that associated with the initial collection from the reactors spread across the country. We reduced the GAO 2009 transportation costs assumptions to reflect these considerations.[5]

Transportation cost uncertainties are a huge factor in the comparison of costs of centralized versus on-site storage of spent fuel. These issues need to be resolved regardless of whether or not a centralized facility is built, but there are several advantages to moving toward a

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[5] Cask loading and transportation costs were reduced by 25% when shipping from the centralized facility to the repository. With respect to the transportation support costs, these were reduced by 50% when shipping from the reactors to the repository, and by 60% when shipping from the reactors to the centralized facility, under the assumption a regional centralized facility would be located closer to the source reactor. System support costs were reduced by 90% when shipping from the centralized facility to the repository since it is always on a single route and it is expected that both facilities are located in lesser-populated areas of the country.

centralized interim storage as a means of learning more about these costs and how they can be effectively managed. First, the start date of a centralized facility will likely be easier to predict than for a repository. This will allow better planning during the initial phase of transportation. Second, since the cost of the centralized facility is substantially less than that of the repository, transportation disruptions, should they occur, will not leave the massively expensive repository sitting unused. Third, operating a centralized facility will provide an opportunity to work out logistical, technical and process-related details associated with transportation. While spent fuel has been shipped before, a multi-decade program to move many thousands of tons of spent fuel is unprecedented. It is reasonable to expect substantial learning from the earlier shipment opportunities provided by the centralized facility.

Earlier, we presented analyses under several sets of assumptions. In the first row in the table below, we present our previous results for our base case, which is based on GAO 2009 assumptions but with priority given for shutdown reactors. In the second row, we adopt the low-cost scenario from the MIT 2010 report solely for transportation cost assumptions. The change in NPV savings is substantial.

Savings from Centralized Interim Storage
Assuming 2020 Centralized Facility, 2050 Repository

	NPV Savings (Million 2009 $)		
Scenario	**0% Real Discount Rate**	**1% Real Discount Rate**	**4% Real Discount Rate**
Base Case: - Priority for Shutdown Reactors	$5,645	$2,308	-$742
- Priority for Shutdown Reactors - Low MIT 2010 Transportation Cost	$7,542	$4,117	$464

Another critical assumption is the rate at which spent fuel will be shipped. Most plans assume up to 3,000 MTU/year, based on planning for the repository. At that rate, it will take 50 years to move the inventory away from existing reactors. At the same time, there are no obvious scale barriers to the rate of shipment. With a centralized interim storage facility, fuel will be moving from locations all over the country, largely on existing railroads, and generally deposited on a parking lot in one (or more) centralized locations. It may take some years to scale up the rate, and more rolling stock will be required for higher shipment rates, but there is no known reason why the 3,000 MTU/year rate could not be exceeded. The rate of acceptance and permanent disposition at a repository, we note, may indeed be limited to the design level of 3,000 MTU/year, but if the fuel is arriving in dual purpose canisters there is no apparent reason why above ground, temporary storage could not be built to handle the surge from the reactor sites. A centralized interim storage program may even provide the critical facility that allows shipments away from reactor sites to greatly exceed 3,000 MTU/year, while allowing the permanent repository to operate at its design level.

In order to understand the implications of greater acceptance rates, we assume the yearly ramp-up of fuel acceptance continues beyond 3,000/year to 6,000 MTU/year. Accepting fuel at a faster rate substantially improves the ability to deal with the coming wave in stranded storage costs.

Stranded Storage Costs for Different Fuel Acceptance Rates (Million 2009 $)

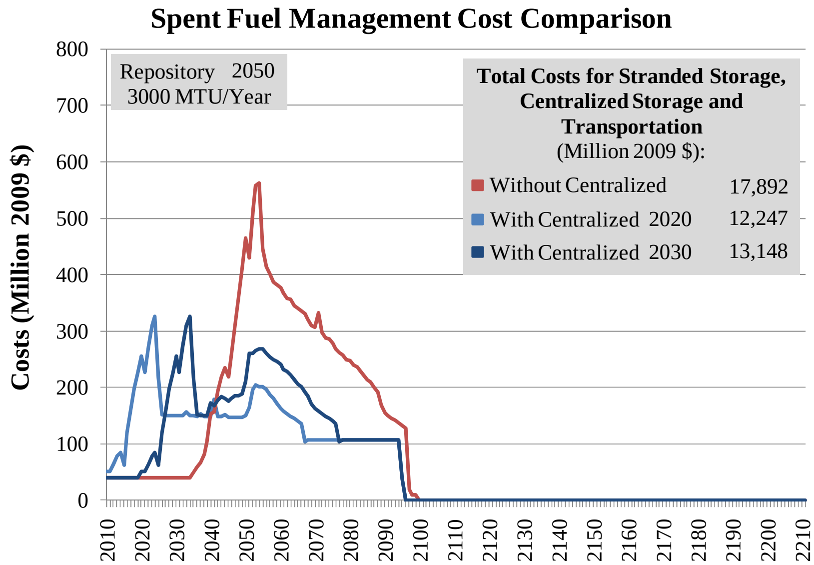
Fuel Acceptance Begins	3,000 MTU/Year	6,000 MTU/Year	Difference
2020	923	477	446
2030	2,849	887	1,962
2040	6,066	3,614	2,453
2050	9,396	6,899	2,498
2070	16,056	13,541	2,516
2090	22,716	20,201	2,516

There are two dynamic effects that drive these stranded storage costs: the cost from currently shutdown reactors and the surge in costs from further retirements. In the 3,000 MTU/year 2020 fuel acceptance scenario about half of the costs are from the nine shutdown plants. Those plants account for virtually all of the costs in the 6,000 MTU/year, 2020 and 2030 scenarios. In all other scenarios, the majority of costs result from a surge of retirements after 2030. The data demonstrates that the higher acceptance rate allows for deferral of action on spent fuel storage, particularly if the existing fuel can be consolidated. We note again that this higher rate is highly speculative at this time. Nevertheless, it seems prudent to recognize that there is the potential for higher rates of shipping in coming decades, particularly because it could substantially reduce costs. This is another example where there is a tendency to look at today's decision too narrowly, failing to recognize the ability to make adjustments over time.

IX. Timing of the Start Date for the Repository and Centralized Storage are Uncertain

The timing of the centralized storage facility is a major uncertainty in any evaluation. In our initial analysis, we assume it comes on line in 2020. Assuming work begins in earnest in 2012, that leaves eight years before operations start in January of 2020. EPRI 2009 assumes it would take 6 years to proceed from site selection to licensing and construction. MIT 2010 states that a more appropriate assumption for licensing alone is ten years, based on the time that process took for the Private Fuel Storage site, although in its analysis it assumes the centralized facility could be built on a federal site by 2015 (four years). Private Fuel Storage, LLC submitted a license application to the NRC for a fuel storage facility in Utah in June of 1997 and is still waiting for clearance to proceed. It remains unclear when, or if, that facility will be able to start operations. The DOE 2008 report assumed six years for the entire site selection-through-construction process. The GAO 2009 report allows three years for construction, but assumes it takes until 2025 for construction to begin based on an assessment that the process of site selection and permitting could take anywhere from 17 to 33 years. Also relevant, the Nuclear Waste Policy Amendments Act of 1987 called for creation of the Office of Nuclear Waste Negotiator to assist in finding a site for a Monitored Retrievable Storage (MRS) facility. Following passage in 1987, through the expiration of the position in 1995, the Negotiator was unable to find a site for the facility with willing participants (at least, not at the state level). Clearly, this process is difficult and unpredictable.

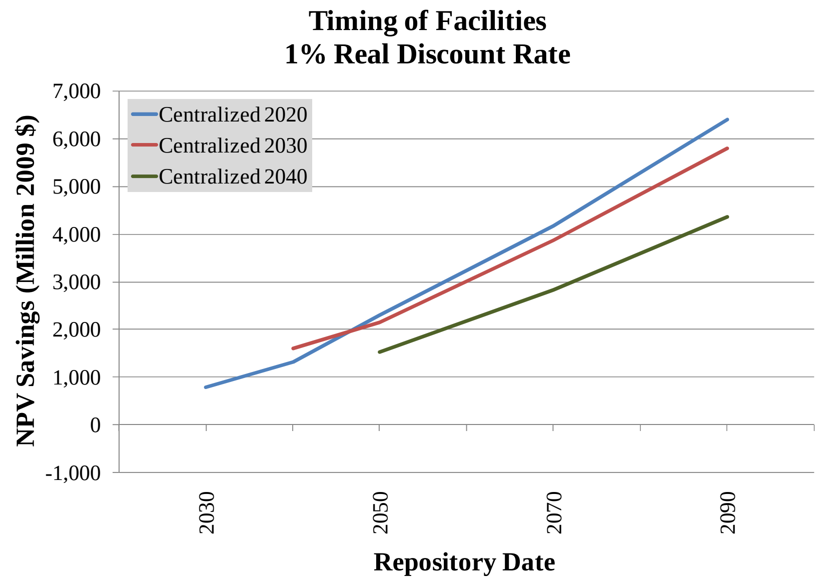
These various assumptions point out the substantial uncertainties over the timing of a centralized storage facility. Arguably, there is even the question of whether efforts toward construction of a facility will be successful. Given the challenges encountered in other aspects of spent fuel management, the potential for failure cannot be dismissed. Our assumption of a 2020 start date is clearly optimistic. The chart below compares a 2020 start date with that for 2030, along with assuming no centralized facility is ever built.



In some respects, the uncertainties over the time needed to site and build a centralized facility provides an impetus for starting work now, since it may only be through sustained efforts that we may learn what it takes to get past the permitting stage. And if best efforts are simply unable to find a way to get a centralized facility permitted and in operation, it is best to recognize that this is not an alternative as other options for spent fuel management are considered.

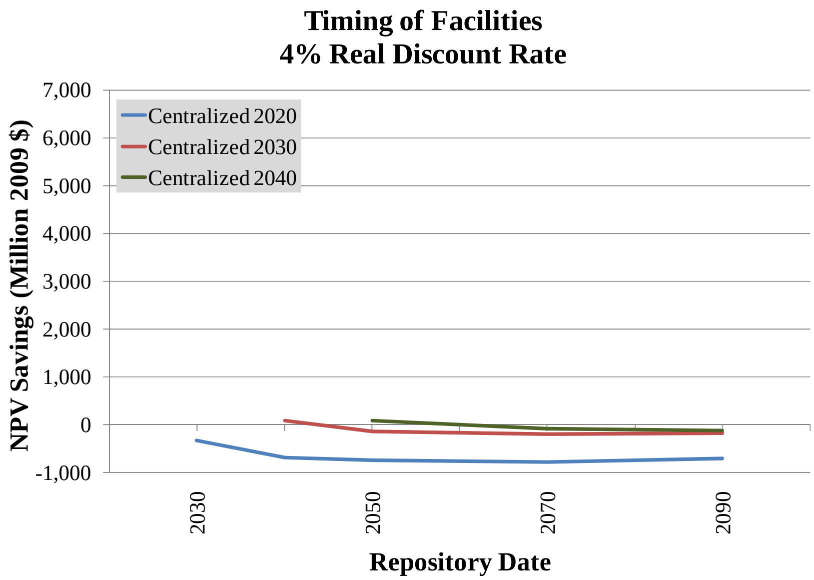
As was discussed earlier, the discount rate used has a profound effect on the net present value cost calculations and ultimately, decision makers need to decide what discount rate best reflects the time value of money for this decision. We have conducted analyses with real discount rates of 1% and 4%, and we discuss the 1% real results first.

Low Discount Rate of 1% Real. A 1% real discount rate (1% above inflation) is very low, and generally reflects consideration of a preference to not pass on costs and obligations to future generations. Under this assumption, and in our base case analysis that assumes preference is given to shutdown reactors, proceeding with centralized interim storage reduces costs in all cases. Almost without exception, the sooner the centralized facility is put in operation, the greater the savings. Also, the later the date of the repository, the greater the savings realized from centralized storage.



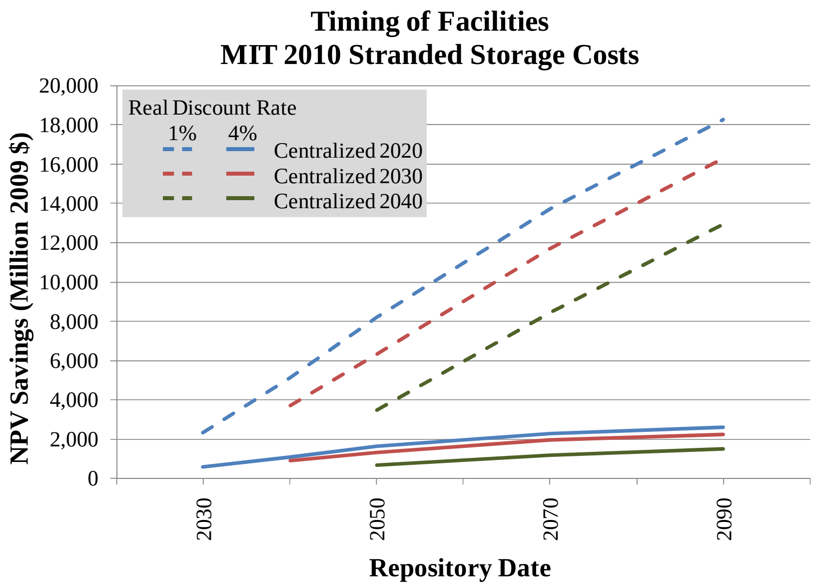
In reviewing the results presented in the chart above, consider a situation where the repository is built in 2050. A centralized interim facility produces savings, regardless of when it is built. The savings are approximately $1.6 billion, $2.2 billion or $2.3 billion, depending on whether the centralized facility is built in 2040, 2030 or 2020. For any later repository, the savings are increased, which is why the curves slope upward. We also considered scenarios where the stranded storage costs were higher than $4.5 million a year, and where transportation costs were lower. These alternative assumptions (not presented) consistently made centralized storage more attractive with the 1% discount rate.

Higher Discount Rate of 4% Real. With the 4% discount rate assumption the results are not as straightforward. The higher discount rate puts a greater emphasis on near-term expenditures. Centralized storage involves spending more money up front for the facility and transportation, and the early cash flows detract from the benefit of reduced stranded storage costs. The results are shown in the figure below.



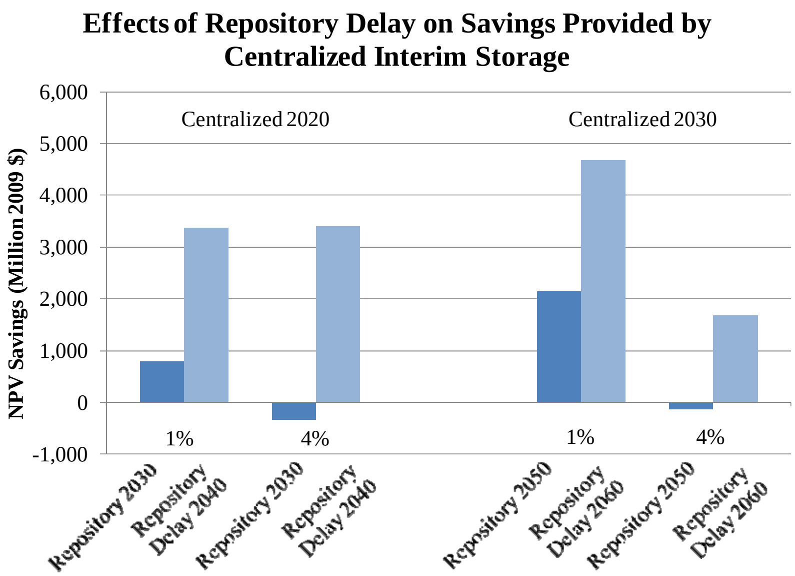
The results can be a bit confusing. Start by again looking at the circumstance with a repository in 2050. If the centralized facility comes on line in 2020, it produces negative savings (i.e., has extra costs) of approximately $800 million. With the centralized facility in 2030 or 2040, the savings are much closer to zero. Overall, the centralized facility in 2030 or 2040 has roughly zero savings regardless of when the repository comes on line, and installing the centralized facility in 2020 always results in extra costs (negative savings). In the scenarios with near-zero-savings indicated, it would seem that the decision would be driven by the non-quantified considerations. If centralized storage was considered advantageous for the flexibility it provided the overall spent fuel management program, this analysis indicates that those benefits would come at no additional cost.

These analyses, however, do not reflect all considerations. If the cost of stranded storage is $8 million as assumed in MIT 2010, all scenarios have positive NPVs. The results are shown in the graph below for both the 1% and 4% discount rates. All scenarios indicate positive savings. The lower discount rate produces dramatically higher savings, but the savings are substantial even in the 4% discount rate cases, with most scenarios having savings in excess of $1 billion. In all cases, the sooner the centralized facility comes on line, the greater the savings. In addition, the longer it takes for the repository to come on line, the greater the savings. Clearly, learning more about the actual costs of stranded storage can dramatically change the perspective on the costs savings that result from centralized interim storage.



All of these analyses assume the start date for the repository is unchanged if fuel is shipped to a centralized interim facility. This assumption, however, has been contested on many occasions because of concerns that once a storage facility is available to allow the government to meet its obligation to accept spent fuel from utilities under the standard contract, pressures to proceed with the repository would ease and economic incentives to defer expenditures on the repository would favor delay.

Whenever there is a positive discount rate, even a slight delay in the repository produces large savings. If that delay is attributed to the construction of the centralized facility, the savings should be included in the cost analysis. These analyses become conceptually difficult to present in the same format as the curves above. Instead, we present two specific, representative examples in the simpler bar charts below. In these analyses we have returned to using the GAO 2009 assumptions about the cost of stranded storage.



On the left we consider the situation where the centralized facility comes on line in 2020, and absent the centralized facility, the repository comes on line in 2030. The results are shown for both the 1% and 4% discount rates. Looking at the 4% discount rate analysis, the left-hand (dark blue) bar shows that the centralized facility produces negative savings (i.e., adds costs) of around $200 million before considering the change in repository date. This is the same result that was presented in the charts a few pages earlier. If the repository is delayed until 2040 as a result of the centralized facility, however, the savings are dramatically different, with the centralized facility scenario providing a cost savings of approximately $3.5 billion. Results for a centralized facility in 2030 and the repository in 2050 are shown on the right, with the additional results shown if the repository is delayed 10 years as a result of the centralized facility.

From a cost perspective, the effect of delaying the repository is profound. Returning to the 2020 centralized/2030 repository scenario presented above, it should be recognized that this is the scenario that pointed most strongly to the conclusion that the centralized facility could increase costs. Even in this case, however, if the repository is delayed by only one year the centralized facility results in cost savings.[6]

[6] A ten year delay changed the savings figure from negative $0.2 billion to positive $3.5 billion, which is an increase of around $0.4 billion a year.

Similarly, the presence of the centralized facility may allow the slowing of the loading of the repository which may produce similar cost savings. The presence of a centralized facility allows for a difference in the rate of acceptance of fuel from the reactors (which reduces stranded storage costs) and the loading of the repository (which is very expensive). It is also consistent with a major theme for considering the centralized facility, which is valuing increased flexibility and options. This flexibility might be used to allow for more above-ground cooling to for maintaining the reprocessing option. Thus, even after the repository is open, centralized interim storage can provide substantial value to the overall spent fuel management program.

X. Total Commitment to Centralized Storage Is Not Needed

There is no way to eliminate the substantial uncertainty over the repository start date in the timeframe when the initial decision about the centralized facility has to be made. Cost and other uncertainties are also likely to remain. Moving forward toward construction and operations will provide information about costs and capabilities, as well as open up opportunities for other changes in the overall spent nuclear fuel management program. It is possible that these actions will demonstrate that a centralized storage program is more costly and complicated than expected. If that happens, future decision makers will change the program. Regardless of what decisions are made today, leaders in future years will have the opportunity to revise implementation strategies. Today's decisions can increase the options available in the future, but do not prevent future modifications in light of changed circumstances. Conversely, future decision makers finding themselves in need of centralized storage cannot implement the option if the developmental work has not been completed.

There are at least three general phases of a centralized storage project. The first involves permitting, licensing and a variety of legislative actions that may be required. The duration of this phase is highly uncertain, as we have discussed. The second phase is initial construction. A basic centralized dry storage facility can be a relatively simple design, essentially just a large parking lot similar to those built at all the reactor sites, and therefore both the cost and construction timing are predictable. A simple facility could probably be built in around three years. The transportation equipment also has to be built, which may take longer, and there is complexity in dealing with the different kinds of transportable casks that have to be accommodated. However, the capital-intensive aspects of constructing transportation equipment can start at roughly the time as the facility construction and transportation equipment for all fuel cask designs are not needed when the system first goes into operation. The third phase is operations, which includes the shipment of the spent fuel to the storage location. Arguably there is also a fourth phase, when consideration is given to upgrading the facility to add capabilities and expand its role in the overall spent fuel management program.

The critical insight is that the highly uncertain development phase has a relatively low cost. Estimates of its cost from the three recent studies that provide these details are provided below. The estimated cost of finding an appropriate site ranges from \$10 million to \$30 million. When one adds in the design and licensing costs, the totals range from \$30 million to \$76 million. Relative to the financial implications of other aspects of the overall spent fuel management program, these are small costs. And these costs assume completion of the process. If a site is never located, the costs incurred will be modest, and probably less than the full cost of siting and licensing the facility.

Initial Costs for
Centralized Interim Storage Facility
(Million 2009 \$)

Study	Reference	Siting	Design	License	Total
DOE 2008	p. 14	10	20		30
EPRI 2009	pp. 2-2 to 2-3	18.1	40.3		58.4
GNEP 2009	p. 7-5	30	20	26	76

The first critical decision for substantial funding comes when the permitting is completed and it is time to commence construction. At that point, there would still be uncertainties about the repository, but decision makers will know more than they do today. Should the decision be made to stop, the loss incurred from permitting expenses would probably total no more than a few tens of millions of dollars. This is not only small in the overall perspective of spent fuel management, but it is small relative to the potential value centralized storage could have provided if it had been needed.

At the time of construction, there are various choices regarding how the facility will be built. The facility could be built in stages, starting small with expansions as needed to minimize costs. The EPRI 2009 study provides data for different sized storage facilities, demonstrating that considerable costs can be deferred if the facility is built in stages. The GNEP 2009 report provides extensive analysis of a phased construction program. The conclusion is overwhelming: not only is a phased approach cost-effective if the entire facility is built, but it dramatically reduces costs if needs change and the program is terminated before becoming fully loaded. In our analyses where the full capacity is built, we assume the second centralized facility is delayed by five years. If there is any doubt about the need for centralized storage, the second could be delayed further or canceled, because a single facility alone could accommodate substantial volumes of spent fuel during this period of uncertainty.

XI. Other Advantages of Centralized Storage

Listed below are several advantages associated with centralized storage that have not been quantified in the economic analysis, which considers only the cost aspects.

Earlier compliance with standard contract. DOE is long overdue in its 1998 obligation to begin accepting fuel. Simply put, a centralized interim facility will allow DOE to move forward. Moving spent fuel off of reactor sites will have many economic, political, regulatory and safety implications. The level of desire by the utility industry to see this step taken should not be underestimated.

Support new nuclear construction. As the nuclear industry attempts to move forward with the first new construction in decades, the lack of acceptance of spent fuel is viewed to be a significant impediment. Centralized interim storage would provide a solution.

Potential shipment of bare fuel assemblies. If there was a place to store spent fuel, it is possible that the cost of dual purpose casks might be avoided. DOE could transport bare fuel assemblies in its transportation casks and store them in a wet pool or dry storage unit at the centralized location. If a decision is made to substantially reduce the amount of fuel stored in spent fuel pools, perhaps in response to safety reviews following the Fukushima Daiichi accident, such bare shipment in specially designed transportation casks may be particularly useful.

The possibility for a centralized facility's acceptance of bare fuel assemblies creates an opportunity for large savings beyond those achievable with a facility only capable of dry storage. However, evaluation of this option is complicated by further uncertainties, and fewer cost estimates exist to evaluate it. The main economic advantage of such a facility is that by accepting bare fuel assemblies, the purchase of dual purpose casks could be avoided. According to the 2009 GAO report, each 13-MTU dry cask costs almost $1 million. It seems inevitable that, even if the capability for bare fuel acceptance were developed, it would come after acceptance of dual purpose casks had begun. This option requires DOE to build transportation casks that can accept fuel from the utility's spent fuel pool and then DOE's storage facility needs to be able to load the casks and store the bare fuel, in either a wet or dry condition.

Spent fuel will continue to be loaded in dual purpose casks to maintain full core reserve in the spent fuel pool. Nevertheless, by 2030 less than half of the total spent fuel production from existing reactors will already be loaded in dry casks. The cost of dual purpose casks for the remaining fuel would cost $4.5 billion. Savings from the elimination of dual purpose cask purchases would be offset by the cost of DOE transportation costs, the storage facility and other charges. Analysis of this scenario is complicated because the optimum shipping schedule will likely involve establishing priorities on neither for shutdown reactors or OFF, but some middle ground to minimize total costs. Also, if this option is created, it seems inevitable that shipments would continue with both dual purpose casks and bare assemblies, since both sets of equipment will have been in operation, so greater than 3,000 MTU/year would be shipped. This potential to reduce stranded storage costs through faster acceptance could be significant.

The GNEP 2009 report assumes the capability for bare spent fuel shipment is developed and deployed. Our analyses based on the cost estimates in that report indicate the potential for (but not certainty of) significant savings, but these analyses are particularly sensitive to many uncertainties.

Dry canister opening and maintenance. If the repository is significantly delayed or there are technical problems associated with the storage of spent fuel, there are significant advantages to having all of the spent fuel in a central location. It will be much easier to conduct new tests, upgrade equipment or re-package the fuel if it is all located in the same place (or two). There are several reasons why dual purpose dry storage canisters may have to be opened at some point. Since the design parameters of a final repository are not known, these canisters may not be compatible for long term storage in a geological repository. Some have raised the issue that the fuel may have to be repackaged at some point simply because of aging concerns before being placed in the repository, such as after 100 years as was assumed in the GAO 2009 report. There could also be unexpected technical problems that lead to the need for opening the canisters. If canisters have to be reopened for any reason, it surely would be easier to accomplish if the fuel were located in a centralized facility. The GAO study, for example, assumed repackaging was required every 100 years in the scenario where the repository was assumed to be delayed by 500 years. Until the spent fuel is permanently deposited into a repository, the potential for needing to reopen the canisters will remain.

Safety issues. Some people raise safety issues with respect to fuel scattered at plants across the country. We have no reason to doubt that the fuel at reactor sites is safe and that the NRC's oversight is appropriate. Nevertheless, the at-reactor option requires monitoring at some 70 different sites, some of them located close to major population centers such as New York City and Chicago. It seems obvious that security and safety could be better or simply more cost-effectively managed at centralized locations selected for this purpose.

As of this writing, the full implications of the accident at the Fukushima Daiichi plant in Japan are not known, but at a minimum, there will be increased scrutiny over spent fuel issues, storage of fuel in pools, and spent fuel management generally. Centralized interim storage would add flexibility and an option for removal of fuel from reactor sites that would promote safety and address post-Fukushima Daiichi issues.

Earlier retirements. Stranded storage costs will increase if any of the currently operating reactors do not achieve their expected 60-year lives. Early retirements could result from a variety of equipment problems, poor operating economics or licensing issues. Such issues have had an effect on some of the reactors already in stranded shutdown conditions. Whether the Fukushima Daiichi accident becomes a motivator of earlier shutdowns is not clear at this time, but the accident is raising questions about nuclear operating and spent fuel storage specifically. A centralized interim storage facility will provide added capabilities to manage spent fuel in the case of early retirements and help to minimize stranded storage costs.

Possible 80 year operating lives. Though the possibility of early retirements creates one element of uncertainty, there is also the potential for reactor lives to be extended beyond 60 years. This is unprecedented, but some studies are underway concerning this possibility and in general it is too early for potential of longer operating lives to be fully explored. With respect to spent fuel management, the delay in reaching stranded storage conditions is offset by the additional spent fuel that is produced. Specifically, fuel acceptance at a rate of 3,000 MTU/year would be offset by the 2,000 MTU/year of additional spent fuel produced. As a result, if reactor lives are extended by 20 years, this delays the need to deal with spent nuclear fuel by only seven years. With the potential for further life extension speculative, and the probability that it would only apply to some reactors in any event, this does not appear to offer much promise as a means of delaying the urgency of dealing with spent fuel management issues.

Other potential efficiencies. Currently, utilities manage spent fuel, and as a result of the standard contract breach, recover essentially all costs through litigation. While the legal standard for recovery of costs requires the plaintiff (utility) to seek to minimize those costs, the legal standard for justifying costs tends to be lower than that associated with typical cost recovery from ratepayers under public utility oversight. This is a gross simplification of legal issues, but in general, there is little incentive for utilities to minimize spent fuel storage costs if utilities assume those costs will be recovered from the federal government. If the fuel is transferred to

DOE and held in a centralized facility, there may be greater incentives to limit costs and a larger scale of operations to promote the development of operational efficiencies.

XII. Reasons to Delay a Decision to Develop Centralized Interim Storage

Even if it is agreed that a centralized interim storage facility has benefits, one might conclude that delaying the decision to proceed is an even better option. Analysis provided earlier considers different starting dates for a centralized facility. In the economic analysis, a critical assumption is the discount rate and higher discount rates are more likely to lead to concluding that the decision can be delayed. Attempts to optimize the start date for the facility must be weighed against the uncertainties over the time needed for siting, licensing and construction. Nevertheless, putting off the decision to build centralized storage can have other implications, some of which may be beneficial.

There will be substantial cost savings if the centralized facility can be located at the permanent repository. If a modest delay could make the difference to assure this location, it probably would be worthwhile from a cost perspective. Unfortunately, it is not known what could be done to make sure that delaying the decision could have this outcome. On the other hand, some conclude that there should be more than one centralized facility. In that circumstance, planning on having the second facility built at the repository when its location is known, while building the first facility at another site in the mean time, could be an optimum strategy.

It is possible that a delay could result in a more optimized centralized facility in other ways, related to aspects like location, technology, integration with other spent fuel management issues, etc. One can always make the assertion that better decisions might be made further in the future. Other than locating the facility at the repository site, there do not appear to be obvious scenarios where a substantially better decision might be made in the future.

Another reason tending to favor delay would be if one concludes that transportation rates in excess of 3,000 MTU/year can be reliably expected. This rate was used because it is consistent with planning for the repository, but it is not an absolute limit and may not be appropriate for a centralized interim storage facility. The analyses of the 6,000 MTU/year rate that were provided earlier demonstrate that substantial stranded storage costs are not imminent if spent fuel can be shipped at that rate. If a higher acceptance rate could be counted on, centralized interim storage is probably best implemented by building a scalable facility with limited capacity in the near-term to accommodate the spent fuel at currently shutdown reactors, and possibly continued shipments at a low rate, but delaying the full-scale ramp-up of shipments. Thus, the ability to ship at 6,000 MTU/year may not delay the commitment to start the facility, but could affect planning assumptions for shipments over its life.

XIII. Conclusion

The decision to pursue centralized interim storage involves complicated issues and tremendous uncertainty. Economic analysis can play a supporting role, in quantifying issues and demonstrating the consequences of certain developments. If the only complications were uncertainties over assumptions, probability weighted values could provide cost analyses on an expected value basis to support the decision analysis. If the only further complication was the potential for additional changes in strategy as a result of ongoing developments, then more sophisticated analyses could be adopted where the expected values would include the effect of further decisions over time in response to evolving circumstances. But instead, this decision is even further complicated by differing views on issues of risk aversion, intergenerational equity, appropriate discount rates and the importance of DOE meeting its obligation to accept the spent fuel accumulating around the nation. We recognize that reasonable people who accept the entirety of our analysis may still disagree on the appropriate next steps. If this decision were easy it would have been made decades ago.

Our analysis suggests that decision makers recognize that centralized storage would have clear, if difficult to quantify, advantages in the overall spent fuel management program for the nation. These advantages relate to flexibility, safety, compliance with contractual obligations and a host of other issues. If there were no incremental costs of centralized interim storage, clearly it would be an option worth having. Absent a centralized facility it seems inevitable that spent fuel will languish at locations across the country that would not have been chosen for stand-alone storage. The move toward centralized storage should produce a defined, tangible and licensable alternative. The construction of a facility and movement of fuel will not only be a positive step forward in the management of this problem, but there will be a great deal of learning about how to meet the challenges of managing spent fuel at a national level. Optimistically, those lessons may uncover different options and processes that will be beneficial in this process. But even the pessimist will recognize that if this turns out to be more difficult than expected and greater problems are encountered, it is better that these challenges be known. Either way, the learning that results will move us forward.

In looking at the costs of pursuing the centralized storage option, they are quite modest. There is the chance that the efforts prove fruitless, or the process is abandoned because progress is made on the repository, but in those circumstances the extra costs incurred are likely to be only a few tens of millions of dollars. While not trivial, in the perspective of the overall spent fuel management program, these are small levels of commitment. On the other hand there is a wide variety of circumstances where centralized storage facilities could prove invaluable. Savings of billions of dollars are possible. Having dug through the many reports that assess the centralized storage option and having conducted extensive analysis, we find ourselves drawn to the conclusion that it would be prudent to take actions now to move toward centralized interim storage.