8.2.2. DISADVANTAGES OF THE APPROPRIATIONS PROCESS

Even if competition with other programs for limited discretionary funding were not an issue, the current statutory requirement that makes use of the NWF subject to appropriations has led to unforeseen difficulties caused by the appropriations process itself. Although the current system assures Congress explicit and extensive year-to-year oversight and control as intended by the NWPA, it has clearly proven to be a poor mechanism for financing a very long-term and complex effort. First, the annual appropriations process creates substantial funding uncertainty, which can make it difficult for the implementing agency to make and honor longer-term commitments, retain staff expertise, and exercise independent judgment about programmatic priorities and resource allocation. Second, Congress has increasingly failed to pass appropriations bills in a timely manner in recent years, forcing federal agencies to operate on continuing resolutions for extended periods of time while coping with the delayed availability of requested funds.

A 2005 report on the management and funding of nuclear waste management programs in the 11 member nations of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)[185] noted that all these nations have applied the principle that waste producers should pay for the management of their wastes. Where EDRAM members differ is in how they estimate, collecte, and manage waste management fees. The United States stands out as the only nation where the national legislature directly controls, on an annual basis, the expenditure of funds collected for nuclear waste management purposes.[186]

8.3 FIXING THE FUNDING PROBLEM

The federal government's failure to deliver on its statutory waste management obligations to date and the fact that the Waste Fund and fee are not working as intended have prompted the National Association of Regulatory Utility Commissioners, along with some nuclear utilities and the NEI, to pursue legal action against DOE aimed at suspending the collection of nuclear waste fees until such time as a new waste management plan for the country is in place. The outcome of this and other pending legal actions remains uncertain at present, but they underscore the growing frustration among state regulators, nuclear utilities, and consumer advocates about the continued lack of progress toward a durable waste management solution. In fact, there is a growing sense of outrage that the only aspect of the waste management program that has been implemented in full and on schedule is the part that involves collecting fees for a contractually required service that the federal government has never managed to deliver.

The Commission concludes that for the waste management program to succeed, the nuclear waste funding mechanism must be allowed to work as intended so that the ability to implement the waste program is not subject to unrelated federal budget constraints. If that is not done, key recommendations of the Commission will be undermined—e.g., efforts to develop both storage and disposal facilities will be in conflict rather than mutually supportive and commitments to provide benefits to host communities over the life of the program will lack credibility. Fixing this problem requires extricating the nuclear waste fee and NWF from the web of budget rules that have made these user-provided resources effectively unavailable to federal budgeters and appropriators, forcing them to take limited discretionary funds away from other federal programs in order to pay for the activities needed to meet federal waste management contractual obligations and thereby put an end to growing taxpayer financial liability for failure to meet those obligations.

The Commission also concludes that a new waste management organization bound by a well-defined mission should be entrusted—subject to an appropriate level of oversight by Congress and relevant regulatory authorities—with greater autonomy and control of its budget over multiple year periods than is possible under the annual appropriations process, just as the TVA has control of the use of its receipts from electricity sales (subject to congressional oversight). This kind of authority is crucial, among other reasons, to allow the new organization to negotiate meaningful, enforceable, and ultimately *credible* commitments with other parties—including with the communities, states, and tribes that will be most directly affected by its activities. Fixing the current funding problem requires removing waste program funding decisions, to the extent they concern activities related to the civilian wastes for which the nuclear waste fee is being paid, from dependence on the annual federal budgeting and appropriations process, while ensuring appropriate oversight by Congress and other third-party agencies.

The Commission recommends that this transition be accomplished in two stages:

1. Near-term non-legislative actions that would allow full access to future waste fee revenues subject to appropriations control but independent of competition with other funding needs.
2. Legislative action as part of the establishment of an independent waste management organization that would

allow it to function as an autonomous self-financed entity like TVA or the Bonneville Power Administration, with full control of the use of its revenues subject to congressional and other independent oversight and with access to future fee receipts and, eventually, the current corpus of the Nuclear Waste Fund.

8.3.1 NEAR-TERM NON-LEGISLATIVE ACTION TO INCREASE ACCESS TO FEE REVENUES

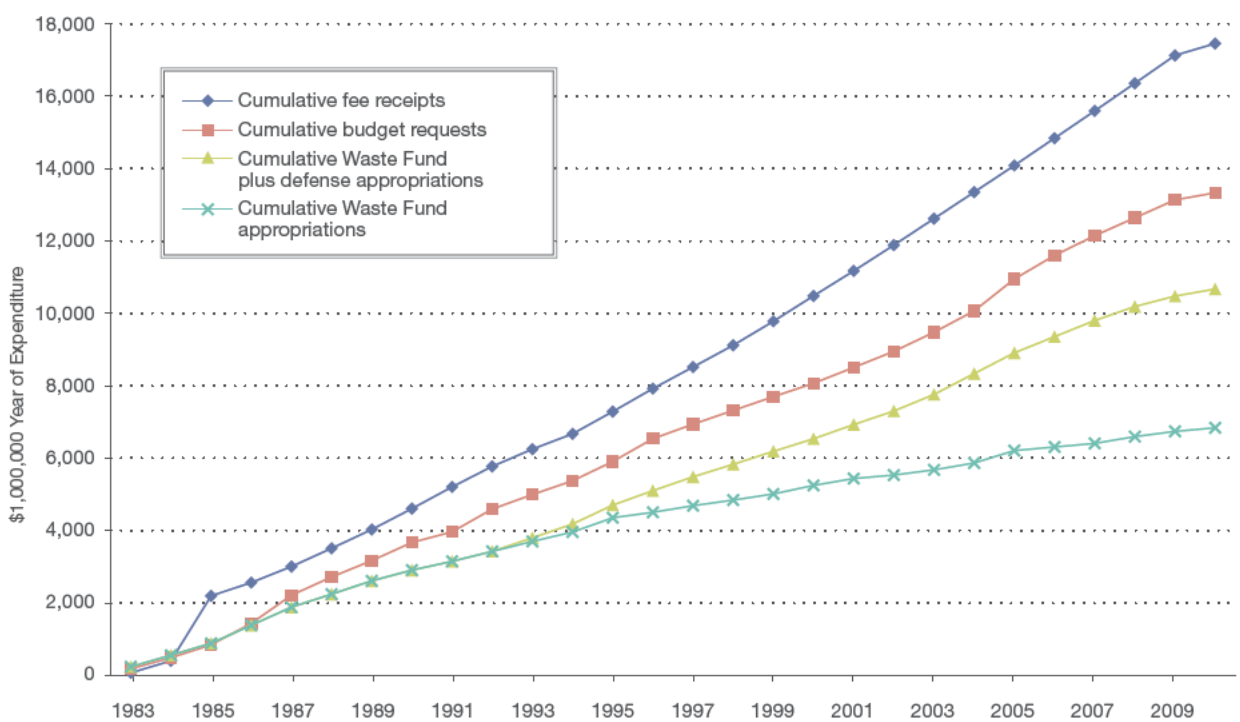
The Commission recognizes that legislative action to create a new waste management organization with full access to the nearly $27 billion balance in the NWF will be difficult in the current political and budgetary climate, despite the fundamental equity arguments for this action. Therefore, we urge the Administration to take prompt action aimed at enabling appropriators to use the annual nuclear waste fee revenues for their intended purpose, free from competition with other spending priorities, while stopping further additions of surplus revenues to the NWF until such access has been guaranteed. We believe this can be accomplished by adopting a combination of measures that are already allowed under existing legislation.[187]

Specifically, the Administration should (1) change the way in which the nuclear waste fee is collected so that only an amount equal to actual appropriations from the NWF is collected each year, with the remainder retained by utilities in approved trust funds to be available when needed for future use, and (2) work with the congressional budget committees and the Congressional Budget Office to reclassify the fee receipts from mandatory to discretionary so that they can directly offset appropriations for the waste program.[188] Taken together, these steps would make the nuclear waste program funding mechanism work essentially as Congress intended in the NWPA, at least for future fee revenues. Each is discussed further below.

Change the Timing of Nuclear Waste Fee Collections

Under the current approach, the entire 1 mill/kwh fee is collected from contract holders each year (the total collected amounts to approximately $750 million per year) and deposited in the Treasury, independent of the sum actually appropriated from the Fund for use by the waste management program. This annual revenue stream is counted in the federal budget baseline as an offset to mandatory spending, which raises the criticism that

FIGURE 18. CUMULATIVE NUCLEAR WASTE FEES, BUDGET REQUESTS, AND APPROPRIATIONS[189]



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the fee is simply being used to reduce the budget deficit instead of for its intended purposes. This criticism becomes more acute as the gap between annual fee payments and appropriations from the Fund widens. Figure 18 shows the large and growing gap between cumulative nuclear waste fee receipts (not including interest on the NWF balance) and appropriations from the NWF. The longer annual fee payments continue to accumulate in the Fund, the greater the budgetary and political difficulty of restoring the Fund to its intended purpose will be.

To stop the flow of waste fees to an inaccessible account in the Treasury, to put an end to the perception that the fee is simply being used to reduce the federal budget deficit, and to take the first crucial step towards making future fee revenues accessible to appropriators, the Administration should adopt a modified version of an approach proposed by the Secretary of Energy in 1998 as part of a litigation settlement concept.[190]

The key element of that proposal was to change the timing of fee payments into the NWF through administrative action so as to match the annual flow of cash into the Fund with actual spending from the Fund in support of nuclear waste management activities. Specifically, DOE proposed to offer to amend its contracts with utilities to allow utilities to retain the portion of the 1 mill/kwh fee that exceeded the annual appropriations level. As soon as the federal government began to accept waste, utilities would pay the deferred fees plus interest at the Treasury rate.[191] The modified approach proposed here would require each utility to place the unused fee receipts in an irrevocable trust account at an approved, third-party financial institution, allowing the money to be withdrawn only for the purpose for which the trust account was created, at the time and in the amounts needed to fund the federal waste management program. This would make the "waste disposal trust accounts" similar to the decommissioning "sinking funds" most utilities use to meet NRC requirements that they provide assured funding for reactor decommissioning. Funds in those accounts can only be used for decommissioning. By analogy, if a similar irrevocable trust account were created for NWPA purposes, the licensee could only pay out the money to the waste management organization as required to meet program needs. This approach would make the utility waste trust accounts collectively serve the function that the Nuclear Waste Fund was supposed to, providing a source of funds in reserve that can be used in years in which the waste program's funding needs exceed the total annual fee receipts.

A key feature of this proposal is that it would be accomplished using the Secretary of Energy's existing authority under the NWPA to establish procedures for the collection and payment of the fees.[192] Under current

budget rules, any legislative action that has the effect of reducing NWF receipts to the U.S. Treasury will be subject to "pay as you go/cut-as-you-go" or "PAYGO/CUTGO" requirements.[193] This means that new revenues or budget cuts will be needed to cover the change in funds flowing to the Treasury resulting from new legislation. However, any changes to fee revenues resulting from non-legislative action under existing law would have no PAYGO/CUTGO impact.[194] At the same time, by ending the practice of counting revenues from the entire 1 mill/kwh fee in the federal government's budget baseline, this step would substantially ease the PAYGO/CUTGO burden associated with subsequent legislative action to transfer fee receipts to an independent organization.[195] Furthermore, tying annual fee collections to actual appropriations for the waste program would strengthen the rationale for reclassifying fee receipts as a discretionary offsetting collection, which is the second step required to implement our recommendations for interim funding.[196]

Reclassify Waste Fee Revenues from Mandatory to Discretionary

The above-described step of splitting fee collections does not, by itself, address the problem that appropriations from the Fund are subject to caps on discretionary spending, because the fee receipts have been placed on the other side of the mandatory/discretionary spending firewall where they are not directly available to appropriators. A second step is needed to move the receipts to the discretionary side so they can be used by appropriators to fund the waste program without reducing funds available for other discretionary programs. ***To implement this approach, the Administration should work with the appropriate congressional authorities to re-classify waste fee receipts from mandatory to discretionary offsetting collections so that they can directly offset appropriations for the waste program.*** Combined with the previous step that would tie annual fee receipts to actual appropriations levels, this would enable a funding process similar to that used to fund the NRC (i.e., where funding is provided primarily by user fees that are set at the level of annual budgetary authority established in appropriations bills).

DOE's 2001 analysis of alternative means of financing and managing the waste program, which was prepared at the request of Congress, specifically considered this option and concluded it would be feasible. Current practice would require OMB to seek the concurrence of the Congressional Budget Office and the congressional budget committees for this reclassification. In addition, appropriations language would be required to credit the fee to waste management appropriations; indeed, we urge the Administration to include such language in its FY 2013 budget proposal.[197]

Implications of the proposed approach

The two-step approach we propose would accomplish several things:

- It would reduce PAYGO/CUTGO challenges for future legislative action to give a new organization access to the nuclear waste fee and Fund by lowering the baseline projection of fee receipts for federal budget purposes and by slowing the continued build-up of the corpus of the Fund.
- By eliminating surplus collections, it would address the concern of utilities and public utility commissions about the misuse of the fee and Fund to reduce the annual deficit instead of for the purposes of the NWPA. Instead, the surplus fee revenue would go into approved third-party trust accounts that would be available when needed to meet the operational costs of disposal, when program expenditures can be expected to exceed fee receipts.
- It would facilitate adequate appropriations for the program in the near term by giving appropriations from the Fund (up to the amount of revenue generated annually by the 1 mill/kwh fee plus any additional amount obtained from balances in the utility trust accounts) a net budgetary impact of zero, since the appropriation would be directly offset by the collection of an equal amount in fee revenues. As noted above, a similar approach is already being used to fund the NRC.
- Finally, it would demonstrate the federal government's determination to make the funding mechanism established in the NWPA work as originally intended.

There are also several things this two-step action would *not* do:

- It would not reduce Congress's oversight role in the budget process for the waste program. Under current practice, OMB would seek the concurrence of the Congressional Budget Office and congressional budget committees for reclassifying fee receipts, appropriations language would be needed to credit fee receipts against appropriations, and congressional appropriations committees would continue to control the annual level of program funding through the appropriations process. Legislation will be required to remove this funding from the annual budget process while retaining an appropriate degree of external oversight of program spending, as recommended earlier.
- It would not increase access to the corpus of the NWF. This must be accomplished in subsequent legislation since DOE's existing contracts with utilities create a legal obligation for the federal government to ultimately

expend these funds for the waste management purposes for which they were collected.
- It would not adversely impact the discretionary funding of any single program or agency since the changes would occur on the mandatory side of the budget, although it would—by removing projected fee revenues from the budget baseline—lead to a very small percentage increase in the federal government's nominal annual budget deficit.

We understand that nearly 30 years of interpretation and application of general budget concepts and practices have led to the current treatment of the waste fee receipts and program expenditures. But the application of general concepts and practices to unique situations can sometimes have unintended and perverse results—as they have in this case. We cannot believe that anyone intended the current situation: the government is in default on a contractual obligation to dispose of spent fuel from nuclear utilities; the user fees being paid to the government to finance the activities needed to meet that obligation are used to offset the deficit, while expenditures for those activities are constrained under limits on discretionary appropriations; and all the while, taxpayer liabilities resulting from failure to meet the government's contractual obligations continue to grow. The Financial Report of the United States Government for FY 2011 reports that these liabilities totaled $49.1 billion—including both the unpaid damages for non-performance and unspent Nuclear Waste Fund fees and interest.[198]

We believe that this situation must be changed, in order to put an end to the continuing damage to taxpayers, nuclear utilities and their ratepayers, and the credibility of the federal government's commitment to meet its statutory and contractual obligations. To do so, we believe that budget policy leaders in the Administration and Congress can and should act in the same bipartisan spirit of cooperation that characterized passage of the NWPA to make whatever reinterpretations of, or even exceptions to, the decades of budget interpretations and practices that will be needed to make the waste management funding mechanism work as originally intended.

We recognize that there may be concerns that the actions to give full access to the nuclear waste fee and Fund the Commission recommends might set precedents that would have broader implications for other federal programs. However, we believe that the current circumstances—involving a highly unusual contractual arrangement mandated by the NWPA and the existence of growing taxpayer liabilities for failure to comply with the terms of that arrangement—are so narrowly drawn that any precedents that are set would have at most very limited implications elsewhere.[199]

8.3.2 LEGISLATIVE ACTION TO PROVIDE BUDGETARY AUTONOMY (SUBJECT TO OVERSIGHT)

The above-described steps would enable appropriators to fund a restart of the waste program from future fee receipts without taking funds from other programs. However, growing delays and uncertainties in the overall federal appropriations process will continue to make long-term planning and commitments difficult; and eventually access to the unspent balance in the Nuclear Waste Fund will be needed. Legislation to establish a new waste management organization should give the organization the same authority to use its revenues to carry out its civilian nuclear waste obligations independent of annual appropriations (but with congressional oversight) as is now given to the Tennessee Valley Authority and Bonneville Power Administration.

As noted earlier, legislation that has the effect of reducing nuclear waste fee receipts to the U.S. Treasury or increasing projected spending from the NWF will be subject to PAYGO/CUTGO requirements, depending on when the changes will occur. The Commission recognizes that there have been numerous unsuccessful legislative proposals to increase access to the fee revenues and the NWF while addressing such requirements.[200] Nonetheless, access to the corpus of the NWF will ultimately be needed to meet the fluctuating revenue demands of the waste management program going forward. This will include covering years when costs peak—for example during the construction of waste management facilities. That the balance in the NWF (including accrued interest) would be fully accessible when and as needed was a fundamental premise underlying the commitments made in the NWPA—that premise must be restored. Anticipating that the near-term non-legislative actions proposed above may be able to provide adequate funding for a restarted waste program for the next decade or perhaps longer, the Commission recommends that legislation establishing a new waste management organization include a defined schedule of payments to transfer the balance of the Fund to the organization over a reasonable future time period, starting 10 years after the organization is established.[201]

As we have already noted, our recommendations for separating the NWF from the congressional budget process are in no way intended to imply a diminished need for rigorous program oversight. On the contrary, we believe these budget and funding reforms—to be acceptable to Congress and the public—must be coupled with strong provisions to ensure that the waste program is being implemented effectively and is making appropriate use of the NWF and fees with which it has been entrusted.

Finally, as discussed above, the Commission is aware that efforts to fix the use of the NWF could be caught up in broader questions such as the treatment of trust funds in the federal budget more generally. However, DOE has testified to Congress that proposals to correct the treatment of the waste fee and Fund are unlikely to create wider precedents beyond similar contractual fee-for-service situations (if any exist).[202]

8.4 PAYING FOR THE DEFENSE WASTE SHARE

The preceding discussion has addressed only the portion of waste program costs that are attributable to the management of commercial waste and that are paid for through the nuclear waste fee and NWF. Since current policy presumes that national defense wastes will be disposed of in a repository developed pursuant to the NWPA, a portion of the costs of the program are paid directly by appropriations from the national defense side of the federal budget.[203] Using a methodology for allocating costs between government-managed nuclear materials and commercial wastes that was first published in 1987,[204] DOE's 2007 Fee Adequacy Assessment estimated the defense share of total program costs at 19.6 percent for 2007.[205] (The defense share adjusts each year as assumptions change.)

Steady progress on implementing a disposal solution will require that appropriations for the defense share are made as needed to pay the full cost of defense waste disposal (note that, in the absence of a disposal facility, the GAO has estimated that continued storage of defense wastes at DOE sites will cost well over a billion dollars through 2040[206]). Historically, appropriations from the defense side of the waste management budget have not been nearly as constrained as those from the civilian side. Since the inception of the program through the end of FY 2010, defense appropriations (in nominal dollars) amounted to $3,756 million compared to $6,837 million from the NWF, or just over 35 percent of total waste program appropriations. By comparison, the defense share of total program cost over the life of the repository was estimated at 19.6 percent in 2007. In the last ten fiscal years, defense appropriations have represented over 61 percent of total appropriations for the waste program.[207]

Given this history, it would not appear that measures are needed to ensure adequate appropriations for the defense share of repository costs in the future.[208] However, once it becomes necessary to fund the construction of a repository (whether that repository is for commingled civilian and defense wastes or for defense wastes only), consideration might be given to mechanisms like multiyear appropriations that are sometimes used with large defense procurements (e.g., for the construction of an aircraft carrier) to ensure that expensive and complex projects can be completed in a timely and cost-effective manner.

8.5 DEALING WITH ONGOING LITIGATION

For reasons discussed in other chapters, DOE was unable to begin accepting commercial spent fuel by January 1998, as required under the Standard Contract. DOE and utilities have been engaged in protracted litigation since then over the Department's failure to perform its obligations,[209] as shown in table 2. Some 78 lawsuits have been filed, dozens of lawsuits have yet to be tried, some utilities have reached settlements with the government, and courts have reached judgments in other cases that find DOE in "partial breach" of its contracts. This means taxpayers must pay damages incurred by utilities as a result of DOE's failure to accept fuel,[210] even as DOE remains obligated to do so in the future.

DOE currently estimates that total damage awards to utilities could amount to $20.8 billion if the federal government begins accepting spent fuel in 2020. DOE has previously estimated that liabilities could increase by hundreds of millions of dollars annually if the schedule for starting acceptance slips beyond 2020. DOE and the Department of Justice (DOJ) note a significant development in 2008 that substantially affects future damage estimates. The Court of Appeals for the Federal Circuit ruled in one case that DOE was obligated to accept spent fuel at higher rates than were used in the settlements on which previous damage estimates were based, and directed the trial court to apply these higher rates in determining damages.[211] The new rates have been assumed for future settlements and decisions in the most recent liabilities estimate, and are largely responsible for the increase over the 2010 estimate of $16.4 billion.

To date, damages and judgments in the amount of $2 billion have been paid from the taxpayer-funded Judgment Fund, which is overseen by the DOJ. The Judgment Fund is being used because a federal court ruled in *Alabama Power Co. v. United States Department of Energy*, 307 F.3d 1300 (11th Cir. 2002), that the government could not use the Nuclear Waste Fund to pay for damages incurred as a result of DOE's delay. In addition, DOJ has incurred $188 million in costs for the cases it has litigated through 2011 and more cases are expected in the future. Because DOE is only in "partial breach" of the contracts, utilities can only file for actual damages incurred as of the date of filing. As a result, utilities must re-file periodically—at least every six years because of the statute of limitations—to recover additional damages after the previous claim was filed. For this reason,

TABLE 2. STATUS OF DOE-UTILITY STANDARD CONTRACT LITIGATION (AS OF DECEMBER 2011)[212]

Standard contracts	76
Reactors covered by contracts	118
Cases filed through 2010 • Second-round	78 (12)
Claims	$6.4 billion
Voluntarily withdrawn	7
Settled	23
Separate settlement agreements	21
Reactors covered by settlements	65
Final judgments • Not appealable • On appeal	24 (13) (11)
Pending before the trial court	24
DOJ trials through 2010	30
Litigation costs through 2010 (Experts and support; no DOJ or DOE staff)	$188 million
DOJ trials expected 2011 through 2012	up to 6
Amount of judgments on appeal	$509 million
Payments for final judgments and settlements to date	$2 billion
Estimated total damages (if acceptance starts in 2020)	$20.8 billion
Estimated increase for each year slippage	Up to $500 million

a steady stream of lawsuits can be anticipated until either (a) DOE has accepted enough waste to "catch up" with the amount it should have accepted on the schedule determined by the courts or (b) DOE has negotiated settlements with all contract holders that would allow damages to be paid without further litigation.

The litigation that has already occurred over the federal government's failure to meet its existing waste acceptance obligations has been expensive, time-consuming, not conducive to resolving the current impasse in the nation's nuclear waste management program, and detrimental to the full and open communication among parties needed for integrated planning concerning spent fuel management. Because most of the major recurring issues have been resolved in litigation and the outcomes are now more predictable, moving toward a simplified claims process for the purpose of settling existing lawsuits has been suggested,[213] and since February 2011, the Department of Justice has executed 13 additional settlements resolving claims covering 25 reactors and has authorization to enter another settlement covering four reactors.[214] Settling current and pending lawsuits as quickly as possible would reduce unnecessary litigation costs, make it possible to assess the cost impacts of changing current spent-fuel acceptance priorities more reliably, and facilitate more open communication and coordination between the waste management organization and contract holders. The Commission therefore urges all parties to continue to work to conclude these proceedings in a fair manner, either through settlement agreements or through another process, such as mediation or arbitration, consistent with the precedents set by past court decisions.

9. TRANSPORTATION ISSUES

The ability to safely and securely transport nuclear materials is critical to implementing a comprehensive and workable waste management system.

Overall, the set of standards and regulations that currently exists to govern the transport of spent fuel, high-level waste, and other nuclear materials has functioned well and the safety record for past shipments of these types of materials has been excellent. Indeed, states have been working cooperatively with DOE for many years to plan for shipments, often through agreements with regional groups of states and in ways that involve radiological health, law enforcement, and emergency response personnel. However, past performance and mere compliance with current regulations does not guarantee that future transport operations will match the record to date or that these operations will be conducted in a way that inspires public confidence, particularly as the logistics involved expand to accommodate a much larger number of shipments. This chapter discusses the Commission's specific findings and recommendations with respect to the transport of spent fuel and nuclear waste in the context of the broader waste management strategy we are proposing.

9.1 BACKGROUND AND CONTEXT

In 2006, the National Academies issued a report titled *Going the Distance: the Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States*.[215] The report concludes that there are "no fundamental technical barriers" to the safe transport of such materials, but it made a number of recommendations to improve safety, communicate risk, and conduct planning and other activities in preparation for a large-scale transport campaign for spent fuel. Many of these recommendations have since been adopted, at least in part, by federal agencies such as the NRC, DOE, and the U.S. Department of Transportation (DOT).[216] Table 3 below summarizes the key NAS study recommendations and their current status. The Commission believes that other NAS recommendations that have not yet been implemented, for whatever reason, should be revisited and addressed as appropriate.[217]

TABLE 3. RECOMMENDATIONS OF THE NAS
GOING THE DISTANCE REPORT AND THEIR CURRENT STATUS

Recommendation	Current Status (as of January 2012)
Undertake full examination of spent fuel transport security by independent, cleared technical experts.	Members of the BRC and staff with appropriate clearances have been briefed by NRC and DOE on transportation and storage security analyses undertaken since 2006. However, the BRC does not believe this constitutes the "full examination" recommended by the NAS study and we are not aware of any other efforts that would satisfy the NAS recommendation.
Be proactive in formally assessing and managing "social risks." Expand Transportation External Coordination (TEC) Working Group to include this issue, establish external risk advisory group, potentially under NWTRB auspices.	Research on social risks and risk perception has been ongoing, but the Commission is unaware of any specific changes that have been implemented by DOE or other agencies as a result. The TEC Working Group (now defunct) did not expand its scope to address this issue. The NWTRB has periodically examined public perceptions of transportation risks but has not established an external risk advisory group.
The NRC should analyze very long-duration fires, and implement regulatory controls to reduce the chances of a spent fuel shipment being involved in such a scenario.	The NRC has made a practice of studying real-world fires and analyzing how casks would perform under such conditions. The NRC has also worked with the Association of American Railroads to establish a "no pass" rule for tunnels that would be used to transport spent fuel, effectively precluding the possibility that other trains with flammable materials would be in a tunnel at the same time. This would prevent a long-duration fire of any significant size.
Full-scale package testing should continue to be used as part of package performance evaluation. Testing to destruction should not be required.	The NRC had planned to implement a Package Performance Study that would involve a full-scale cask and would not "test to failure." The project was never begun due to lack of funding and the eventual cancellation of the Yucca Mountain project. The study would have involved use of a Transportation, Aging and Disposal (TAD) canister in an overpack; initial design work for this canister has been completed but none have been fabricated.
DOE should continue to ensure systematic involvement of states and tribal governments in decisions about routing and scheduling for current spent fuel shipments.	DOE has continued to involve states and tribes in transportation planning, and has established a National Transportation Stakeholders' Forum for that purpose. After the Yucca Mountain project was cancelled, DOE's EM program and NRC's Spent Fuel Storage and Transportation office provided funding to state regional groups (albeit at reduced levels).
DOT should ensure states rigorously comply with requirements for sound risk assessments in designating routes.	DOT has developed regulations for determining "preferred routes" for highway shipments, and the NRC reviews routes for security. DOE follows the same requirements for its shipments. The Commission is unaware of any recent or proposed campaigns where a state has attempted to re-route spent fuel shipments using impermissible assessments or practices.

Recommendation	Current Status (as of January 2012)
Mostly rail has clear advantages; DOE should complete the Nevada rail line and examine how to reduce the need for cross-country truck shipments by expanding intermodal service.	The Yucca Mountain project had formally established a "mostly rail" policy before the program was cancelled. Construction of the Nevada rail line never commenced. Federal Railroad Administration (FRA), DOE and some state agencies began a pilot project to examine near-reactor infrastructure and related intermodal issues, but that work too has been halted.
DOE should ship oldest fuel first to a repository or storage facility. Conduct a "pilot" campaign by shipping fuel from shutdown reactors first.	This recommendation was never implemented, but is consistent with the Commission's recommendation to ship fuel from shutdown reactors first.
DOE should identify and make public its suite of preferred routes as soon as practicable to support state, tribal and local planning and preparedness, following the research reactor fuel program's process of involvement.	The Yucca Mountain project began development of a formal route assessment process based on DOE's established practices, but this effort too was halted. DOE programs continue to consult with states and tribes on routing issues.
Immediately implement Section 180(c) of the NWPA to provide funding and technical assistance to corridor states and tribes.	This recommendation was never implemented, but it is consistent with the BRC's recommendation that funding should be provided to implement Section 180(c) early in the planning process.
Federal agencies should develop clear and consistent guidance on what and how information about transportation should be protected, and commit to open access to information that does not need such protection.	DOE and other agencies did develop a joint Transportation Classification Guide for Yucca Mountain shipments, which have not commenced. DOE programs continue to follow their own security requirements.
DOE should fully implement its dedicated train decision before large-quantity shipments begin.	The Yucca Mountain project did issue a formal decision to use dedicated train service for its shipments. The BRC is unaware of any recent or proposed spent fuel rail shipments that would not involve use of dedicated trains.
DOE and Congress should transfer responsibility for spent fuel transportation to an outside entity.	This recommendation was never implemented, but is consistent with the BRC's recommendation that a new entity is needed to manage transportation (and everything else) related to SNF and HLW.

9.2 REGULATORY AND TECHNICAL ISSUES

Several transportation-related regulatory and technical issues received particular attention in the course of the Commission's deliberations. For example, the BRC's Transportation and Storage Subcommittee heard testimony that DOE's plans to use its own self-regulating authorities under the Atomic Energy Act sharply undercut credibility in the proposed transportation program. The existing regulatory framework for commercial transportation—which features extensive oversight and involvement by the NRC, mode-specific administrations of the DOT,[218] and state and tribal officials—is proven. Consistent with the recommendations articulated in chapter 7 of this report, the Commission believes that a new waste management organization should be subject to independent regulation of its transport operations in the same way that any private enterprise performing similar functions would be—in other words, the new organization should not receive any special regulatory treatment. This will help assure regulatory clarity and transparency.

Another transport-related issue that will need to be addressed concerns the fact that the NRC has not yet granted a license for the transport of higher burnup fuels, which are now commonly being discharged from reactors.[219] It will be necessary to reexamine current regulations and to develop a technical basis for assigning burnup credit to ensure that these higher-burnup fuels can be transported when needed. In addition, spent fuel that has been stored for extended periods may be degraded and may require additional handling and preparation before it can be transported.

Finally, numerous parties have suggested that expanded full-scale testing of transportation casks (in addition to computer modeling) could be useful in enhancing public confidence in transport safety. Full-scale testing is part of the testing methodology used by the NRC in its integrated evaluation program. The NAS *Going the Distance* study endorsed the NRC's approach and recommended that full-scale cask testing, as well as other accepted methodologies, should continue to be used for technical reasons. In 2005, the NRC approved a staff proposal for the full-scale testing of a rail cask (like one shown in figure 19)—of the kind expected to be used in transporting spent fuel to a HLW repository—in a scenario involving a collision with a locomotive traveling at high speed followed by a hydrocarbon fire.

DOE supported the proposed Package Performance Study and suggested combining it with an emergency response exercise to maximize the benefits of the study. Plans to provide NRC with needed funding in 2009 did not materialize because of budget constraints (the estimated cost of the study was approximately $15 million) and uncertainties about the Yucca Mountain project. The Commission's view is that funding for the proposed test, if it has independent value, should be provided from the Nuclear Waste Fund so that the NRC can update these plans and proceed with those tests the NRC determines to be most useful.

With regard to transportation security, the NRC has existing security regulations and orders in place and is currently undertaking a separate rulemaking to codify further transportation security requirements.[220]

The proposed protective strategy for transportation includes several elements:

- Advance planning and coordination with states
- Increased notifications and communications before and during shipment
- Continuous and active shipment monitoring
- Use of armed escorts over the entire shipment duration (previously, armed guards had been required only in highly populated areas)
- Background investigations of personnel with access to Safeguards Information.

In its *Going the Distance* report, the NAS noted that "[m]alevolent acts against spent fuel and HLW are a major technical and societal concern." However, the report authors were unable to perform an in-depth analysis of transportation security due to informational constraints (primarily lack of access to classified materials).[221] Accordingly, the committee recommended that experts with full access to all relevant information conduct an independent assessment of security

FIGURE 19. CASKS BEING TRANSPORTED BY RAIL

risks before any large-scale campaign to ship materials to a disposal or consolidated storage facility is launched.

In subsequent discussions with the NRC's Office of Nuclear Security and Incident Response, BRC Commissioners and staff reviewed the additional analyses NRC has conducted following the release of the NAS report and others developed since that time.[222] We found that the NRC has taken reasonable actions to respond to the vulnerabilities that have been identified to date and we expect the current NRC rulemaking process to be sufficient to ensure that any needed future changes will be made appropriately.

9.3 THE ROLE OF STATE, TRIBAL AND LOCAL GOVERNMENTS AND THE IMPORTANCE OF EARLY PLANNING FOR FUTURE TRANSPORT NEEDS

Extensive planning and preparation for transport arrangements will be required even if only the 2,800 metric tons of spent fuel currently being stored at shutdown reactors are slated for initial transfer to consolidated storage.[223] The Commission has heard testimony indicating that advance planning timeframes on the order of a decade could be required to plan and coordinate a transport strategy and to establish the institutional and physical infrastructure to conduct a large-scale shipping operation.[224] Historically, some programs have treated transportation planning as an afterthought. No successful programs have done so.

This lead time is important from a purely logistical standpoint because some critical elements of infrastructure and equipment do not currently exist and will need to be designed, fabricated, tested and licensed before significant amounts of waste can be moved. For example, the Association of American Railroads requires the use of cask cars, buffer cars and escort cars with special safety features for future rail shipments of SNF. No such cars currently exist, and developing and placing this type of equipment into service will require between five and seven years.[225] The current commercial fleet of licensed casks is quite small and is primarily limited to legal-weight truck (LWT) casks. While a significant transportation campaign could begin using trucks and current LWT casks, a sizeable fleet of rail rolling stock will be needed to move larger quantities of SNF (such as those currently loaded in dual-purpose containers in dry storage at reactor sites). Moving significant quantities of spent fuel from reactor sites will require substantial new, specially-designed and dedicated equipment; it will also require infrastructure modifications and improvements at existing reactor sites, which vary widely in terms of their condition and accessibility. These logistical issues, which must be addressed sooner or later in any event, do not present large technical challenges, but they are nonetheless complex and will take time to resolve.

Substantial lead time is also needed to ensure that planning and institutional arrangements are in place and tested by the time major shipments commence. This means early efforts are needed to undertake planning activities that involve state, tribal and local officials. To that end, DOE should complete the development of procedures and regulations for providing technical assistance and funds (pursuant to section 180(c) of the NWPA) for training local and tribal officials in areas traversed by spent fuel shipments. Although the final destination of the material to be shipped (whether for storage, recycling or disposal) is not known, every origin site is known. DOE has a well-established practice of working with state and regional groups and other organizations to coordinate and provide technical assistance for transportation. Future programs should build upon these proven approaches.

In particular, DOE has for many years supported cooperative agreements with state regional groups, or SRGs, to partner with local authorities through whose jurisdictions radioactive materials will be transported. Collaboration through the SRGs has proved important, not only because states have primary responsibility for protecting the health and safety of their citizens, but because they share (and sometimes disagree about) common concerns. Bringing corridor jurisdictions together under the auspices of these groups allows issues to be identified and resolved by all parties. It also means the shipper and carrier do not have to negotiate individually with jurisdictions that may have inconsistent or even conflicting priorities. States have extensive experience with transportation issues and important roles to fulfill with respect to issues such as routing, inspections, training, emergency preparedness, communications, public information, and security for radioactive materials and other hazardous shipments.

The WIPP facility in New Mexico, for example, provides a longstanding and highly successful model for partnering with states to achieve shared success in addressing issues related to the transport of nuclear materials. Beginning with the Western Governors' Association (WGA) and later expanding to include other SRGs, states worked with one another and DOE over a period of years to develop inspection protocols, training programs, information products and other areas of transportation planning. The goal of such efforts, according to one policy statement issued by the WGA, was to achieve "the safe and uneventful transport of radioactive, radioactive materials, and spent nuclear fuel" by (among other things) conducting "early coordination and effective communications with state, tribal, and local governments."[226] On occasion, DOE agreed to go beyond regulatory requirements when doing so was reasonable and prudent, and would enhance overall safety. For example, the Commercial Vehicle Safety Alliance developed an enhanced inspection standard to ensure that trucks carrying waste to WIPP, and spent fuel to other sites, were "defect free" before departure, and inspected again upon arrival. Over time, inspectors in "downstream" corridor states became confident that WIPP trucks were among the safest on the highway and would waive en-route inspections, allowing them to spend more time examining other trucks whose equipment was deficient and posed significant safety risks. This program, which was originally a voluntary "extra-regulatory" measure, was later incorporated into regulations. Overall it lowered the time-in-transit and related costs for WIPP shipments.

In a paper examining the WIPP transportation record and safety program after ten years of operation, several participants on the WGA working group noted that:

> Working Group members recognized that there were three key elements to achieving the Governors' objectives of safe and uneventful transportation and public acceptance of the program: accident prevention; effective emergency response if there were an accident; and a successful public information program. They also recognized that a cooperative effort by federal, tribal, state and local governments was necessary to achieve the objectives.[227]

This basic approach to collaborative planning has been applied to other campaigns with the Southern States Energy Board and the Northeastern and Midwestern offices of the Council of State Governments. Spent fuel transportation programs (including those supporting research reactors and the Navy) continue to follow the same basic approach, with modifications as appropriate (for example, Navy SNF shipments are classified). The Commission believes that while DOE has frequently been criticized for its management of the civilian nuclear waste program more generally, the Department's record of planning in cooperation with concerned stakeholders to address transportation issues has for the most part been quite successful. Any new entity charged with managing spent fuel and waste in the future should emulate and build on this success.

9.4 NEXT STEPS

Under Section 180(c) of the NWPA, DOE is required to provide funding and technical assistance for the training of public safety officials to states and tribes whose jurisdictions would be traversed by shipments of spent fuel to storage facilities or to a repository. Over the course of more than a decade and several stops and starts, DOE's Office of Civilian Radioactive Waste Management (OCRWM) developed a policy for implementing a 180(c) program. The BRC commissioned a paper on the background and history of the 180(c) program in an effort to develop recommendations for the future implementation of this or a similar initiative.[228] The results of this paper, in combination with the recommendations put forward by the NAS in 2006 and comments received by the BRC in the course of our deliberations, suggest that at least two actions are needed in the near term.

First, early implementation of the 180(c) program as currently defined in the NWPA should be initiated by DOE and should be supported by the Nuclear Waste Fund, *even before* any potential storage or disposal site is identified. DOE should (1) finalize procedures and regulations for providing technical assistance and funds for training to local governments and tribes pursuant to Section 180(c) of the NWPA and (2) begin to provide such funding, independent from progress on facility siting. While it would be premature to fully fund a technical assistance program before knowing with some certainty where the destination sites for spent fuel are going to be, substantial benefits can be gained from a modest early investment in planning for the early transport of spent fuel from shutdown reactor sites. Consistent with the Commission's recommendation that spent fuel from shutdown reactor sites be "first in line" for acceptance at a consolidated storage facility, initial routes from those sites can be easily identified, and pilot training programs for emergency responders along those routes should begin without further delay. This would be consistent with the recommendation of the *Going the Distance* study that DOE initiate transport "through a pilot program involving relatively short, logistically simple movements of older fuel from closed reactors to demonstrate its ability to carry out its responsibilities in a safe and operationally effective manner."

Second, legislation to implement the broader waste management strategy being recommended by the BRC should include amendments to Section 180(c) that would expand the authority and responsibility of the new waste management organization to include authorities equivalent to those given to DOE in the WIPP Land Withdrawal Act with respect to transportation to WIPP, including:

- A program to provide information to the public about the transportation of spent fuel or high level waste to or from a repository or storage facility. [WIPP LWA Sec. 14(c)(1)(D)(iv)]

THE WIPP TRANSPORTATION SYSTEM
A DECADE OF SAFE, SECURE SHIPMENTS OF RADIOACTIVE WASTE

In March 1999, the Waste Isolation Pilot Plant (WIPP) in New Mexico received its first shipment of transuranic (TRU) radioactive waste. WIPP has received over 10,200 shipments as of January 2012. The experience of the WIPP transportation system provides grounds for confidence that nuclear waste can be transported across the nation safely and securely. The system was designed by DOE and includes multiple coordinated elements aimed at assuring safe and secure transport.

The Transport Container – All waste is transported in packages approved for use by the NRC. Several different types of shipping containers have been developed to enable shipment of different types of waste. All packages must meet NRC and U.S. Department of Transportation (DOT) radiation limits.

The Drivers and Carriers – DOT sets standards for drivers of trucks that carry hazardous cargo. DOE agreed to go beyond these requirements for its WIPP drivers and carriers. WIPP drivers must meet or exceed experience, licensing and training qualifications, and maintain good driving records. Once hired, drivers are also instructed in defensive driving, adverse weather, road hazards, and mountain driving, in addition to extensive WIPP relevant training, and are subject to stringent penalties if they deviate from specific procedures. Drivers work in pairs to ensure that the truck and payload are attended at all times and that drivers are rested while driving. WIPP drivers must stop and check their trucks and payload every 150 miles or three hours en route.

The Shipping Network and Emergency Preparedness and Response Systems – DOT regulations require radioactive materials to be shipped on the interstate highway system unless states designate other routes. WIPP shipment protocols and routes were developed through cooperative efforts between states, tribal governments and DOE. Prior to departing a TRU waste site, state police inspect WIPP trucks to Commercial Vehicle Safety Alliance Level VI standards, the most rigorous in the commercial trucking industry. WIPP drivers notify state officials two hours before entering each state and WIPP trucks are subject to inspections at each state port of entry. The states and DOE have agreed on procedures to monitor weather and road conditions so that shipments can avoid hazards. Shipments will not depart DOE facilities if they are likely to encounter severe weather along the route. If unexpected bad weather or road conditions are encountered, procedures for the selection and use of safe parking areas have been developed. Designated federal, state and tribal officials can also monitor the shipments. While designed to prevent accidents from occurring, the WIPP transportation system also has extensive measures in place to address emergency response in the event a shipment is involved in a serious accident. Specific plans and procedures for dealing with an accident are in place throughout all routes used in the transportation system; these plans cover notification, incident command, and response procedures. In addition, more than 26,000 trained emergency response professionals are in place along the routes. In coordination with DOE, the states have developed a WIPP-specific training regimen for emergency first responders; this regimen has been incorporated directly into hazardous materials training programs for fire fighters, police and emergency medical staff along the routes. In 1994, the National Academy of Sciences projected that WIPP's planned shipping program would be "safer than that employed for any other hazardous material in the US." Experience to date bears out this assessment.

- Authority and direction to assist states, tribes, and local governments, through monetary grants or contributions in-kind (subject to appropriation) in acquiring equipment for responding to an incident involving shipments covered by the law. [WIPP LWA Sec. 14(c)(2)]
- Broad authority and direction to provide in-kind, financial, technical, and other appropriate assistance (subject to appropriations) to states and tribes whose jurisdictions would be traversed by shipments of spent fuel to interim storage or to a repository, for the purpose of transportation safety programs related to such shipments that are not otherwise addressed in the law. [WIPP LWA Sec. 14(d)]

10. REGULATORY ISSUES

Regulation is an essential element of a safe, secure, environmentally responsible and ultimately effective nuclear waste management strategy.

The federal government has sole authority to regulate SNF and high-level radioactive waste. Under current law, the two agencies with primary responsibility for regulating facilities or activities related to radioactive waste management are the NRC and EPA.[229] Storage facilities for spent fuel and HLW are regulated and licensed by the NRC, while disposal repositories are subject to both EPA and NRC regulation. Specifically, EPA is responsible for issuing "generally applicable standards for protection of the general environment from offsite releases from radioactive material in repositories." These standards apply to the management and storage of waste during the operational period, as well as to the performance of a disposal facility during the post-closure period (i.e., after waste is no longer being actively emplaced). The NRC, meanwhile, is charged with issuing "requirements and criteria" to be used in approving construction, operation, and closure of repositories. These criteria, which may not be inconsistent with the standards issued by EPA, must require a repository to use a system of multiple barriers and must include any restrictions on the retrievability of the emplaced waste that the NRC deems appropriate. In addition, the NRC is responsible for regulations dealing with nuclear materials safeguards and security and with protection of facility workers from radiological exposures. Other categories of worker protections are the responsibility of OSHA. Finally, the DOT has direct regulatory responsibility for important aspects of the systems and practices used to transport radioactive wastes, while the Department of Homeland Security and other agencies play a role in addressing security and counter-terrorism-related issues involving nuclear facilities and materials.

This chapter discusses a number of regulatory issues that will have important implications for the future storage and disposal of SNF and HLW. We focus particularly on regulations for disposal facilities, as this is the area that presents the most challenging regulatory issues. The discussion in this chapter reflects current arrangements under which authority for establishing regulations and evaluating compliance is held by the federal regulatory agencies; as discussed in section 6.6, we recommend that state and tribal governments have the opportunity to negotiate important roles in aspects of regulation, permitting and operational oversight.

10.1 ISSUES AND CHALLENGES IN REGULATING STORAGE AND TRANSPORTATION

As noted in chapter 3 of this report, the NRC recently extended its "Waste Confidence Decision" to up to 60 years after the termination of an operating reactor's license (with extensions up to 60 years).[230] Several states have since filed suit against the NRC over this finding.[231] In the meantime, the NRC has also begun researching the potential environmental impacts of storage over even longer timeframes—more than one hundred or even several hundred years. It is important to emphasize, however, that even if the NRC finds that storage can be safely implemented over these very extended timeframes, this would not mean that deferring disposal for additional decades to (in the worst case) centuries would be justified or would make sense—in either cost or risk management terms.

In June 2010, the NRC launched a comprehensive review of regulations related to extended storage and transport including, specifically, the adequacy of existing mechanisms for ensuring safe and secure storage and transportation for extended periods beyond 120 years.[232] This review is expected to be complete in 2017. A newer and unanticipated challenge involves developing an appropriate regulatory response to the events that occurred at Japan's Fukushima Daiichi nuclear power station following the March 2011 earthquake and tsunami. The NRC and other agencies, such as the IAEA, are in the early stages of conducting in-depth investigations of the crisis; in addition, the Commission is recommending a separate NAS study of Fukushima. As a result of these efforts, new storage-related regulatory requirements may be deemed necessary and appropriate and if so, should be implemented as expeditiously as possible.

More generally, the primary regulatory challenge for storage facilities (given a realistic appraisal of the time likely to be necessary to open and load one or more geologic disposal facilities) remains ensuring their performance over extended periods of time (120 years or more). This will require a better understanding of degradation mechanisms that could, over multiple decades, potentially affect the integrity of spent fuel or its cladding. It also requires better information about environmental conditions and the state of spent fuel inside existing dry storage systems. As noted in chapter 5, because these systems generally lack instrumentation, knowledge of key parameters such as (but not limited to) gas pressure, the release of volatile fission products, and moisture is limited to non-existent for most dry cask installations. Some of these issues will be addressed as part of the Extended Storage Collaboration Program that EPRI has launched—in conjunction with the NRC, DOE, the Nuclear Energy Institute, individual utilities and dry storage system vendors—to research the technical basis for long-term dry storage of SNF.

The current regulatory system for assuring the safety and security of nuclear waste shipments, meanwhile, has functioned well to date. As discussed in chapter 5 of this report, however, the challenge will be to ensure that the current system can keep up in terms of managing health and safety risks and providing adequate physical security if the quantity and volume of waste shipments—including shipments of higher-burnup fuels—increase substantially in the future. A separate NRC rulemaking is currently underway to codify further transportation security requirements for future nuclear waste shipments.

10.2 ISSUES AND CHALLENGES IN SETTING REGULATORY STANDARDS FOR DISPOSAL FACILITIES

Regulating facilities for the disposal of HLW and spent fuel presents unique challenges because of the extraordinarily long time periods over which these materials present health, safety, security, and environmental concerns.

In its 2006 *Safety Requirements* report, the IAEA elaborated on the basic aims of geological disposal:[233]

- To contain the waste until most of the radioactivity, and especially that associated with shorter lived radionuclides, has decayed
- To isolate the waste from the biosphere and to substantially reduce the likelihood of inadvertent human intrusion into the waste
- To delay any significant migration of radionuclides to the biosphere until a time in the far future when much of the radioactivity will have decayed
- To ensure that any levels of radionuclides eventually reaching the biosphere are such that possible radiological impacts in the future are acceptably low

The task for regulators is to translate these general aims into specific standards or technical performance requirements that must be met before a facility can be licensed. Different countries have taken different approaches to this task with the result that regulatory requirements for disposal facilities vary around the world. Increasingly, however, there is some convergence in these requirements, particularly as international organizations such as the Nuclear Energy Agency (NEA)[234] and the IAEA have published recommendations or guidance in this area.

In the United States, there are currently two sets of federal regulatory standards for high-level radioactive waste disposal facilities—one set that was developed specifically for Yucca Mountain and another, earlier set that would, under current law, apply to all other sites (this earlier, generic set of standards was essentially complete by the time Congress directed the development of Yucca Mountain-specific standards in 1992; see further discussion in the text box).[235]

Because the thinking about repository regulations evolved considerably during the development of the Yucca Mountain requirements, the Commission concludes that the generic regulations that would currently apply to all other sites will need to be revisited and revised in any case. In addition, the Commission has heard a range of views both about broader reforms to the current U.S. regulatory framework for geologic disposal facilities and about specific changes to existing repository requirements. We have addressed some of the broader reform questions, but have not attempted to develop specific recommendations concerning the appropriate form and stringency of regulatory standards for disposal facilities. Resolving these issues will involve societal value judgments that should be mediated through the normal regulatory development process. In that process, EPA, NRC, and other agencies can and should draw from an extensive literature and considerable regulatory experience to make appropriate determinations for assuring safe and secure nuclear waste disposal in this country.

The remainder of this section briefly reviews some of the most important and controversial technical and policy issues to be resolved in setting performance standards for disposal facilities, before offering some general principles to guide the development of future regulations in the United States.

10.2.1 TIMEFRAME

Since long-term protection of human health is one of the core functions of deep geologic disposal, quantitative limits on the public's future exposure to radioactivity are typically included in disposal facility standards. These limits may take the form of a dose-based or risk-based standard (the two are essentially equivalent in practice) that limits the exposure to individuals resulting from radiation releases from the repository. Alternatively they can take the form of a release-based standard that limits the amount of radioactive material that is allowed to escape the repository (see text box describing U.S. disposal facility regulations).

A critical regulatory question then centers on the timeframe over which compliance with these numeric limits must be demonstrated. This has been a controversial question in the past, because the long-lived nature of the radiological hazard posed by SNF and HLW creates an inherent tension between the objective of protecting future generations on the one hand, and the practical difficulties of making very long-term projections about human and natural systems on the other hand. In the United States, the EPA initially proposed a compliance timeframe of 10,000 years for the proposed Yucca Mountain repository; however, this limit was later increased to 1 million years.[236] Many individuals have told the Commission that it is unrealistic to have a very long (e.g., million-year) requirement for demonstrating compliance in a traditional regulation; the Commission agrees. Other countries have taken different approaches to this issue: some have opted for shorter timeframes (a few thousand to 100,000 years), some have developed different kinds of criteria for different timeframes, and some have avoided the use of a hard "cut-off" altogether and have instead opted to require a demonstration that the proposed facility is at very low risk for catastrophic disruptions that could lead to large-scale releases of radioactivity. Some countries, such as Finland and Sweden, have more stringent regulations for the first few thousand years after repository closure, compared with the period from 1,000 years to 100,000 or 1,000,000 years. In doing so, they acknowledge the fact that uncertainties in predicting geologic processes, and therefore the behavior of the waste in the repository, increase with time.

10.2.2 COMPLIANCE METHODOLOGY

As critical as the form and stringency of the standards to be applied to a disposal facility is the decision about what approach or methodology will be used to determine whether they have been met. An integral part of EPA's standards for geologic disposal facilities is a requirement (embedded in the standards themselves) that compliance be demonstrated using a quantitative performance assessment to project repository performance over very long time periods: 10,000 years in the case of WIPP and up to 1,000,000 years for Yucca Mountain.[237] Over the last decade or more, however, there has been increasing attention worldwide to compliance methodologies that integrate quantitative and qualitative lines of argument to show that a repository will remain safe after our ability to monitor a repository is lost.[238,239] This shift has been motivated in part by increasing recognition of the inherent limitations of quantitative projections over geologic time periods.[240]

Instead of focusing on comprehensive calculations of projected dose levels to populations hundreds of thousands of years or more in the future, for example, the safety analysis used to support regulatory demonstrations of compliance might use such calculations for an initial period for which they would be most defensible, and then follow the evolution of troublesome radionuclides in the given geologic environment over the long term using other existing and compelling scientific knowledge.[241] For example, Finnish regulators require quantitative assessment where possible, but also call for use of complementary considerations when quantitative analyses are not feasible or are too uncertain.[242]

Performance assessment is valuable as a systematic method for organizing the understanding of a geologic repository.[243, 244] It is also valuable for focusing the information used to support a compliance demonstration.[245] Furthermore, NRC regulations stipulate that additional factors (such as the demonstration of the effectiveness of multiple barriers, empirical observations, and a performance confirmation program) are to be considered in a licensing decision.[246] Nonetheless, the heavy emphasis on quantitative performance assessment in U.S. disposal facility safety standards may lead to a focus on showing numerical compliance that could obscure understanding of the actual operation of the disposal facility system[247] and divert attention from the overall strategy being employed to safely dispose of nuclear waste.[248] While EPA recognized this concern when it extended the compliance period to 1

CURRENT U.S. DISPOSAL FACILITY REGULATIONS

"GENERIC" EPA AND NRC REGULATIONS

EPA standards for all sites other than Yucca Mountain are defined under 40 CFR Part 191, "Environmental Radiation Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (with additional implementation and compliance criteria for WIPP found in Part 194). This regulation was first issued in 1985, remanded by a federal court for reconsideration of certain provisions, and reissued in 1993 to apply only to geologic disposal facilities other than Yucca Mountain (see below).

The core of Part 191's disposal standard is a "containment" requirement designed to protect human populations by limiting the cumulative releases of key radioactive isotopes over the 10,000-year period following closure of a disposal facility. Compliance is to be demonstrated by use of quantitative performance assessments that take into account "all significant processes and events" to show that there is a "reasonable expectation" (not absolute proof) that cumulative releases for a number of specific isotopes will have a low likelihood (less than one chance in 10 for low releases and less than one chance in 1,000 for higher releases). The EPA regulation also includes an individual protection requirement, which stipulates that for 10,000 years there should be a reasonable expectation that no member of the public will receive an annual dose greater than 15 millirems (150 microsieverts), considering only the undisturbed performance of the repository (rather than all significant processes and events, as required for the containment standard).

NRC regulations for all sites other than Yucca Mountain are defined in 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geological Repositories." These regulations were originally issued in 1983 (before EPA's first set of standards had been completed) and revised in 1987 to reflect the NWPA Amendments Act of 1987. NRC's regulation incorporates EPA's generally applicable standards by reference, and includes additional performance requirements for specified individual barriers in the repository system.

YUCCA MOUNTAIN-SPECIFIC REGULATIONS

The Energy Policy Act of 1992 directed EPA to issue an individual dose standard for Yucca Mountain, based upon and consistent with recommendations by the NAS. The process to develop this EPA standard (40 CFR Part 197) and matching NRC implementing regulations (10 CFR Part 63) was complex—it involved an NAS study, multiple lawsuits, and another court remand that required EPA to reconsider certain provisions it had initially proposed. Thus, it was not completed until 2008. The EPA Yucca Mountain standard limits doses to members of the public (not total releases of specified radioactive materials) and extends to 1 million years (consistent with a recommendation of the NAS study), with a 15 millirem limit for the first 10,000 years and a 100 millirem limit thereafter. The NRC Yucca Mountain regulations incorporate the new EPA standard and drop the performance standards for individual repository barriers that are contained in the generic regulations (10 CFR Part 60).

million years for its Yucca Mountain standard in compliance with a judicial decision,[249] the standard itself makes no distinction between the roles of the performance assessment in demonstrating compliance for the first 10,000 years and for the very long term—use of performance assessment is an integral part of the standard for both time periods. The need for flexibility in demonstrating compliance with any very long-term quantitative performance standard might be better met if performance assessment were included as one of a set of methods to be used in formulating the overall safety case for compliance, rather than being incorporated in the statement of the standard itself.[250]

10.2.3 STANDARD OF PROOF FOR COMPLIANCE DEMONSTRATIONS

The "standard of proof" required for compliance demonstrations should be viewed as integral to a long-term performance standard. While EPA disposal facility regulations (both generic and Yucca Mountain-specific) require the use of quantitative performance assessments to show compliance with quantitative standards, they also state that unequivocal proof of compliance is neither expected nor required because of the inherent limitations of such assessments.[251] Thus, licensees must demonstrate a "reasonable expectation" of compliance with standards for the post-closure period. The NRC adopted EPA's approach of applying a "reasonable expectation" standard to the post-closure period, while using a "reasonable assurance" standard for the operation of facilities during the pre-closure period (consistent with the NRC's practice for other licensed operating facilities subject to active licensee oversight and control).

10.2.4 OTHER PROTECION REQUIREMENTS

Protection of the natural environment (along with, but distinct from, human health per se) is widely accepted as an important objective of geologic disposal; however, there has been less convergence internationally around how to assess this objective and develop appropriate criteria. A recent (2010) NEA review of regulatory developments pertaining to geologic disposal describes a number of national and international efforts—some ongoing—to develop ways of accounting for the long-term protection of flora and fauna. Existing regulations in some countries (e.g., Canada, Finland, Sweden, Switzerland, and the UK) include qualitative requirements for the protection of non-human organisms and biodiversity; several countries also require that these impacts be explicitly included in future risk and performance assessments. In the United States, EPA standards for the disposal of high-level radioactive waste and TRU waste include a separate groundwater protection standard.

10.2.5 DIVISION OF REGULATORY RESPONSIBILITY BETWEEN EPA AND NRC

In the course of the Commission's deliberations, numerous witnesses expressed the view that greater consistency was needed between the EPA and NRC regulatory systems. Some witnesses also suggested that any effort to rationalize or harmonize the EPA and NRC systems be undertaken before new disposal sites are identified, even for screening purposes, to avoid or at least minimize the perception that standards are being set to ensure that one or more (pre-selected) sites will meet them. This seems particularly important for individual protection requirements, which have been a clear point of contention in the past; however, it is likely to be

KEY QUESTIONS IN SETTING A REGULATORY STANDARD FOR DEEP GEOLOGICAL DISPOSAL

- What should the basis be: a desired level of protection or what is reasonably achievable using today's technology?
- For how long must compliance be demonstrated?
- Who is to be protected—individuals or populations?
- What is the desired level of protection?
- What is the measure of compliance (e.g., doses to individuals vs. releases to the environment)?
- How should compliance be demonstrated—primarily through quantitative calculations or through a broader safety analysis that involves multiple lines of qualitative as well as quantitative considerations?
- What level of confidence is required?
- How should the potential for human intrusion be addressed?
- How should retrievability be addressed?
- Can compliance take credit for institutional controls and if so, for how long?
- Should groundwater be separately protected?
- Should there be performance requirements for sub-elements of a disposal facility (e.g., the waste package or the geologic setting)?

relevant for many other issues as well. Comments submitted by both the NRC and the EPA in response to the BRC's draft report indicate that coordination between these two regulatory agencies has improved markedly in recent years.

The Commission also received and considered recommendations for a more fundamental redrawing of regulatory roles and responsibilities at the federal level (i.e., transferring all regulatory authority to the NRC or EPA). We concluded that while there are opportunities for improvement in the EPA/NRC regulatory process and in the working relationship between these agencies, the general division of roles and responsibilities that currently exists between EPA (establishing standards) and NRC (licensing and regulating waste management facilities) is appropriate and should be preserved. We return to this point in the next section.

10.3 RECOMMENDATIONS FOR DEVELOPING FUTURE DISPOSAL FACILITY STANDARDS

Without making specific recommendations regarding the standards to be applied to geologic disposal facilities in the future, the Commission recommends a number of general principles or propositions to guide the development of future regulations:

1. **The standard and supporting regulatory requirements to license a facility should be generic—that is, applicable to all potential sites.**

   While there may be advantages to developing standards and requirements that recognize the specific features and characteristics of a particular site, experience with Yucca Mountain indicates that this approach can create suspicions that regulations are being tailored to make a pre-selected site "work." Generally-applicable regulations are more likely to earn public confidence. A generic standard will also support the efficient consideration of multiple sites.

2. **Regulatory standards and requirements for compliance demonstrations (including the required level of confidence in the demonstration or "standard of proof") should not go beyond what is scientifically possible and reasonable.**

   Both the standards themselves and the process used to demonstrate that they have been met must be credible to the scientific community and the public. The Commission has heard the view that some aspects of the current Yucca Mountain regulations lack credibility. A specific concern is the requirement that the compliance demonstration be primarily based on a complex quantitative projection of repository performance for 1 million years. While making calculations over such a long time horizon might be appropriate as a part of establishing a broader safety case, the Commission believes that over-reliance on million-year calculations can reduce credibility rather than enhance it. As the IAEA has warned: "Care needs to be exercised in using the criteria beyond the time where the uncertainties become so large that the criteria may no longer serve as a reasonable basis for decision making."[252]

   Whatever the time frame, the standard of proof for compliance should likewise be based on what is scientifically achievable. As discussed above, both existing sets of generic disposal facility and Yucca Mountain-specific regulations emphasize that absolute proof in the normal sense of the word is not possible over long time periods. They therefore stipulate that compliance determinations should be based on a "reasonable expectation" that the standards will be met. This is also the standard of proof defined by EPA[253] and ultimately adopted by the NRC for its Yucca Mountain regulations. This approach has proved workable in the WIPP context and we recommend that it be carried over into new regulations.

3. **Rules for demonstrating compliance and for documenting the required level of confidence in the compliance demonstration (i.e., the standard of proof) should be defined at the same time that the performance standards are developed.**

   Rules for demonstrating compliance (including meeting the standard of proof) are integral to any regulatory standard. These rules should be included when developing the overall standard and should be applied in the way that was expected when the performance standard was adopted. This is particularly important when different agencies are charged with setting the standard (EPA) and implementing the standard (NRC). In these cases, the potential exists for different agencies to apply different regulatory philosophies to the same standard.[254]

4. **Standards for a disposal facility should explicitly recognize and facilitate an adaptive, staged approach to development.**

   Current EPA and NRC regulations were developed before international thinking about repository development shifted in favor of a more staged, adaptive approach (this is also the approach the Commission is recommending for the United States). The NRC, in particular, has a robust and exacting regulatory process for reactor operators and other facility licensees that generally requires very high levels of design specificity and performance assessment at the initial licensing phase. This structure is not necessarily incompatible with a staged, adaptive approach; in fact, the NAS study of staged repository development observed that the "The U.S. licensing process already follows a staged approach" and concluded that "there are no restrictions precluding DOE from implementing Adaptive Staging."[255] However, future disposal facility regulations should be designed to accommodate a process in which decisions about design, construction, and operations might be kept open beyond the initial license application.[256] In general, adaptive staging could make the licensing process more complex by increasing the number of changes made in the course of the process. This in turn would increase the number of regulatory review steps and the potential need for license amendments.[257] Recent NRC planning documents suggest the agency has already recognized that it may need to develop new performance assessment tools that are flexible enough to accommodate different scenarios for the management of spent fuel and HLW (in part to respond to the findings of the BRC in its draft report).[258] More broadly, we believe a revised regulatory structure for future disposal facility development should be designed with express attention to providing the flexibility needed to support an adaptive, staged process.

5. Safety and other performance standards and regulations should be finalized prior to the site-selection process.

If site selection occurs before final performance standards are defined, there are two risks. The first is that time and effort could be spent on a site that should have been ruled out as unsuitable earlier in the process. The second risk is one of perception. The public and other stakeholders could suspect that standards are being adjusted to fit the site. These considerations argue for setting generic standards that would be applicable to any facility wherever it is located, *before* any particular site is selected for further study. In developing such regulations, however, it will be important to avoid setting excessively detailed and rigid requirements that could prove unworkable when applied to an actual site or that could have the effect of screening out potentially suitable and otherwise promising sites.[259] The Commission believes there is no reason to wait to start the process of developing generic regulations for future geologic disposal facilities. As discussed below, we are not recommending any change in the current allocation of regulatory responsibilities and authorities that would require enabling legislation. Given that we are recommending a flexible process for finding new sites, standards development need not delay early progress on the siting front. Moreover, the fact that the regulatory issues to be resolved have been well defined and extensively analyzed over more than 30 years of EPA and NRC experience in this area, and the fact that some of the key issues have already been tested in court and in the regulatory process, should help expedite the process of developing generic disposal facility safety and performance standards.

6. EPA and NRC should coordinate closely in the development of new disposal regulations.

Problems of coordination between EPA and the NRC in developing repository standards have been widely cited as having contributed to negative perceptions of, and loss of confidence in, the Yucca Mountain project. As we have already noted, the Commission has heard proposals for a fundamental redrawing of regulatory roles and responsibilities for disposal facilities at the federal level (e.g., by consolidating all regulatory authority in the NRC or the EPA). Broadly speaking, however, our examination of the roles of the NRC and EPA, with respect to nuclear waste management under existing law, suggests that while there are opportunities for improvement in the EPA/NRC regulatory process and in the working relationship between these agencies, the general division of roles and responsibilities that currently exists is appropriate and should be preserved.

While we are not recommending a change in the regulatory roles of EPA and NRC, we believe the process of developing EPA standards and NRC regulations for implementing those standards should be carefully coordinated to avoid repeating past problems. For example, the Commission has heard testimony that the processes used to develop standards in the past were confusing and frustrating to the public,[260] and that more coordinated and dedicated efforts are needed in the future to draw not only on the expertise of EPA and NRC but also on input from the knowledgeable public. We have also heard that public disagreements between these agencies over matters of regulatory philosophy can confuse the public and undermine confidence in the regulatory system,[261] and that it is important that such disputes be resolved promptly.[262]

The Commission believes that a coordinated and open process should be used to develop new generic regulations for future disposal facilities, and that that any differences in regulatory philosophy between the two agencies be laid out clearly and resolved as early in the process as possible. We further believe that actions to coordinate the development of new disposal regulations can be undertaken by the Executive Branch without additional action by Congress.

Specifically, we recommend that EPA and NRC begin working together to define an appropriate process (with opportunity for public input) for developing a generic disposal facility safety standard and associated implementing regulations.[263] In addition the two agencies should continue to coordinate efforts during the regulatory development process. This process should be designed to accomplish the following:

- A clear definition of the regulatory issues to be resolved,
- A comprehensive identification of alternative approaches to resolving these issues,
- A thorough and fair analysis of the alternatives,
- A clear explanation of the regulatory choices that are made,
- A shared understanding between the two agencies and with other stakeholders about the compliance demonstration methods and standard of proof that are to be used in implementing the standards.

We also recommend that the administration and Congress ensure that NRC and EPA have sufficient resources to complete this process in a thorough and timely way. The cost of delays in being able to move ahead with finding new sites would certainly be far higher than the cost of a process to establish the necessary standards as soon as possible.

7. The EPA and NRC should also develop a new regulatory framework and standards for deep borehole disposal facilities

As noted in chapter 4 of this report, the Commission has identified deep boreholes as a potentially promising technology for geologic disposal that could increase the flexibility of the overall waste management system and therefore merits further research, development, and demonstration. While a regulatory framework and safety standards for deep boreholes would have much in common with those for mined geologic repositories, the technologies also have key differences. For this reason the Commission recommends that the EPA and NRC develop a new safety standard and regulatory framework for deep boreholes (consistent with the new standard recommended for mined repositories) informed by RD&D efforts aimed at developing a licensed demonstration project.

8. Security and Safeguards

Robust security arrangements are needed at storage and disposal facilities for SNF and HLW, as well as during the transport of these materials, to prevent unauthorized access and acts of sabotage or theft. From a security standpoint, the most sensitive stages at a deep geological repository are when materials are above ground (transported or in a pre-load stage) and during the pre-closure period when materials are emplaced in the disposal facility, but the facility itself is not sealed and could therefore be accessed more easily.[264] As the IAEA has recommended, the regulatory authority (for us, the NRC) will need to provide guidance to the implementing organization concerning the effective application of security measures. Such measures could include physical protection, control and accounting, and verification procedures. Recognizing the importance of international rules, the United States should offer to place all future geologic disposal facilities under IAEA safeguards monitoring.[265]

10.4 OCCUPATIONAL SAFETY AND HEALTH

Another important area of regulation for waste management facilities pertains to the health and safety of facility workers and personnel (as distinct from the protection of the general public). Currently, responsibility for occupational safety and health at nuclear facilities is the shared responsibility of the NRC, OSHA, and (in some cases) the Mine Safety and Health Administration.

On the whole, a white paper commissioned by the BRC finds that the U.S. nuclear industry has had a much better occupational health and safety record than other energy sectors.[266] However, the same report also determined that performance was not uniform across facilities and that further improvement could be achieved by assuring more consistent safety and health performance standards. In terms of occupational safety and health issues specific to the back end of the nuclear fuel cycle, the fact that the United States has not yet opened or operated a deep geologic repository or consolidated storage facility for spent fuel and HLW means there is no direct experience with these types of facilities. However, the United States has had experience with constructing two deep geological facilities (WIPP in the 1980s and the Yucca Mountain Exploratory Studies Facility in the 1990s) and more than a decade of experience operating WIPP. The overall occupational safety and health record for these facilities—and for more than a decade of waste transport operations in connection with WIPP—has been excellent so far. But this record does not argue for complacency. On the contrary, occupational safety and health is an area where continued rigor is warranted and where experience with existing facilities and operations must be looked to for useful insights about how to manage risks to workers at waste management facilities in the future.[267]

For example, constructing facilities deep underground is in and of itself a complex undertaking that poses inherent risks. The major risks to workers at a deep geological repository are the same as those associated with any large-scale underground construction project; they include, principally, traumatic injuries from working around heavy equipment and explosives, lung disease from both dust and diesel exhaust fumes, and noise-induced hearing loss. That said, current construction procedures and technologies make it possible to minimize the risk of traumatic injuries, suppress dust and other respiratory irritants, and protect workers' hearing. Other kinds of facilities could present different risks. For example, deep boreholes do not involve the construction of underground facilities, but the surface facilities involve occupational hazards similar to those associated with oil and natural gas drilling.

10.5 WASTE CLASSIFICATION

NRC regulations and other statutory requirements for the handling of nuclear materials rely on a system for classifying those materials. This section discusses the classification system that is currently in place in the United States for nuclear wastes. While there have been concerns about aspects of that system for some time, some of the (potentially) most important shortcomings of the current framework are especially pertinent to the wastes that would be generated by fuel cycles that include the reprocessing and recycling of SNF.

Generally speaking, the purpose of waste classification systems is to facilitate the safe and efficient management of waste materials. This goal is best served if the classification system identifies groups or classes of wastes that could be handled and disposed of safely using essentially the same

THE CURRENT U.S. WASTE CLASSIFICATION SYSTEM

All classes of nuclear waste defined in federal law apply only to waste that contains radioactive material as defined in the Atomic Energy Act (AEA) of 1954 [AEA, 1954]. The AEA defines three types of radioactive materials: source, special nuclear, and byproduct. Classes of waste have been defined in the AEA and its amendments, or in other federal laws; of necessity these definitions have been used in regulations (which, in some cases, have established sub-classifications). A description of the most important classes of nuclear waste—as defined under the AEA, its amendments or in other federal laws—follows:[268]

Spent nuclear fuel (SNF), also called "used nuclear fuel," is fuel irradiated in a nuclear reactor that has not been reprocessed. When declared to be waste, SNF is generally assumed to be destined for disposal in a deep geologic repository.

High-level waste (HLW) is the highest-activity primary waste that results from reprocessing SNF. It is ultimately destined for disposal, such as in a deep geologic repository.

Transuranic (TRU) waste is waste other than SNF and HLW that contains concentrations of transuranic elements—long-lived alpha-emitting radionuclides created during the irradiation of nuclear fuel (e.g., plutonium)—at levels that are sufficiently high so as to make the waste not generally acceptable for near-surface disposal. TRU waste is generally assumed to be destined for ultimate disposal in a deep geologic repository. There are two sub-classes of TRU waste: remote handled (meaning so radioactive that it must be handled in containers that shield workers from radiation) and contact handled (meaning it does not require shielding).

Mill tailings are solid residues from the processing of ores to recover uranium or thorium. Tailings are generally destined for disposal in large, capped piles on the land surface at or near the facilities that produce them.

Low-level waste (LLW) is waste other than SNF, HLW, TRU waste, or mill tailings. Most LLW is destined for disposal in near-surface facilities. LLW is further divided by regulation into three subclasses (A, B, and C) that contain increasing radionuclide concentrations. All of these subclasses of LLW are generally acceptable for near-surface disposal. A fourth subclass of LLW is defined by reference to the concentration limits for Class C wastes: LLW that has radionuclide concentrations in excess of the Class C limits is termed "greater than Class C" or "GTCC" waste. GTCC wastes are not generally acceptable for near-surface disposal. Disposal in a deep geologic repository and disposal in boreholes at depths up to 1,000 ft are among the alternatives being considered.

technologies, rather than classifying wastes primarily based on their source of origin.

The most important overarching criticism of the U.S. waste classification system is that it is not sufficiently risk-based. Rather, it is (for the most part) directly or indirectly source-based—that is, based on the type of facility or process that produces the waste rather than on factors related to human health and safety risks. The legal definitions of SNF, HLW, and tailings are explicitly source-based. The definitions of TRU waste and LLW are indirectly source-based in that these classes of waste are defined by excluding one or more of the source-based waste classes.

A source-based classification system can confound efforts to manage and dispose of wastes based on the risks they pose because wastes in different classes can have essentially the same radionuclide composition and characteristics, while wastes in the same class can have substantially different radionuclide compositions and characteristics. For example, the radionuclide content of some of DOE's HLW is similar to that of Class A or B LLW, but because of its source, the HLW must still be managed by disposal in a deep geologic repository. Generally speaking, it is more often the case that wastes are "over-classified"—in the sense that they are assigned to a more restrictive (and more costly-to-manage) classification than their actual hazard requires—rather than the reverse. Moreover, the requirement that specific disposal sites meet criteria to ensure safety (e.g., dose limits) is designed to prevent any "under-classified" waste from posing an unacceptable risk.

The definition of HLW, in particular, has attracted the most criticism. Much of this criticism focuses on three major issues.

1. HLW is currently defined solely in terms of its source (i.e., wastes from reprocessing), and not in terms of the characteristics that are relevant from a waste management standpoint (e.g., TRU content, radiotoxicity). To the extent that terms such as "highly radioactive," "sufficient concentrations," and "requires permanent isolation" are used to define HLW, they have not been quantified. This is potentially problematic because the liquid waste stream from the front end of a reprocessing plant can have a broad range of characteristics—including characteristics that may be altered by time (decay) or by subsequent processing (which DOE has done with many of its defense wastes). The waste that remains after these changes, while still classified as HLW, may have characteristics similar to TRU waste or LLW. Conversely, some TRU and LLW wastes that do not come from reprocessing can have characteristics similar to HLW.
2. The current system creates obstacles to managing low-concentration HLW as TRU waste or LLW. In 2003, an Idaho district court ruled that any material containing even very small amounts of the radionuclides in HLW had to be disposed of in a deep geologic repository. In response, Congress passed a law designed to allow DOE to close tanks and dispose of material containing HLW (defined as "waste incidental to reprocessing"), provided certain conditions could be met. Applying this exception, however, has proved challenging because of differing views concerning how much radioactive material can be left in tanks and differing views on the performance of vaults and closed tanks.
3. DOE recently decided to classify waste streams bearing radionuclides such as tritium, carbon-14, krypton, and iodine-129 as HLW, even though these radionuclides are not typically part of the HLW stream.[269] This approach would have significant ramifications for spent fuel reprocessing because some of these radionuclides (especially tritium and iodine-129) are likely to be distributed in multiple process streams and wastes throughout a plant that uses current reprocessing technology.

As noted in chapter 11, most reprocess/recycle fuel cycles would be expected to generate larger quantities of LLW, compared to the once-through fuel cycle, but would reduce the front-end creation of mill tailings. As with HLW, several concerns have been raised in connection with the current classification system for LLW:

- The current distinction between HLW and LLW has created practical problems in the context of DOE's remediation efforts. A more straightforward approach would be to use a quantitative boundary—such as concentration limits on shorter- and longer-lived radionuclides, similar to the LLW Class C limits—to make this distinction. This would allow a particular waste to fall into either class depending on its characteristics; it would also allow the effects of waste processing to be taken into account.
- Currently LLW is subdivided into classes—Class A, B, C, or GTCC—according to a list of specified radionuclides and concentrations. If a waste contains only radionuclides other than those on the list it is automatically categorized as Class A, regardless of its radionuclide concentration or the level of hazard it poses. The NRC developed the current list of radionuclides in 1982 by anticipating the types of LLW that might be produced in the future. However, the NRC's foresight was not perfect and wastes now exist, or have the potential to exist, that contain radionuclides not on the list. The most important current

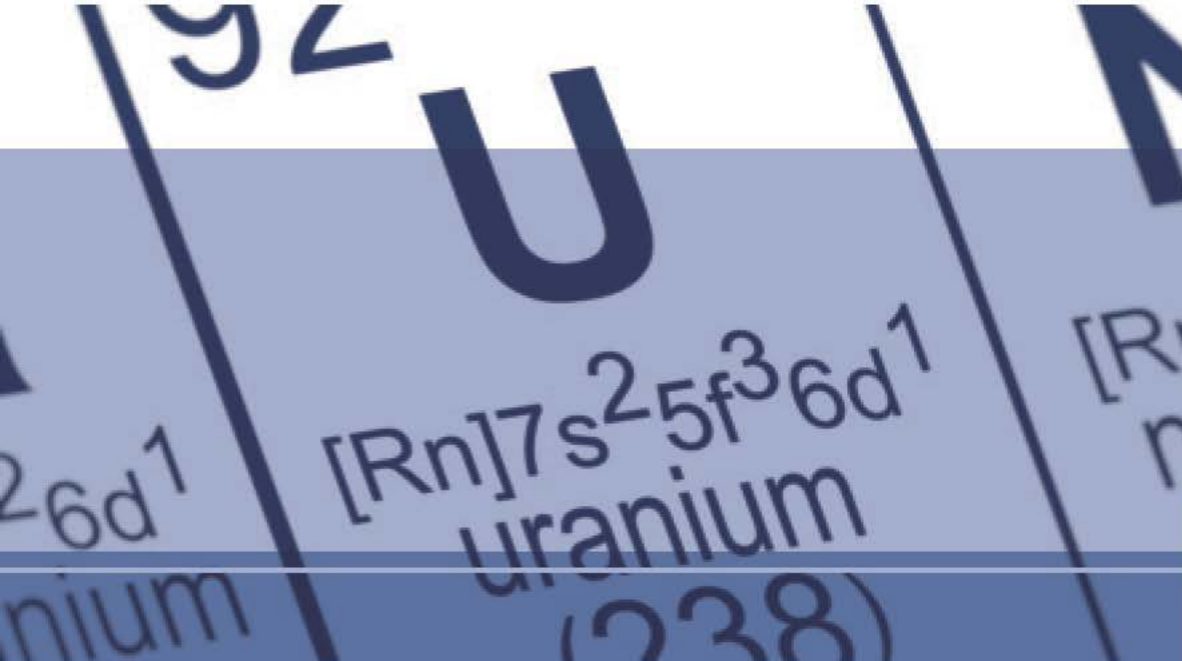
example is uranium. More than 500,000 metric tons of concentrated depleted uranium currently exist in the United States, much of which is destined for disposal. It is considered Class A LLW but NRC staff analyses indicate that near-surface disposal of this material is not likely to meet performance objectives at some sites. There are many other examples that can be found. For example, closed fuel cycles would release gaseous krypton-85 from spent fuel and current regulations would require that a substantial fraction of such releases would need to be captured and disposed of as waste. DOE has also considered separating the radioactive fission product cesium from spent fuel and allowing the cesium-137 it contains (which has a 30-year half-life) to decay to innocuous levels in an engineered surface storage facility, after which it would be disposed of as LLW. However, cesium-137 is accompanied by long-lived cesium-135 and, since the latter is also absent from the 10 CFR 61 list, this leaves the appropriate classification of the decayed cesium open to question. Some of these wastes may be determined to be GTCC and, as a consequence, may become "orphans" for reasons discussed below.

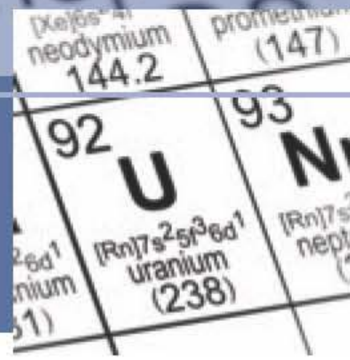
- Because the definition of LLW is implicitly source-based and thus not risk-informed, LLW, TRU waste, and HLW can all contain similar radionuclide concentrations but would nevertheless be managed differently. Similarly, the sub-classification of civilian LLW into Classes A, B, C, and GTCC under 10 CFR 61 is not fully risk-informed. In addition, no disposal pathway has been specified for GTCC waste, which is currently orphaned with nowhere to go. DOE is currently developing an environmental impact statement (see endnote 17) aimed at identifying such a pathway and closing this gap (as noted previously, deep geologic disposal in either a repository or boreholes is being considered for this category of waste).
- Compared to the once-through fuel cycle, future fuel cycles that involve reprocessing would produce considerably more GTCC waste under the current classification system. Reprocessing would leave metal cladding hulls along with a wide range of waste forms generated in the process of recovering, purifying, and fabricating plutonium or other transuranic elements. These would be considered TRU wastes under certain EPA regulations and GTCC waste under NRC regulations. In both cases, these wastes would be orphaned because they are not considered SNF or HLW destined for a repository. Moreover, because the material is not of defense origin, it cannot be accepted at WIPP under current law.

In light of these shortcomings, a number of alternative classification systems, or changes to the current system, have been proposed—both by the NRC and the IAEA —over the years. As yet, however, no comprehensive reforms have been implemented in the United States. Instead, the NRC has used case-by-case exemptions to address issues with particular wastes as they arise. Adopting the most recent IAEA waste classification proposal would represent a major departure from current U.S. practice and would need to be carefully evaluated.

Though many stakeholders believe the time has come for an overhaul of the U.S. waste classification system, there is also considerable concern that changes could have unintended consequences—especially considering the complex web of laws and regulations that rely on the current system. If changes are made, it will be important to assure the public and other stakeholders that wastes are not being inappropriately re-assigned into lower classes and that protections for human health and safety and the environment remain rigorous. The fact is that the current approach to classification—for nuclear waste generally, and for LLW in particular—appears to be working to provide adequate public protection, despite its shortcomings and complexities. Nevertheless, the decision to pursue alternative fuel cycles—especially if they include reprocess and recycle elements—seems likely to strengthen the case for a more comprehensive reconfiguring of the current waste classification system.

Recent developments suggest that the NRC may consider revising the LLW classification system. In 2009 the NRC directed its staff to include in a future budget request a proposal "for a comprehensive revision to risk-inform the 10 CFR Part 61 waste classification framework …" In 2010, an NRC official reported that the staff was working on the issue and is considering a range of options including specific changes to the current structure (e.g. along the lines of recent recommendations by the International Commission on Radiological Protection), a new classification system (e.g., one based on site-specific analysis), and other changes to 10 CFR Part 61 beyond the classification system.[270] Additionally, the NRC staff is planning to identify a number of options for changing the definition of HLW as part of developing a framework for licensing fuel reprocessing plants and plans to send a paper on the framework to the NRC Commissioners by the end of fiscal year 2011. ***The Commission endorses and encourages efforts underway at the NRC to review and potentially revise the U.S. waste classification system (while recognizing that a comprehensive statutory revision to establish a risk-based system will eventually be required).***





11. ADVANCED REACTOR AND FUEL CYCLE TECHNOLOGIES

All of the commercial nuclear power reactors operating in the United States today were built based on reactor designs that are at least 30 years old and in some cases even older.

Technology has advanced in the several decades since, so while reactors in operation today are required to meet all relevant NRC safety standards, new plants are expected to achieve still higher levels of safety, efficiency, and reliability than their predecessors. Clearly, any comprehensive and forward-looking strategy for managing the back end of the nuclear fuel cycle in the United States needs to consider the potential impact not only of current technology but of further technology advances in the decades ahead.

More importantly, we cannot be sure today of the national and global context that will determine which nuclear fuel cycle technologies and systems will be considered for use in the future. Concerns over global climate change and greenhouse gas emissions, the cost and sustainability of alternatives to nuclear power, and any number of other factors may appear very different to future generations than they do to us today. The integrated and flexible strategy that we propose for nuclear waste management puts a premium on creating and preserving options that could be employed by future generations to respond to the particular circumstances they face. RD&D is a key to maximizing those options.

To that end, the charter of the BRC asks the Commission to evaluate existing fuel cycle technologies and R&D programs in terms of specific criteria (those listed in the charter include "cost, safety, resource utilization and sustainability, and the promotion of nuclear non-proliferation and counter-terrorism goals"). Or, as Energy Secretary Steven Chu expressed the charge to the Commission in opening remarks at the Commission's first meeting in March 2011, our task was "to look at all the science and technology and all the other things that would influence how we deal with the back end of the fuel cycle."

This chapter discusses the Commission's conclusions concerning the impact of new reactor and fuel cycle technology developments, both for the nature and magnitude of the immediate and longer-term nuclear waste management challenges this country faces and in terms of the potential to provide options for advancing broader nuclear-energy-related policy objectives in the decades ahead. Additional information concerning the current DOE nuclear R&D program and nuclear RD&D infrastructure needs is available in separate Commission documents (at www.brc.gov).

Finally, this chapter includes a short discussion of nuclear workforce needs. While clearly a cross-cutting issue we chose to cover it here because of its links to science and technology and to the kinds of entities (universities, national laboratories, reactor vendors, etc.) that would be involved in nuclear energy RD&D. An appropriately educated and trained workforce is obviously needed, not only to conduct RD&D work but to design, build, and operate all the facilities involved in the nuclear fuel cycle, from mines and enrichment facilities to commercial power plants and storage and disposal facilities.

11.1 ADVANCED TECHNOLOGIES AND THE NATURE OF THE NUCLEAR WASTE MANAGEMENT CHALLENGE

All of the commercial nuclear reactors operating in the United States today and the vast majority of reactors operating worldwide are light-water reactors operating on the once-through fuel cycle. This means ordinary water serves as the reactor coolant and enriched uranium is used only once in the reactor core and is then stored pending final disposition (as opposed to undergoing reprocessing to separate still usable constituents for re-use as reactor fuel).

Technologies exist today or are under development that would allow spent fuel to be at least partly re-used; systems have also been proposed that could—in theory and at some point in the future—possibly allow for the continuous recycle of reactor fuel, thereby fully "closing" the fuel cycle. Substantial uncertainties exist, however, about the cost and commercial viability of the more advanced of these technologies; in addition, significant concerns have been raised about their impacts on weapons proliferation risks and other aspects of the fuel cycle (e.g., the production of LLW) even if they could be successfully deployed. Without getting into these debates, the central point for purposes of this discussion is that expanded deployment of reprocess and recycle technologies would clearly affect the quantity and composition of nuclear material slated for final disposition and in this way have implications for managing the back end of the fuel cycle.

At the same time, technological advances also hold promise for improving the efficiency and resource utilization of the once-through fuel cycle. To the extent that these improvements make it possible to increase the quantity of electricity produced for every unit of reactor fuel used, this will also have an impact on the overall quantity of spent fuel generated to meet a given level of nuclear power demand.[271] Thus, a central question for the Commission was whether any currently available reactor and fuel cycle technologies, or any not-yet commercial technologies that are now under development, have the potential to change either the fundamental nature of the nuclear waste management challenge this nation confronts over the next several decades or the approach the United States should take to implement a strategy for the storage and ultimate disposition of SNF and high-level radioactive waste.

To answer this question the Commission reviewed the most authoritative available information on advanced reactor and fuel cycle technologies, including the potential to improve existing light-water reactor technology and the once-through fuel cycle, as well as options for partially or fully closing the nuclear fuel cycle by reprocessing and recycling SNF. We concluded that while new reactor and fuel cycle technologies may hold promise for achieving substantial benefits in terms of broadly held safety, economic, environmental, and energy security goals and therefore merit continued public and private R&D investment, ***no currently available or reasonably foreseeable reactor and fuel cycle technology developments—including advances in reprocessing and recycling technologies—have the potential to fundamentally alter the waste management challenge this nation confronts over at least the next several decades, if not longer***.[272] Put another way, we do not believe that today's recycle technologies or new technology developments in the next three to four decades will change the underlying need for an integrated strategy that combines safe storage of SNF with expeditious progress toward siting and licensing a disposal facility or facilities. This is particularly true of defense HLW and some forms of government-owned spent fuel that can and should be prioritized for direct disposal at an appropriate repository.

The above conclusion rests on several practical observations. First, the United States has a large existing inventory (on the order of 65,000 metric tons) of spent fuel and will continue to accumulate more spent fuel as long as its commercial nuclear reactor fleet continues to operate. In addition, the U.S. inventory includes materials with a very low probability of re-use under any scenario, including high-level radioactive waste from past nuclear weapons

programs and some forms of government-owned spent fuel. Second, the timeframes involved in developing and deploying *either* breakthrough reactor and fuel-cycle technologies *or* waste disposal facilities are long: on the order of multiple decades even in a best-case scenario. Given the high degree of uncertainty surrounding prospects for successfully commercializing advanced reactor and fuel cycle concepts that are, for the most part, still in the early R&D phases of development it would be imprudent to delay progress on developing disposal capability—especially since that capability will be needed under any circumstances to deal with at least a portion of the existing HLW inventory. The final and most important point, which further strengthens this conclusion, is that all nuclear energy systems generate waste streams that require long-term isolation from the environment: nuclear fission creates radioactive fission products.

Our conclusion concerning the need for geologic disposal capacity stands independently of any position one might take about the desirability of closing the nuclear fuel cycle in the United States. The Commission could not reach consensus on that question. *As a group we concluded that it is premature at this point for the United States to commit irreversibly to any particular fuel cycle as a matter of government policy given the large uncertainties that exist about the merits and commercial viability of different fuel cycles and technology options. Rather, in the face of an uncertain future, there is a benefit to preserving and developing options so that the nuclear waste management program and the larger nuclear energy system can adapt effectively to changing conditions*. Future evaluations of potential alternative fuel cycles must account for linkages among all elements of the fuel cycle (including waste transportation, storage, and disposal) and for broader safety, security, and non-proliferation concerns.

To preserve and develop those options, we believe RD&D should continue on a range of reactor and fuel cycle technologies, described in this report, that have the potential to deliver societal benefits at different times in the future. If and when technology advances change the balance of market and policy considerations to favor a shift away from the once-through fuel cycle, that shift will be driven by a combination of factors, including—but hardly limited to—its waste management impacts. *In fact, safety, economics, and energy security are likely to be more important drivers of future fuel cycle decisions than waste management concerns per se*. We also note that other elements of our proposed approach to managing the back end of the fuel cycle—including, notably, our recommendations concerning the need to move forward with consolidated storage capacity—will provide the flexibility needed to take full advantage of advanced technologies if and when these technologies materialize.

The remainder of this chapter summarizes the Commission's findings with respect to the potential benefits and trade-offs associated with different broad categories of advanced nuclear reactor and fuel cycle combinations. We also briefly discuss the need for continued public and private investment in nuclear energy R&D, the status of DOE's nuclear energy R&D program, and the adequacy of existing regulatory and legal frameworks to accommodate new types of technologies and facilities.

11.2 RESULTS OF A HIGH-LEVEL COMPARISON OF REACTOR AND FUEL CYCLE ALTERNATIVES

As directed by our charter, the Commission undertook to evaluate existing fuel cycle technologies and R&D programs in terms of a set of broad criteria that will have a critical influence on the nuclear energy industry's prospects going forward (e.g., safety, cost, security, etc.). In doing so, we relied on the numerous studies that have been undertaken in the last decade to assess and compare various reactor and fuel cycle options.[273] It is important to emphasize that the Commission could not and did not attempt to draw definitive or quantitative conclusions about the relative merits of different technology combinations. This is because the numerous studies we considered—although collectively they analyze a wide array of strategies and technologies—use often very different underlying parameters and assumptions. As a result, the quantitative results of these studies are not comparable. Additionally, many of the potential technologies require considerable development before a defensible comparison could be made. Thus, it is impossible at this time to distill quantitative comparisons across alternative nuclear energy systems and then draw definitive conclusions based on those comparisons.

We approached the task of comparing advanced nuclear energy systems by first identifying three representative alternatives to the once-through light water reactor (LWR) strategy. One of these alternatives is already in use; the other two are substantively different from the once-through cycle and have received extensive previous study. We then focused on the major qualitative differences between these alternatives and the existing once-through LWR fuel cycle, based on the findings contained in the literature available to the Commission. The results, which are summarized in table 5, indicated a wide range of trade-offs in terms of safety, cost, resource utilization and sustainability, waste management, and the promotion of nuclear non-proliferation and counter-terrorism goals. These trade-offs complicate any effort to compare the relative merits of different nuclear energy systems, particularly given uncertainty about future technological developments and social conditions. Moreover (and as we have already noted) the conclusions reached by different technology assessments and comparative analyses are heavily influenced by input assumptions and by the relative weight given to different policy objectives (e.g., reducing waste vs. minimizing proliferation risk vs. maximizing resource utilization)—making it difficult to compare results across studies.

The four systems (one baseline plus three alternatives) considered in our qualitative comparison are characterized as follows:

- **Once-through fuel cycle with light-water reactor technology:** We chose this system as the baseline because it is the dominant fuel-cycle and technology combination currently in use in the United States and in the majority of the world's nuclear nations. That said, future technology advances can be used to improve on this system; an example might include the ability to achieve higher fuel burnup using improved cladding and improved safety features.
- **Modified open cycle using mixed-oxide (MOX) fuel with light-water reactor technology:** This system was selected for comparison chiefly because it is the only alternative fuel cycle strategy that is currently being utilized on a commercial scale.[274] Used in France since the 1970s, MOX fuel is also used in reactors in Germany, Switzerland, Belgium and Japan. The United States is currently building a MOX fuel fabrication facility in South Carolina to utilize excess defense plutonium, and the United Kingdom, China, and Russia are also in various stages of operation or planning for the use of MOX fuel.
- **Closed fuel cycle system with fast reactors:** This system was considered because it has the theoretical potential to maximize the use of uranium resources and therefore to be sustainable for centuries while simultaneously reducing the amount of long-lived radionuclides in resulting waste streams. Lower amounts

of radionuclides would allow a larger quantity of waste to be placed in a given repository; in addition, this fuel cycle would greatly reduce uranium mining requirements and eventually eliminate the need for uranium enrichment.

- Once-through fuel cycle with high-temperature reactors: The defining feature of this fourth system is a high-temperature reactor that can achieve temperatures greater than 600°C (light water reactor outlet temperatures are about 300°C).[275] It was selected because it has the potential to displace the use of fossil fuel across all energy sectors, not just electricity production. Examples of energy-intensive industries where high-temperature nuclear process heat could be used include cement and steel manufacturing, and petroleum refining. High-temperature nuclear process heat could also be used to produce hydrogen for transportation fuels by directly decomposing water instead of using electrolysis or decomposing natural gas, and the high power conversion efficiency can also make dry cooling and thermal desalination of seawater practical.

Many additional system options exist that have received varying levels of study. For example, nuclear energy systems that involve a fast-spectrum reactor capable of achieving very high temperatures by using a molten salt or gas coolant, or a thermal-spectrum, high-temperature molten-salt reactor using thorium have also been proposed. Such systems could potentially offer many of the combined benefits of the alternatives listed. However, these systems have not received systematic study and the component technologies for these types of systems are less well developed. Other concepts, such as fusion energy, are even further from being successfully demonstrated—but if they ever prove feasible they may have even larger impacts on fuel cycles and nuclear waste generation.

The results of this comparison for the baseline strategy and the three nuclear energy systems selected for comparison are shown in table 4. The entries in this table generally refer to a steady-state condition. The Commission recognizes that in some cases a long transition time is necessary to reach a steady state. Each of the four nuclear energy systems is assumed to produce the same amount of electric power and the outcomes are stated in relative terms in relation to the baseline strategy.

TABLE 4. A COMPARISON OF THE EXISTING ONCE-THROUGH, CONVENTIONAL LIGHT-WATER REACTOR FUEL CYCLE WITH REPRESENTATIVE ADVANCED NUCLEAR ENERGY SYSTEMS IN THE LONG TERM[276]

Criterion	Once-Through LWR	Once-Through with High-Temperature Reactor
Nuclear Energy Description	Clad uranium oxide fuels irradiated in LWRs with evolutionary improvement	High-temperature reactors (such as those using graphite-based fuels) capable of temperatures over 600°C operating on a once-through fuel cycle. Being pursued in DOE's Next Generation Nuclear Plant project
SAFETY		
Reactor and fuel cycle safety[277]	Baseline, with potential for further improvement	Potential for improvement; all must meet similar regulatory requirements
COST		
Capital and operating costs	Baseline	Test reactors have operated well, but demo (Fort St. Vrain) was unreliable. Fuel costs are uncertain and may be high. RD&D is needed on to provide a basis for design, licensing, and evaluating long-term economic viability.
SUSTAINABILITY		
Uranium utilization[279]	Baseline	Similar uranium requirements although can vary by design
Climate change impacts	Baseline	Potential for major reduction in carbon dioxide by using nuclear process heat in fossil-energy-intensive industries and to produce hydrogen for non-carbon-based transportation fuels
Energy security	Baseline	Potentially large benefit in reducing petroleum imports now used to fuel non-electricity sectors
NON-PROLIFERATION AND COUNTER-TERRORISM		
Non-proliferation	Baseline	Reference designs require similar enrichment capacity capable of producing 8%-20% uranium enrichment. Fuel is more difficult to reprocess than LWR fuel.
Counter-terrorism	Baseline	Similar to baseline
WASTE MANAGEMENT		
Disposal safety: toxicity and longevity of waste	Baseline	Repository: Similar to baseline Fuel Cycle: Similar public and occupational risk from mining and milling
Volume of waste[280]	Baseline	~10X increase in SNF volume going to repository. About the same non-mill tailings LLW as baseline.
Repository space requirements	Baseline	~25% reduction due to higher reactor efficiency.

LWR Modified Open Cycle	Fast-Spectrum Reactor with Closed Fuel Cycle
Clad uranium- and mixed-oxide fuels irradiated in LWRs with evolutionary improvements. MOX fuel is irradiated once and then sent to repository.	Fast-spectrum liquid-metal-cooled reactors capable of continuous recycle of actinides
SAFETY	
Potential for improvement; all must meet similar regulatory requirements	Potential for improvement; all must meet similar regulatory requirements
COST	
Capital cost increased because of need to build reprocessing and MOX fuel fabrication plants. Operating costs also increased due to the high cost of fabricating fuels containing Pu. Cost of electricity increased a few to several percent. Technology is relatively mature with evolutionary improvements largely in the hands of industry.	Previously built reactors (mostly prototype/demo) were often unreliable and not economic. Significant capital cost for recycle facilities. RD&D is needed to provide a basis for design, licensing, and evaluating long-term economic viability.[278] Operating costs relative to baseline largely depend on the future price of uranium, fuel fabrication cost, and operational reliability.
SUSTAINABILITY	
~19% reduction in uranium requirements	~95% reduction in uranium requirements
About the same as the baseline	About the same as baseline
About the same as the baseline	Modest benefit from potential for long term reliance on indigenous uranium resources
NON-PROLIFERATION AND COUNTER-TERRORISM	
Involves use of reprocessing, enrichment, and MOX fuel fabrication technology, and deployment of facilities for same. Increased proliferation risk from substantial normalized inventory of Pu or Pu-plus other actinides in reactors and the fuel cycle.	Involves use of reprocessing and plutonium-bearing fuel fabrication technology, and deployment of facilities for same. Enrichment technology needed during transition to fast reactors. Increased proliferation risk from substantial normalized inventory of Pu or Pu-plus other actinides in reactors and the fuel cycle.
Involves production and inventory of co-processed nuclear materials (U/Np/Pu) and 5%-10% enriched uranium, and fuels containing same. Increased security risk due to separated materials and additional facilities and transportation.	Involves production and inventory of co-processed nuclear materials (U/Np/Pu) and fuels containing same. Increased security risk due to separated materials and additional facilities and transportation.
WASTE MANAGEMENT	
Repository: Noticeable reduction in the amount of TRU in wastes. Tailored waste form for ~90% of the HLW Fuel Cycle: 15%–20% reduction in fuel cycle public and occupational risk from reduced mining and milling. Although there is an increase in emissions from reprocessing, overall risk is reduced as a result of reduced risks on the front end.	Repository: Tailored waste form for fission products; potential for reduction in long-term repository dose from TRU elements if recycle is sustained for decades to centuries Fuel Cycle: ~85% reduction in fuel cycle public and occupational risk from reduced mining and milling, increase from emissions from reprocessing
Similar repository waste volume: less SNF/HLW, more secondary waste. ~20% decrease in near-surface wastes, esp. mill tailings and depleted uranium. Besides mill tailings and depleted uranium, about the same amount of LLW as baseline.	~40% increase in repository waste volume: less HLW, more secondary waste. ~95% decrease in near-surface wastes, primarily due to mill tailings and depleted uranium. ~40% decrease in non-mill tailings LLW due to greatly reduced throughput in the front end of the fuel cycle.
Similar to baseline, with some reduction in long-term decay heat generation.	~75% decrease in repository space required when TRU are recovered and recycle is sustained over many decades to a couple of centuries.

The fact that there are no clear winners among the main alternative fuel cycles summarized in the table and others considered by the Commission suggests that the United States should pursue a policy of keeping multiple options open. That said, certain fuel cycle strategies and technologies are clearly better developed than others—research in some areas has been underway for decades and it is possible that more mature technologies could be implemented more quickly, perhaps within a few decades. Other concepts are barely at the proof-of-principle stage and would require substantial investments of time and funding (and in some cases a number of revolutionary technical developments) to bring them to a level of maturity sufficient to evaluate their suitability for further development and potential implementation. Consequently, the level and duration of R&D effort needed to advance these concepts varies widely. Ironically, near-term funding needs for technologies that are relatively more developed can be greater than for technologies still in an earlier phase of the RD&D process—particularly in the case of technologies that are ready to be demonstrated. At that point, large investments may be needed to provide the demonstration facilities required to make further progress. In the next section, we explore U.S. nuclear energy R&D plans and programs and offer suggestions for addressing the challenges facing those programs.

11.3 THE CASE FOR CONTINUED PUBLIC AND PRIVATE INVESTMENT IN NUCLEAR ENERGY RD&D AND THE STATUS OF THE CURRENT DOE PROGRAM

The results of our qualitative assessment suggest that while it is too early to select "winners," advanced nuclear energy systems could offer a range of benefits in terms of broadly held policy goals with respect to safety, cost, security, etc. In a world facing rising energy demand and significant resource and environmental concerns, including the threat of climate change, preserving an improved nuclear energy option could be extremely valuable. Therefore, the Commission concludes that the United States should continue to pursue a program of nuclear energy RD&D both to improve the safety and performance of existing nuclear energy technologies and to develop new technologies that could offer significant advantages in terms of the multiple evaluation criteria identified in our charter (i.e., safety, cost, resource utilization and sustainability, waste management, and non-proliferation and counter-terrorism). We believe a well-designed federal RD&D program is critical to enabling the U.S. to regain its role as the global leader of nuclear technology innovation and should be attentive to opportunities in two distinct realms:

1. Near-term improvements in the safety and performance of existing light-water reactor technology as currently deployed in the United States and elsewhere as part of a once-through fuel cycle, and in the technologies for storing and disposing of SNF and HLW.
2. Longer-term efforts to advance potential "game-changing" nuclear technologies and systems that could achieve very large benefits across multiple evaluation criteria compared to current technologies and systems. Examples might include fast-spectrum reactors demonstrating passive safety characteristics that are capable of continuous actinide recycling and that use uranium more efficiently, or reactors that—by using molten salt or gas coolants—achieve very high temperatures and can thereby supply process heat for hydrogen production or other purposes, or small modular reactors with novel designs for improved safety characteristics and the potential to change the capital cost and financing structure for new reactors.

At the same time the federal government and nuclear industry should ensure that necessary efforts and investments are made to maintain valuable existing capabilities and assets, including critical infrastructure and facilities such as are present at a number of DOE sites, as well as vital human expertise (in the form of highly trained nuclear scientists, engineers, and workers, etc.).

In making these recommendations, the Commission is mindful that federal RD&D funding of all kinds will be under enormous budget pressure in the years ahead. It will therefore be especially important to focus scarce public resources on addressing key gaps or needs in the U.S. nuclear RD&D infrastructure and to leverage effectively the full range of resources that exist in industry, the national laboratories, and the academic community. This could include funding well-designed, multipurpose test facilities that can be used to advance knowledge in several areas of inquiry. Such facilities would be available to scientists from different institutions around the country (an example is the Advanced Test Reactor National Scientific User Facility at Idaho National Laboratory) and exemplify the kind of RD&D infrastructure that could yield particularly high returns on public investment. Furthermore, while this Commission is charged with making recommendations to the government, we also want to clearly emphasize the importance and value of industry RD&D efforts, such as those of the Electric Power Research Institute, and the importance of continuing and stable industry RD&D investment in reactor and fuel cycle technologies.

In recent years, DOE's budget for nuclear energy R&D has totaled approximately $500 million per year. The Commission is not making a specific recommendation with respect to funding levels in future years, recognizing that this is a decision that will have to be made in the context of larger energy policy considerations and increasingly difficult federal budget constraints. Generally speaking, however, the Commission concurs with recent findings issued by the President's Council of Advisors on Science and Technology concerning the need for better coordination of energy policies and programs across the federal government; for a substantial increase in federal support of energy-related research, development, demonstration, and deployment; and for efforts to explore new revenue options to provide this support.[281] Meanwhile, with federal discretionary budgets under increasing pressure, the ability to articulate a clear direction or agenda for the U.S. nuclear energy R&D program, to prioritize elements of that agenda, and to set performance objectives and evaluate the effectiveness of related activities on an ongoing basis will obviously be critical.

To that end, the Commission believes that DOE's nuclear energy R&D Roadmap provides a good, science-based step toward the development of an effective, long-term RD&D program. The Roadmap should be periodically updated in the future (we recommend once every four years) and in the process should be informed by broader strategic planning efforts, such as DOE's recently launched Quadrennial Technology Review and Quadrennial Energy Review process. In addition, it should explicitly apply the evaluation criteria noted in the BRC's charter and it should build in the flexibility needed to respond to unexpected technology developments and changing societal concerns and preferences. (The recent and still-unfolding events at the Fukushima Daiichi nuclear power plant are just one example of the type of development that should be reflected in future updates of the roadmap.) Finally, we urge DOE to support future versions of the Roadmap with more detailed, frequently updated, and transparent research and implementation plans.

Additional principles or objectives that should guide DOE's approach to nuclear energy RD&D in the future include the following:

- System assessments and evaluations must account for the interconnections among the various elements of the nuclear fuel cycle (including transportation, storage, and disposal) and for broader safety, security, and non-proliferation concerns. For example, adding facilities to one phase or section of the nuclear fuel cycle could change overall system costs or otherwise affect the performance of the system as a whole. RD&D investment and technology choices can be made most effectively only if the interconnections between and among the elements of the fuel cycle system are well understood.
- Nuclear energy RD&D going forward will continue to involve a broad range of participants including universities, industry, and national laboratories in cooperation with international research partners. Integrating the efforts of these disparate participants will require a concerted effort and is essential if DOE is to maximize the value of the RD&D it supports. DOE should undertake efforts to strengthen coordination and organizational and mission alignment across laboratories, energy hubs, innovation centers, and other entities.
- Federal cost sharing with industry to license new reactor designs has been extremely successful and should be pursued where practical. Indeed, federal support has bolstered U.S. technical leadership in the nuclear energy arena generally and played a role in developing the state-of-the-art AP-1000 and ESBWR[282] reactor designs specifically. These designs employ the most advanced passive safety systems developed to date.
- Safety concerns, along with nuclear weapons proliferation and nuclear material safeguards and security (discussed in the following chapter), deserve special attention in the R&D roadmap and in plans for demonstration facilities. Integrating safety, security and safeguards considerations in future evaluations of advanced nuclear energy systems and technologies will allow the United States to maintain consistency between its technology development agenda, its commercial interests, and its international policy agenda.
- As a result of the focus on repository design issues specific to the Yucca Mountain site, generic R&D on deep geologic disposal for the last few decades has been assigned a lesser priority within DOE's R&D portfolio. The move by DOE to absorb the R&D responsibilities of the Office of Civilian Radioactive Waste Management into the Office of Nuclear Energy presents an opportunity to better integrate waste management considerations into the DOE nuclear energy research agenda.
- Going forward, the nuclear energy R&D program should include an emphasis on the development of disposal and waste form alternatives that are optimized to work with potential natural and engineered barriers in the disposal system. If alternative nuclear energy systems are deployed in the future, however, they will likely generate a greater variety of waste streams than the current system. Efforts to manage these wastes will benefit from an improved understanding of different combinations of geologic disposal environments, engineered barriers and waste forms.

Finally, one area outside the DOE RD&D program where the Commission has identified a specific need for increased funding involves ongoing work by the NRC to develop a regulatory framework for novel components of advanced nuclear energy systems. This is a priority because a regulatory framework can help guide the design of new systems and lower barriers to commercial investment by providing greater confidence that new systems can be successfully licensed. In its draft report to the full Commission, the Reactor and Fuel Cycle Technology Subcommittee recommended that 5 to 10 percent of total federal funding for reactor and fuel cycle technology RD&D be directed to the NRC to support its work in this area; the Commission agrees that adequate funding for this activity should be provided. We also support the NRC's current risk-informed, performance-based approach to developing regulations for advanced nuclear energy systems.

11.4 WORKFORCE DEVELOPMENT

The effective conduct of the U.S. nuclear enterprise (whether that enterprise is expanded, maintained at the current level, or diminished in the future) will require a properly trained workforce, including scientists and engineers in many disciplines as well as skilled workers for site evaluation, construction, operation, decommissioning and closing nuclear facilities—including facilities in the nuclear waste management program. At the professional level there has been healthy growth in the number of students pursuing a nuclear engineering career over the last decade. Several factors account for this, including the availability of federal funding and a recent increase in the number of new plants proposed or under construction in the United States and around the world. In addition, there has been noteworthy progress in developing programs to prepare skilled labor from many different building trades and crafts for the entire spectrum of work at nuclear facilities. Finally, the training available to first responders in other sectors has resulted in improved capabilities for responding to transportation accidents as well as incidents at fixed facilities involving hazardous materials, including radioactive wastes.

Nevertheless, workforce needs in the nuclear industry and in other high-tech sectors of the U.S. economy are expected to grow in the coming years. According to a 2008 report prepared by the Directors of the National Laboratories: "A recent industry study pointed out that over the next five years, half of the nation's nuclear utility workforce will need to be replaced." The Directors called for both government and industry actions to support the development of the future nuclear workforce.[283] Based on testimony presented to the BRC Subcommittee on Reactor and Fuel Cycle Technology, the Commission concurs with this general finding. We recommend expanded federal, joint labor-management, and university-based support for advanced science, technology, engineering, and mathematics training to develop the skilled workforce needed to support an effective waste management program as well as a viable domestic nuclear industry.

12. INTERNATIONAL ISSUES

The United States has long been a global leader in the development of nuclear technologies and policies and in international efforts to address issues of nuclear security and safety.

Throughout its deliberations the Commission has been acutely aware of the international implications of future U.S. actions with respect to innovation in nuclear technologies and the management of the back end of the nuclear fuel cycle. In our view, international collaborations and considerations are especially important in three areas: safety, non-proliferation, and nuclear security (counter-terrorism). This chapter highlights our main conclusions and recommendations in each of these areas.

Unfortunately, our failure to develop a broadly-accepted domestic spent fuel storage and disposal strategy has limited our non-proliferation policy choices in the context of nuclear fuel cycles. In addition to supporting non-proliferation objectives, our international nuclear safety goals will also be served by establishing and implementing effective waste management strategies.

Overall, we believe the United States must continue to strengthen its leadership role on the world stage to assure the safe, secure, and responsible application of nuclear technology, particularly if rising resource demands coupled with climate change concerns prompt a significant global expansion of nuclear capacity in coming decades.

12.1 INTERNATIONAL NUCLEAR SAFETY

Recent events in Japan have reinforced the importance of a focus on nuclear safety. Although the radiological releases in Japan will have no direct impacts of significance on the United States, the events at Fukushima are certain to affect attitudes toward nuclear technology here and abroad. Even if the health consequences of the Fukushima accident prove to be small compared to the direct impacts of the earthquake and tsunami, economic ramifications—including the permanent loss of contaminated land and six costly reactors—and the potential danger of a nuclear accident remain abiding public concerns. These concerns must be directly and forthrightly addressed.

At a minimum, events in Japan will have to be carefully scrutinized to see what can be learned from them and to identify any needed changes in the U.S. regulatory system. Insights gained from Fukushima should also have an influence on the direction of research and development efforts and on the design of advanced nuclear energy systems.

Events in Japan also reinforce the need for expanded international efforts to promote the safe operation of existing and planned nuclear installations, including facilities for spent fuel storage and disposal. A significant expansion of nuclear power is planned in the years ahead in countries such as China, Russia, India, and Korea. Over 60 countries that do not currently have nuclear power plants have approached the IAEA to explore the possibility of acquiring one and the IAEA anticipates that about 15 of these emerging nuclear nations will proceed over the next decade or two. Several of these "new-entrant" countries have already committed to construction. All will have to provide for safe storage and disposal of their nuclear fuel as part of a larger commitment to ensure the safety of all nuclear facility operations.

Safety is an inescapable, continuing, expensive, and technologically sophisticated demand that all new entrants to commercial nuclear power will have to confront over the full lifecycle of these systems—from preparing for construction through decommissioning. The nature and scope of the safety challenges involved might not be fully apparent to new entrants. Managing these challenges requires that robust institutional, organizational and technical arrangements be in place at the very early stages of a nuclear program. Also needed are sufficient technical knowledge and experience, strong management, continued peer-review and training, and an enduring commitment to excellence and a robust safety culture. Many countries will not initially be able to obtain the needed level of expertise and experience on their own. Thus, relevant international organizations and industry groups should expand the assistance available to such countries as they tackle the planning, design, construction, operation and regulation of nuclear energy systems.

All nations that have or plan to construct nuclear reactor facilities will, of course, also face the paramount task of providing for the safe storage and ultimate disposition of spent fuel. Here again, international efforts are needed to help new-entrant countries successfully manage these challenges.

The capacity to pursue nuclear technology in the United States will depend to a large extent on other countries' success in achieving a high level of safety performance. Many of these countries have not yet demonstrated that they have the infrastructure or the commitment to a safety culture that provides confidence they will succeed. Moreover, as the events at Fukushima have shown, even a nation that has successfully operated nuclear reactors can have difficulties preparing for and responding to major accidents. Since Fukushima, the international community has worked to strengthen global nuclear safety, particularly through the work of the IAEA and its focus on enhanced international safety standards and expanded safety services.

However, the Commission does not believe the task of enhancing global reactor safety should fall to the IAEA alone. In that spirit, we strongly support recent actions undertaken by the World Association of Nuclear Operators (WANO), which shortly after the Fukushima accident asked every nuclear power plant operator in the world to take "specific actions to verify their ability to deal with a station blackout or a beyond-design-basis event like fire or flood."[284] In addition, the WANO Governing Board established a high level commission tasked with recommending changes to WANO programs and organization as a result of lessons learned from Fukushima. That commission has recommended that WANO better define its roles and responsibilities in an emergency situation and develop a worldwide integrated event response strategy. It has also urged WANO to add emergency preparedness as a core review area to each and every WANO peer review, to conduct peer reviews for all initial reactor start ups, and to look more closely at fuel storage—including fuel pools and dry cask storage.[285]

In addition to the work being done by the operators of nuclear power plants, efforts by international nuclear vendors to embrace additional and voluntary self-governance regimes have also gained traction. Several "principles of conduct"[286] recently adopted by a number of the world's leading civilian nuclear technology vendors describe a commitment to undertake good faith efforts in several areas: safety, security, environmental protection, compensation for nuclear damage, nonproliferation, and ethics. Participating vendors express their intention to follow these principles in designing and exporting nuclear power plant technologies. These principles are based upon practices derived from the experience of power plant vendors and operators and IAEA standards.[287] *The Commission supports these efforts and encourages industry to continue pushing forward with the implementation of global best practices across a range of issues related to the safe and secure operation of nuclear energy facilities.*

In sum, the United States should work with the IAEA and other interested nations to launch a major international effort, encompassing international organizations, regulators, vendors, operators, and technical support organizations, to enable the safe application of nuclear energy systems and the safe management of nuclear wastes in all countries that pursue this technology. The United States should also participate in other new and ongoing IAEA initiatives to address safety challenges. Finally, we believe DOE and NRC should be explicitly directed and funded to offer nuclear safety assistance and guidance to new-entrant countries who request it.

12.2 NON-PROLIFERATION CONSIDERATIONS

Because enrichment, reprocessing and recycled fuel fabrication facilities typically produce or utilize large amounts of separated materials (including enriched uranium and plutonium) as part of their operations, they present higher proliferation risks and are therefore considered particularly sensitive elements of the fuel cycle. The technologies used in these facilities can not only serve nuclear power needs, but can give countries the technical and physical capacity to obtain the direct-use nuclear materials required for a weapons program. Proliferation risks are varied: they may include the potential for countries to secretly divert materials from civilian nuclear facilities that they have declared to the IAEA under the NPT, or the potential for countries to apply know-how and equipment from declared programs to the construction of clandestine production facilities (e.g., clandestine enrichment plants). Finally, there is the risk that under some circumstances countries might withdraw from the NPT and then overtly misuse materials and facilities.

A number of institutional and technical approaches exist under the NPT and other international and bilateral agreements to address these risks. These include the application of IAEA safeguards to detect the diversion of nuclear materials in a timely manner and to verify peaceful uses of declared civil nuclear energy infrastructure; the IAEA's ability to verify the absence of clandestine production facilities in countries that have ratified the IAEA Additional Protocol; international agreements by nuclear supplier nations to apply export controls to detect and prevent transfers of dual-use equipment to clandestine production facilities; the use of national technical means and human intelligence to detect clandestine production efforts; and initiatives aimed at developing international fuel cycle facilities as a way to provide emerging nuclear energy nations with reliable and affordable access to fuel enrichment and reprocessing services without the need to develop indigenous capacity; and the international system of bilateral and multilateral security and mutual defense agreements that reduce regional security concerns that could otherwise lead some countries to seek nuclear weapons capability.

None of these measures offers a perfect solution to the problem of nuclear proliferation, but together they can help reduce proliferation risks to a manageable level. The ability to identify and isolate non-compliant programs by itself can help ensure that problem countries do not come to be viewed as role models by other emerging nuclear energy nations. In the sections that follow we review the main elements of the current international non-proliferation regime and offer recommendations for improving and strengthening these elements through further U.S. investments and policy leadership.

12.2.1 THE TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS (NPT)

The NPT provides the foundation of the international nuclear non-proliferation regime. Opened for signature in 1968, the Treaty entered into force in 1970. It currently has 189 signatories,[288] divided between nuclear weapon states (NWS) and non-nuclear weapon states (NNWS). Virtually all states in the international system have signed and ratified the treaty: only Israel, India, and Pakistan have declined to sign, and North Korea is the only state that has joined the treaty but later exercised its right to withdraw.

The NPT is designed to promote three main objectives: to limit the spread of nuclear weapons, to encourage eventual nuclear disarmament, and to provide a framework and enable widespread access to peaceful uses of nuclear energy. The key provisions of the NPT therefore outline rights and responsibilities for state parties in the area of nuclear non-proliferation, nuclear energy, and disarmament.[289] Article I states that no NWS may "transfer, assist, encourage or induce" any NNWS to "manufacture or otherwise acquire nuclear weapons." Article II requires NNWS parties not to "receive, manufacture or otherwise acquire" nuclear weapons and "not to seek or receive any assistance in the manufacture of nuclear weapons." Article IV protects the right of all states to peaceful nuclear energy, conditional on their being in compliance with their Article II commitment: "Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty." Article VI of the NPT calls for all parties to work towards nuclear disarmament: "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament." As noted above, Article VI is often treated as exclusively applicable to NWS, though it clearly states that *each of the parties* to the treaty must pursue "negotiations in good faith"[290] in pursuit of nuclear disarmament.

Although the NPT provides a legal framework for the global non-proliferation regime, the workhorse of the regime has been the IAEA safeguards system. This system is used to verify NPT compliance and to affirm that governments are not using civil nuclear energy programs for nuclear-weapons purposes.

All signatories to the NPT are required to have a comprehensive safeguards agreement (CSA) in place. These CSAs cover "all source or special fissionable material in all peaceful nuclear activities within the territory of a State, under its jurisdiction, or carried out under its control anywhere."[291] Because IAEA safeguards depend on correct and complete declarations of countries' nuclear materials and activities, CSAs play an important role in verifying country reports. Typically, they rely heavily on nuclear material accounting measures, complemented by containment and surveillance techniques such as tamper-proof seals and cameras that the IAEA installs at facilities. Verification measures include on-site inspections, visits, and ongoing monitoring.

Unfortunately, some events of the last several decades have challenged the efficacy and credibility of CSAs. In particular, Iraq's engagement in a clandestine nuclear weapons program from the mid-1980s to the early 1990s violated its safeguards obligations under the NPT. In response, the IAEA broadened the scope of materials and facilities covered by the safeguards and strengthened safeguards techniques.[292] In 1992, the IAEA Board of Governors reaffirmed the agency's authority to conduct "special inspections" of suspected undeclared sites in NPT non-nuclear weapon states and in 1997 the IAEA Board of Governors adopted a new safeguards model. Known as the "Additional Protocol" or AP, the protocol gave IAEA inspectors increased access to all aspects of a non-nuclear weapon state's nuclear program, even where nuclear material is not involved; required states to provide more detailed information on their nuclear program; allowed for the use of improved verification technologies (i.e., environmental sampling); and required more extensive inspections at declared nuclear sites.[293] There are currently 104 countries with Additional Protocol agreements in force but some key countries, like Iran, have refused to ratify the AP.[294]

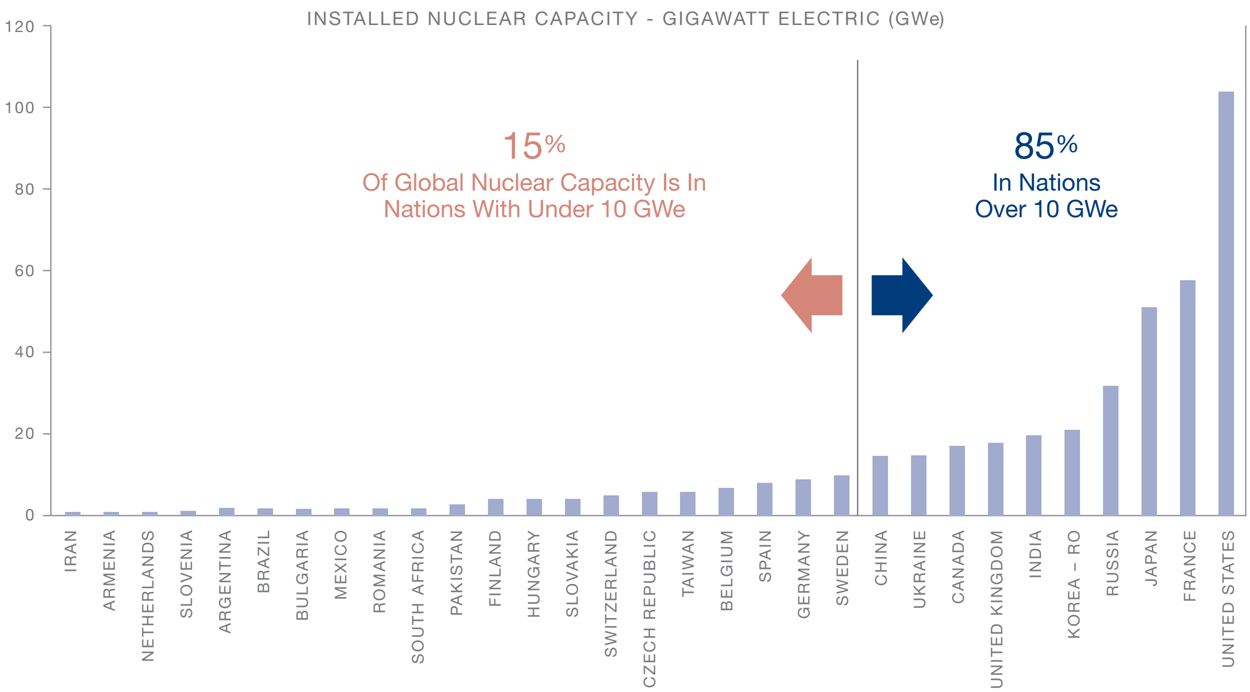
Even with the Additional Protocol in place, plans to expand global nuclear energy production and concerns over the spread of sensitive nuclear technologies are placing increased strain on international safeguards. To the extent that this expansion involves new reprocessing and enrichment facilities, one of the most vexing challenges for the safeguards system will be verifying physical materials at these facilities. In large bulk-handling facilities with high volume throughputs (hundreds to thousands of metric tons) and complicated equipment schematics, material unaccounted for or "MUF" can represent a substantial proliferation challenge. Even as a small percentage of facility throughput, the quantity of material unaccounted for can be significant. Over the last 15 years, material accounting efforts have failed on multiple occasions to detect and resolve anomalies in a timely fashion. These lapses have involved large amounts of MUF that remained unresolved for months, years, or even decades.[295]

The Commission endorses R&D efforts on modern safeguards technologies and urges continued U.S. government support for IAEA's work in this area. The National Nuclear Security Administration is the principal federal sponsor of nuclear non-proliferation-related research and development and is currently (in conjunction with the national laboratories) supporting work on safeguards systems analysis and enhancements, safeguards-by-design, nuclear material control and accountability (MC&A) improvements, modern inventory controls, software and hardware development, collaborative information technology tools, and real-time process monitoring and data integration systems. ***Support for the development of novel safeguards technologies is not only imperative because of the fundamentally important nature of the threat, but because of compounding issues related to the development of these technologies.*** The IAEA finds itself constrained financially, lacking the resources to perform research and development on the necessary technologies, while tasked with ever-increasing responsibilities.[296] In addition, the size of the "safeguards market" simply doesn't support the cost-effective production of units or major R&D investments by commercial players. As a result, the IAEA remains reliant on the R&D efforts of national governments.

12.2.2 MULTILATERAL/MULTI-NATIONAL FUEL CYCLE SERVICES OPTIONS

Proposals for "multi-nationalizing" certain fuel cycle facilities or operations as a way to provide access to sensitive parts of the nuclear fuel cycle are not new and have been discussed in multiple forms since the 1946 Acheson-Lilienthal report and Eisenhower's 1953 Atoms for Peace speech.[297] Striking a

FIGURE 20. WORLDWIDE DISTRIBUTION OF CIVIL NUCLEAR ENERGY GENERATION CAPACITY IN 2010[298]



balance between the reliable provision of fuel supply services on the one hand and guaranteeing adherence to non-proliferation norms on the other hand is difficult, to say the least. In concert with the IAEA, several countries, including the United States, have proposed an array of strategies to provide countries with credible, cost-efficient options for an assured nuclear fuel supply, including the development of backup supplies or "fuel banks" of enriched uranium, multi-national fuel cycle centers, and government-to-government agreements.

Today, as shown in figure 20, the majority of nuclear energy programs worldwide are small, with less than 10 GWe of capacity (fewer than 10 reactors). Furthermore, while some new uncertainty has been introduced by the Fukushima accident, the number of countries with small nuclear energy programs is still widely expected to grow further. In 2011, Iran's first power reactor reached criticality at Bushehr, adding another country to the list shown in figure 20. In addition, 65 more countries are currently participating in IAEA technical cooperation projects related to the introduction of nuclear power. Because most national nuclear energy programs are small, the combined installed nuclear capacity in these countries accounts for less than 15 percent of total global nuclear generation capacity. Given this feature of the current global nuclear energy market, there are compelling practical and economic reasons for countries to make use of regional or multi-national fuel cycle facilities and services, rather than developing their own nuclear fuel cycle capabilities.

In 2004, the Director General of the IAEA appointed an international expert group to consider options for possible multilateral approaches to developing facilities on the front and back ends of the nuclear fuel cycle. Their report, *Multilateral Approaches to the Nuclear Fuel Cycle*, was released in February of 2005;[299] it categorized the options for offering assured fuel supply into three major and distinct categories: assurances of services not involving the ownership of fuel cycle facilities, conversion of existing facilities to multi-national facilities, and the construction of new jointly-owned facilities.

Within the first option, it is generally assumed that a functional market exists for whatever fuel service is required, either through state-owned enterprises or commercial enterprises. Of course, market options currently vary across the fuel cycle (i.e., more commercial options exist for enrichment than they do for reprocessing, and none exist for spent fuel and HLW disposal). While a diversity of supply options alone does not necessary reflect the health of a market and its ability to answer demand, it can affect countries' confidence that their ability to access supplies is really "assured." In some cases, the ability to access fuel supplies via existing and perfectly healthy markets is not sufficient for a country to forgo developing its own indigenous fuel cycle development, ostensibly the case in Iran. Assurance of sufficient supply, beyond that available through the normal market, can be strengthened through additional agreements, including by supplier and government consortia and through the IAEA.

As the 2005 IAEA report noted, the advantages and disadvantages of either converting a national facility to an international facility or to building a new multi-nationally managed facility will vary depending on the type of facility being discussed (enrichment, reprocessing, etc.). The advantages of converting an existing facility to multi-national ownership include lower capital investment required, no further dissemination of facility construction know-how, strengthened proliferation resistance due to multi-national management and operating teams, and pooled expertise and resources. Disadvantages include the potential need for additional facilities in politically diverse countries to provide adequate assurance that fuel supplies will not be withheld for ideological reasons, the need to balance existing property rights, potential proliferation risks due to an increased number of international partners, added international management demands, and the potential need to back-fit safeguards depending on the host nation's prior approach.

The advantages to building a new fuel cycle facility under multi-national controls include the ability to incorporate safeguards during construction instead of back-fitting these controls, the ability to pool expertise and resources, the ability to size the facility economically, and the opportunity to strengthen proliferation safeguards. The disadvantages of building new facilities include potentially higher proliferation risks due to broader access to know-how (depending on the management model chosen), uncertain commercial competitiveness, and potential for breakout and retention of fissile materials.

Regardless of the advantages and disadvantages of each of these options, it is clear that cross-cutting technical, legal, cultural, political and financial factors will affect perceptions about their relative feasibility and desirability. These factors may be decisive in any future multilateral or unilateral efforts to develop multi-national fuel cycle facilities.

Longer term, the United States should support the use of multi-national fuel-cycle facilities, under comprehensive IAEA safeguards, as a way to give more countries reliable access to the benefits of nuclear power while simultaneously reducing proliferation risks. We note that the term "multi-national fuel cycle facility" is commonly understood to encompass facilities associated with all aspects of the nuclear fuel cycle. The Commission wishes to stress that our support for multi-national management of such facilities should not be interpreted as support for additional countries becoming involved in enrichment or reprocessing facilities, but rather reflects our view that if these capabilities were to spread it would be far preferable—from a security and non-proliferation standpoint—if they did so under multi-national ownership, management, safeguards, and controls.

The Urenco uranium enrichment facilities—which are owned by the UK, Germany, and the Netherlands—are a long-standing example of facilities under multi-national ownership. Other examples of multi-national approaches to providing fuel supply "assurance" include the IAEA's $150 million fund for uranium purchases,[300] Russia's creation of an International Uranium Enrichment Center,[301] a 120 MT LEU Fuel Bank[302] in Angarsk, and the UK's Nuclear Fuel Assurance Plan.[303] The latter is basically a bilateral agreement that is supposed to serve as a model for government-to-government arrangements between supplier and recipient states, where the supply of low enriched uranium is not disrupted for non-commercial (political) reasons.

Although discussions of multi-national facilities and fuel services typically focus on securing enrichment and reprocessing facilities, the same concepts can be applied to the disposal of spent fuel and HLW. All countries with nuclear power will have to store SNF and HLW for some period of time and ultimately provide for disposal (internally or multi-nationally) of the spent fuel or of the high-level radioactive waste components that remain if the spent fuel is reprocessed. Spent fuel contains approximately 1 percent plutonium and the self-protecting nature of the radioactivity will diminish over time making the plutonium more accessible. Thus, it is in the best interests of the United States and the international community to have spent fuel under effective and transparent control and to assure that in the coming century no spent fuel becomes "orphaned" anywhere in the world with inadequate safeguards and security.

Fuel "take-away" arrangements[304] would allow countries, particularly those with relatively small national programs, to avoid the very costly and politically difficult step of providing for waste disposal on their soil and to reduce associated safety and security risks. Fuel take-away could also provide a strong incentive for emerging nuclear nations to take key actions, such as ratifying the IAEA Additional Protocol, that can strengthen the non-proliferation regime and further isolate the currently small number of problem states. The United States has implemented a relatively small but successful initiative to ship spent foreign research reactor fuel to U.S. facilities for storage and disposal. This program has demonstrated meaningful non-proliferation and security benefits. ***A similar capability to accept spent fuel from foreign commercial reactors, in cases where the President would choose to authorize such imports for reasons of U.S. national security, would be desirable within a larger policy framework that creates a clear path for the safe and permanent disposition of U.S. spent fuel.*** Unfortunately, the failure to develop broadly-accepted domestic spent fuel storage and disposal strategies thus far limits U.S. non-proliferation policy choices.

The Commission believes the availability of spent fuel take-away would provide substantially greater incentives for some emerging nuclear nations to forgo the indigenous development of sensitive fuel-cycle facilities in return for access to regional or international facilities. In that context, government support for limited fuel supply and take-away initiatives to advance U.S. national security interests can be part of a comprehensive strategy for maintaining the nuclear energy option while simultaneously addressing proliferation and security concerns.

12.3 SECURITY AND COUNTER-TERRORISM

As stated in a communiqué issued by the Washington Nuclear Summit on April 13, 2010, "Nuclear terrorism is one of the most challenging threats to international security, and strong nuclear security measures are the most effective means to prevent terrorists, criminals, or other unauthorized actors from acquiring nuclear materials…Success will require responsible national actions and effective international cooperation."[305] To date, the United States has worked to enhance global capacity to prevent, detect, and respond to nuclear terrorism by conducting multilateral activities aimed at strengthening the operations, plans, policies, procedures, and interoperability of partner nations through a variety of activities. Most recently, these activities have included the 2010 Nuclear Summit, the Nunn-Lugar Cooperative Threat Reduction Program, the Global Threat Reduction Initiative, and the Global Initiative to Combat Nuclear Terrorism.

Held in April 2010 and attended by 47 nations, the U.S.-hosted 2010 Nuclear Security Summit was launched with the goal of securing all vulnerable nuclear material worldwide within four years. Other efforts since that time have included

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signing a plutonium disposition protocol with Russia,[306] returning Russian origin high-enriched uranium (HEU) back to Russia,[307] converting the Kyoto University research reactor in Japan from HEU to low-enriched uranium (LEU), and pursuing ratification to an amendment of the Convention on Physical Protection of Nuclear Materials that would extend and strengthen the Convention's coverage of peaceful nuclear material in storage or use at domestic nuclear facilities, rather than merely in international transit. In preparation for the next summit, some U.S. experts are proposing the development of an international "nuclear material security framework agreement [that] would identify the threats to humankind from vulnerable fissile and radiological materials…and list actions and commitments required to mitigate them."[308]

The domestic division of regulatory responsibility for nuclear security and counter-terrorism is discussed in chapters 5 and 9 of this report; those chapters also describe security measures implemented at U.S. reactor sites following 9/11. As the United States continues to improve its ability to secure and protect nuclear facilities and materials, the Commission urges continued U.S. leadership to improve nuclear security and strengthen nuclear safety standards worldwide. Reviews conducted post-Fukushima will undoubtedly examine the safety and security benefits that could be achieved by improving instrumentation to measure key plant safety parameters including pool water levels under conditions of station blackout and severe damage, reviewing and strengthening procedures for connecting portable pumps and power supplies, and potentially accelerating the transfer of SNF out of reactor pools and into dry storage. The Commission urges that these reviews be completed expeditiously and that unclassified results be widely shared with regulators and other appropriate entities around the world.

Finally, the Commission finds that is important for the U.S. government to continue to support the IAEA's physical protection programs as well as efforts by the WINS to promote global best practices regarding nuclear security. Overall, the physical protection of nuclear material and facilities to deter terrorist activity remains a very high priority in today's security environment as the potential theft and sabotage of nuclear materials and facilities continues to be a real threat.[309] Furthermore, the theft of weapons-usable material or any act of nuclear-related sabotage or terrorism anywhere in the world could create real consequences here in the United States, particularly if it leads to a detonation or large release of radioactivity. For this reason, the United States has a direct interest in encouraging and enabling all nations to uphold their national and international obligations for the security and safety of nuclear materials and facilities.

13. NEAR-TERM ACTIONS

The Commission recognizes that it will take time, commitment to action, and new authorizing legislation to implement our most important recommendations, particularly the recommendation to establish a new waste management organization.

Given uncertainty about how long that might take and the fact that under current law DOE remains responsible for the nuclear waste management activities of the federal government, it is important that those steps that do not require the new organization to be in place be initiated as soon as possible. Specifically, the Commission urges near-term action in the areas described below. To ensure continued progress, we also urge the Secretary of Energy to task a senior official with sufficient authority to coordinate all of the DOE elements involved in the implementation of the Commission's recommendations.

Financing the Waste Program

- DOE should offer to enter into negotiations with contract holders to revise current contracts to provide a new fee payment option in which payments to the Waste Fund each year would be based on actual appropriations from the Waste Fund, with the remainder of the nuclear waste fee being placed in a third-party escrow account by the contract holder until needed.
- The Administration should work with the appropriate congressional committees and the Congressional Budget Office to reclassify receipts from the nuclear waste fee as discretionary offsetting collections and allow them to be used to offset appropriations for the waste program.
- The Administration, DOE, and DOJ should also work with nuclear utilities and other stakeholders toward a fair resolution of outstanding litigation and damage claims.

Establishment of a New Organization

- The appropriate congressional committees should begin hearings on establishment of an independent waste management organization as soon as practicable. The Commission recognizes that there are many details that need to be worked out in creating a new institution, and believes that the sooner the process of obtaining the views of interested parties and developing a detailed legislative proposal can begin, the better.

Storage

- Using existing authority in the NWPA, DOE should begin laying the groundwork for implementing consolidated storage and for improving the overall integration of storage as a planned part of the waste management system without further delay. Specific steps that DOE could take in the near term include:
  - Performing the systems analyses and design studies needed to develop a conceptual design for a highly flexible, initial federal spent fuel storage facility.
  - Preparing to respond to requests for information from communities, states, or tribes that might be interested in learning more about hosting a consolidated storage facility.
  - Working with nuclear utilities, the nuclear industry, and other stakeholders to promote the better integration of storage into the waste management system, including standardization of dry cask storage systems. This effort should include development of the systems analyses needed to provide quantitative estimates of the system benefits of utility actions such as the use of standardized storage systems or agreements to deliver fuel outside the current OFF priority ranking. (These analyses would be needed to support the provision of incentives to utilities to undertake actions such as using standardized storage systems or renegotiating fuel acceptance contracts.)
- The Administration should request, and Congress should provide funding for, the National Academy of Sciences to conduct an independent investigation of the events at Fukushima and their implications for safety and security requirements at SNF and HLW storage sites in the United States.
- DOE, NRC and industry should continue a vigorous research and regulatory oversight effort in areas such as spent fuel and storage system degradation phenomena, vulnerability to sabotage and terrorism, and others.

Transportation

- DOE should complete the development of procedures and regulations for providing technical assistance and funds (pursuant to section 180 (c) of the NWPA), and begin providing funding, for working with states and regional state-government groups and training local and tribal officials in areas likely to be traversed by spent fuel shipments, in preparation for movement of spent fuel from shutdown reactor sites to consolidated storage.
- DOE and other federal agencies should reexamine and address those recommendations from the 2006 NAS *Going the Distance* study that have not yet been implemented. As a part of this reexamination, the NRC should reassess its plans for the Package Performance Study without regard to the status of the Yucca Mountain project, and if it is found to have independent value, funding should be provided from the Nuclear Waste Fund so that the NRC can update these plans and proceed with those tests.

Disposal

- DOE should keep a repository program moving forward through valuable, non-site specific activities, including R&D on geological media, work to design improved engineered barriers, and work on the disposal requirements for advanced fuel cycles. The work of the Used Fuel Disposition Campaign of DOE's Office of Used Nuclear Fuel Disposition Research and Development in this area should be continued.
- DOE should develop an RD&D plan and roadmap for taking the borehole disposal concept to the point of a licensed demonstration.

Facility Siting

- To ensure that future siting efforts are informed by past experience, DOE should build a data base of the experience that has been gained and relevant documentation produced in efforts to site nuclear waste facilities, in the United States and abroad. This would include storage facility and repository siting efforts under the NWPA by both DOE and the Nuclear Waste Negotiator.

Regulatory Actions

- EPA and the NRC should work together to define an appropriate process (with opportunity for public input) for developing a generic safety standard for geologic disposal sites. The implementation of this standard-setting process should be coordinated with the aim of developing draft regulations for mined repositories and deep borehole facilities.

- The NRC should continue efforts to review and potentially revise the existing waste classification system.
- A portion of federal nuclear energy RD&D resources should be directed to the NRC to accelerate the development of a regulatory framework and to support anticipatory research for novel components of advanced nuclear energy systems. An increased degree of confidence that new systems can be successfully licensed is important for lowering barriers to commercial investment.

Occupational Safety and Health for the Nuclear Workforce

- The jurisdictions of safety and health agencies should be clarified and aligned. New site-independent safety standards should be developed by the safety and health agencies responsible for protecting nuclear workers through a coordinated joint process that actively engages and solicits input from all relevant constituencies. Efforts to support uniform levels of safety and health in the nuclear industry should be undertaken with federal, industry, and joint labor–management leadership. Safety and health practices in the nuclear construction industry should provide a model for other activities in the nuclear industry.

Nuclear Workforce Development

- DOE, in cooperation with the U.S. Department of Labor and the Bureau of Labor Statistics, should lead a public–private initiative to develop ongoing labor demand projections and forecast capacity for the nuclear workforce, in areas including science, technology, engineering and mathematics; crafts; and emergency response and hazardous material (HAZMAT). This capacity will help inform expanded federal, joint labor–management, and university-based support for critical high-skill, high-performance nuclear workforce development needs, including special attention to the expansion of the emergency response and HAZMAT-trained workforce.

International

- DOE should identify any legislative changes needed to authorize and direct the U.S. waste management program to support countries that pursue nuclear technologies in developing capacity for the safe management of the associated radioactive wastes and to encourage broad adherence to strengthened international norms for safety, security, and non-proliferation for all nuclear infrastructure and materials.

APPENDIX A

BRC COMMISSIONERS, STAFF, SENIOR CONSULTANTS AND CHARTER

The members of the Blue Ribbon Commission on America's Nuclear Future are:

Lee H. Hamilton, Co-Chair - Director of The Center on Congress at Indiana University; former Member, U.S. House of Representatives (D-IN).

Brent Scowcroft, Co-Chair - President of the Scowcroft Group; former National Security Advisor to Presidents Gerald Ford and George H.W. Bush.

Mark H. Ayers, President, Building and Construction Trades Department, AFL-CIO.

Vicky A. Bailey, Former Commissioner, Federal Energy Regulatory Commission; former Indiana PUC Commissioner; former DOE Assistant Secretary for Policy and International Affairs.

Albert Carnesale, Chancellor Emeritus and Professor, University of California, Los Angeles.

Pete V. Domenici, Senior Fellow, Bipartisan Policy Center; former U.S. Senator (R-NM).

Susan Eisenhower, President, Eisenhower Group, Inc.

Chuck Hagel, Distinguished Professor at Georgetown University and the University of Nebraska at Omaha; former U.S. Senator (R-NE).

Jonathan Lash, President, Hampshire College; former President, World Resources Institute.

Allison M. Macfarlane, Associate Professor of Environmental Science and Policy, George Mason University.

Richard A. Meserve, President, Carnegie Institution for Science and Senior Counsel, Covington & Burling LLP; former Chairman, U.S. Nuclear Regulatory Commission.

Ernest J. Moniz, Professor of Physics and Cecil & Ida Green Distinguished Professor, Massachusetts Institute of Technology.

Per Peterson, Professor and Chair, Dept. of Nuclear Engineering, Univ. of California – Berkeley.

John Rowe, Chairman and Chief Executive Officer, Exelon Corporation.

Phil Sharp, President, Resources for the Future; former Member, U.S. House of Representatives (D-IN).

BRC Staff

John Kotek – *Staff Director*

Matthew Milazzo – *Deputy Director, Staff Liaison to the Reactor and Fuel Cycle Technology Subcommittee*

Tom Isaacs – *Lead Advisor*

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Marika Tatsutani – *Lead Writer and Editor*

Mary Woollen – *Government and Community Liaison*

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Department of Energy
Washington, DC 20585

Blue Ribbon Commission on America's Nuclear Future
U.S. Department of Energy

Advisory Committee Charter

1. **Committee's Official Designation.** Blue Ribbon Commission on America's Nuclear Future (the Commission).

2. **Authority.** The Commission is being established in accordance with the provisions of the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App. 2, and as directed by the President's Memorandum for the Secretary of Energy dated January 20, 2010: Blue Ribbon Commission on America's Nuclear Future. This charter establishes the Commission under the authority of the U.S. Department of Energy (DOE).

3. **Objectives and Scope of Activities.** The Secretary of Energy, acting at the direction of the President, is establishing the Commission to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities. Specifically, the Commission will provide advice, evaluate alternatives, and make recommendations for a new plan to address these issues, including:

   a) Evaluation of existing fuel cycle technologies and R&D programs. Criteria for evaluation should include cost, safety, resource utilization and sustainability, and the promotion of nuclear nonproliferation and counter-terrorism goals.

   b) Options for safe storage of used nuclear fuel while final disposition pathways are selected and deployed;

   c) Options for permanent disposal of used fuel and/or high-level nuclear waste, including deep geological disposal;

   d) Options to make legal and commercial arrangements for the management of used nuclear fuel and nuclear waste in a manner that takes the current and potential full fuel cycles into account;

   e) Options for decision-making processes for management and disposal that are flexible, adaptive, and responsive;

   f) Options to ensure that decisions on management of used nuclear fuel and nuclear waste are open and transparent, with broad participation;

g) The possible need for additional legislation or amendments to existing laws, including the Nuclear Waste Policy Act of 1982, as amended; and

h) Any such additional matters as the Secretary determines to be appropriate for consideration.

The Commission will produce a draft report to the Secretary and a final report within the time frames contained in paragraph 4.

4. **Description of Duties.** The duties of the Commission are solely advisory and are as stated in Paragraph 3 above.

   A draft report shall be submitted within 18 months of the date of the Presidential memorandum directing establishment of this Commission; a final report shall be submitted within 24 months of the date of that memorandum. The reports shall include:

   a) Consideration of a wide range of technological and policy alternatives, and should analyze the scientific, environmental, budgetary, financial, and management issues, among others, surrounding each alternative it considers. The reports will also include a set of recommendations regarding policy and management, and any advisable changes in law.

   b) Recommendations on the fees currently being charged to nuclear energy ratepayers and the recommended disposition of the available balances consistent with the recommendations of the Commission regarding the management of used nuclear fuel; and

   c) Such other matters as the Secretary determines to be appropriate.

5. **Official to Whom the Committee Reports.** The Commission reports to the Secretary of Energy.

6. **Agency Responsible for Providing the Necessary Support.** DOE will be responsible for financial and administrative support. Within DOE, this support will be provided by the Office of the Assistant Secretary for Nuclear Energy or other Departmental element as required. The Commission will draw on the expertise of other federal agencies as appropriate.

7. **Estimated Annual Operating Cost and Staff Years.** The estimated annual operating cost of direct support to, including travel of, the Commission and its subcommittees is $5,000,000 and requires approximately 8.0 full-time employees.

8. **Designated Federal Officer.** A full-time DOE employee, appointed in accordance with agency procedures, will serve as the Designated Federal Officer

(DFO). The DFO will approve or call all of the Commission and subcommittee meetings, approve all meeting agendas, attend all Commission and subcommittee meetings, adjourn any meeting when the DFO determines adjournment to be in the public interest. Subcommittee directors who are full-time Department of Energy employees, as appointed by the DFO, may serve as DFOs for subcommittee meetings.

9. **Estimated Number and Frequency of Meetings.** The Commission is expected to meet as frequently as needed and approved by the DFO, but not less than twice a year.

   The Commission will hold open meetings unless the Secretary of Energy, or his designee, determines that a meeting or a portion of a meeting may be closed to the public as permitted by law. Interested persons may attend meetings of, and file comments with, the Commission, and, within time constraints and Commission procedures, may appear before the Commission.

   Members of the Commission serve without compensation. However, each appointed non-Federal member may be reimbursed for per diem and travel expenses incurred while attending Commission meetings in accordance with the Federal Travel Regulations.

10. **Duration and Termination.** The Commission is subject to biennial review and will terminate 24 months from the date of the Presidential memorandum discussed above, unless, prior to that time, the charter is renewed in accordance with Section 14 of the FACA.

11. **Membership and Designation.** Commission members shall be experts in their respective fields and appointed as special Government employees based on their knowledge and expertise of the topics expected to be addressed by the Commission, or representatives of entities including, among others, research facilities, academic and policy-centered institutions, industry, labor organizations, environmental organizations, and others, should the Commission's task require such representation. Members shall be appointed by the Secretary of Energy. The approximate number of Commission members will be 15 persons. The Chair or Co-Chairs shall be appointed by the Secretary of Energy.

12. **Subcommittees.**

    a) To facilitate functioning of the Commission, both standing and ad hoc subcommittees may be formed.

    b) The objectives of the subcommittees are to undertake fact-finding and analysis on specific topics and to provide appropriate information and recommendations to the Commission.

c) The Secretary or his designee, in consultation with the Chair or Co-Chairs, will appoint members of subcommittees. Members from outside the Commission may be appointed to any subcommittee to assure the expertise necessary to conduct subcommittee business.

d) The Secretary or his designee, in consultation with the Chair or co-Chairs will appoint Subcommittees.

e) The DOE Committee Management Officer (CMO) will be notified upon establishment of each subcommittee.

13. Recordkeeping. The records of the Commission and any subcommittee shall be handled in accordance with General Records Schedule 26, Item 2 and approved agency records disposition schedule. These records shall be available for public inspection and copying, subject to the Freedom of Information Act, 5 U.S.C. 552.

14. Filing Date.

Date filed with Congress: _____March 1, 2010__________

Signed
____
Carol A. Matthews
Committee Management Officer

APPENDIX B

FULL COMMISSION, SUBCOMMITTEE AND REGIONAL COMMENT MEETINGS

March 25 & 26, 2010 – Washington DC – Full Commission Meeting
May 25 & 26, 2010 – Washington, DC – Full Commission Meeting
July 7, 2010 – Washington, DC – Disposal Subcommittee Meeting
July 12 & 13, 2010 – Idaho Falls, ID – Reactor & Fuel Cycle Technologies Subcommittee Meeting
July 14 & 15, 2010 – Hanford Site/Kennewick, WA – Full Commission Meeting
August 10, 2010 – Maine Yankee Site/Wiscasset, ME – Transportation & Storage Subcommittee Meeting
August 19, 2010 – Washington, DC – Transportation & Storage Subcommittee Meeting
August 30 & 31, 2010 – Washington, DC – Reactor & Fuel Cycle Technologies Subcommittee Meeting
September 1, 2010 – Washington, DC – Disposal Subcommittee Meeting
September 21 & 22, 2010 – Washington, DC – Full Commission Meeting
September 23, 2010 – Washington, DC – Transportation & Storage Subcommittee Meeting
October 12, 2010 – Washington, DC – Reactor & Fuel Cycle Technologies Subcommittee Meeting
October 21 & 22, 2010 – Finland – Disposal Subcommittee Site Visits and Meetings
October 23-26, 2010 – Sweden – Disposal Subcommittee Site Visits and Meetings
November 2, 2010 – Chicago, IL – Transportation & Storage Subcommittee Meeting
November 4, 2010 – Washington, DC – Disposal Subcommittee Meeting
November 15 & 16, 2010 – Washington, DC – Full Commission Meeting
January 6 & 7, 2011 – Aiken, SC and Augusta, GA – Savannah River Site Visit and Meeting
January 26, 27 & 28, 2011 – Carlsbad and Albuquerque, NM – Waste Isolation Pilot Plant Site Visit and Meetings
February 1 & 2, 2011 – Washington, DC – Full Commission Meeting
February 3, 2011 – Washington, DC – Classified (Closed) Meeting
February 8-11, 2011 – Japan – Site Visits and Meetings
February 17 & 18, 2011 – Russia – Meetings
February 20, 21 & 22, 2011 – France – Site Visits and Meetings
May 13, 2011 – Washington, DC – Full Commission Meeting
June 21-28, 2011 – United Kingdom and France – Site Visits and Meetings
September 12, 2011 – Denver, CO – Regional Public Meeting
October 12, 2012 – Boston, MA – Regional Public Meeting
October 18, 2011 – Atlanta, GA – Regional Public Meeting
October 20, 2011 – Washington, DC – Regional Public Meeting
October 28, 2011 – Minneapolis, MN – Regional Public Meeting
December 2, 2011 – Washington, DC – Full Commission Meeting

APPENDIX C

STATUS OF NUCLEAR WASTE MANAGEMENT PROGRAMS IN OTHER COUNTRIES

[NOTE: Much of the information herein was derived from a 2009 report of the U.S. Nuclear Waste Technical Review Board (NWTRB) on the status of international repository programs. This appendix may therefore not reflect more recent developments, although we have attempted to update the information below based on information provided to the Commission. For nations covered herein but not covered in the NWTRB report, the information was gathered by BRC staff].

Canada: Canada currently has 18 operating nuclear power plants, which together account for nearly 15% of the country's total electricity production. Responsibility for managing nuclear waste rests with the Nuclear Waste Management Organization (NWMO), a private corporation formed by nuclear plant owners. The Organization's key policies and decisions must be approved by the government, which regulates nuclear waste management activities through the Canadian Nuclear Safety Commission. Similar to the approach taken in the United States, owners of nuclear power plants pay into a Nuclear Fuel Waste Act Trust Fund. Canada does not reprocess commercial used nuclear fuel. The Organization's "Adaptive Phased Management" (APM) plan is guided by five fundamental values: Integrity, Excellence, Engagement, Accountability, and Transparency. It consists of a technical method and a management system. The technical method envisions disposal in an appropriate geologic formation with the option of shallow underground storage at the disposal site. It includes the potential for retrievability, continuous monitoring, flexible design, and an ongoing technical and social research program. The management system calls for collaborative and phased decision making; continuous learning; open, inclusive and transparent engagement; and pursuit of a willing and informed host community in one of the four nuclear provinces. Currently NWMO is in the early stages of the siting phase and a number of communities have expressed interest in learning more about the program in order to inform a decision about their interest in volunteering to host such a facility. The proposed process for selecting a deep geologic repository site does not contain a firm schedule for completing this process or an anticipated start date for repository operations.Canada does not have an independent, centralized interim-storage facility for used nuclear fuel.

Finland: Finland currently has four operating nuclear power plants, which together account for nearly 30% of the country's total electricity production. Responsibility for waste management rests with Posiva Oy, a joint company created by Finland's two nuclear utilities in 1995. The government's Radiation and Nuclear Safety Authority serves as independent regulator. Nuclear power generators pay into a nuclear waste management fund; their annual obligation depends on the gap between estimated waste disposal and plant decommissioning costs and the level of the fund at that point in time. Finland does not reprocess commercial used nuclear fuel. In 2000, the government approved Olkiluoto, a migmatite site in the municipality of Eurajoki, for a deep geologic repository. (Two of Finland's four existing nuclear reactors and a new reactor that is currently under construction are also located at Olkiluoto.) The site was subsequently approved by Finland's Parliament (in 2001) and is currently being characterized at depth using an underground research tunnel known as Onkalo (construction of the tunnel began in 2004). Selection of the Olkiluoto site has the support of the host community, which could have exercised veto power over the government's decision (instead, the Eurajoki Municipal Council approved a positive statement about the site). The community had negotiated a benefits package with Posiva Oy in 1999. Key decisions concerning long-term health and safety requirements, the design of engineered barrier systems, and the methodology to be used for demonstrating compliance with post-closure standards have been taken; details are available from the NWTRB report and other sources. Earlier regulations stipulated that waste emplaced at the site be retrievable in the future; this requirement was lifted in 2008 but Posiva is still obliged to present a plan and cost estimate for waste retrieval when it applies for a license to construct the Olkiluoto repository. The anticipated start date for repository operations is 2020. Finland does not have an independent, centralized interim-storage facility.

France: France has 58 operating nuclear plants, which together account for 76% of the country's total electricity production. A new 1.6 GW plant is currently under construction. Responsibility for managing and disposing of nuclear waste falls to the National Agency for Radioactive Waste Management, a government-owned public service agency which reports to the government's Ministries of Environment, Industry, and Research. France's Nuclear Safety Authority is the independent regulator. In France, all owners of a nuclear license are responsible individually for assessing costs of decommissioning their plants and for the long-term management of the waste and spent fuel—which is not considered "waste" in France. They are also responsible for establishing the necessary financial provisions and for ear-marking the necessary assets for the exclusive coverage of those costs. They are individually responsible for managing those assets, which will be disbursed when the relevant decommissioning and long-term management activities start on an industrial basis. The necessary R&D for long-term waste management is financed through an additional tax on nuclear installations, which is transferred to a fund that goes to the National Waste Agency. France requires reprocessing in the fuel cycle; accordingly, only high-level waste and long-lived intermediate-level waste are authorized for disposal in a deep geologic repository. In 1999, construction began on an underground research facility in argillite rock at a location near the village of Bure in the Meuse area located at the boundary of the Haute-Marne region; the area was subsequently approved for a long-term repository site in 2006. The National Agency has recently identified a 30 square kilometer area to locate the repository. The selection of this area was carried out in consultation with the mayors and authorities from both the Meuse and Haute Marne region. Consultations continue on where to locate surface facilities and the lay-out of the underground facility and its access. Local government in the Meuse and Haute-Marne area have been associated with the site-characterization program in various ways, and both can expect to benefit from a series of measures designed to support their development, funded through a dedicated tax on basic nuclear installations. France has established health and safety requirements for a deep repository site, identified a methodology for demonstrating compliance with post-closure standards, and decided on the design of engineered barrier systems at the site (the plan is to place vitrified waste in stainless steel packages). Current policy stipulates that the repository must be designed to be "reversible" for at least 100 years, a concept that implies technical retrievability. Specific conditions for meeting this requirement will be prescribed by the French Parliament after a license application has been submitted. France currently expects its repository to become operational in 2025. All commercial high level waste is slated for disposal and is stored in a special facility within the spent fuel reprocessing complex at La Hague.

Japan: Japan has 53 nuclear power plants, which prior to the disaster at the Fukushima-Daiichi nuclear power station together account for nearly 25% of the country's total electricity production. In addition, three new nuclear power plants (totaling 3.7 GW) are under construction. The Nuclear Waste Management Organization, a private, non-profit entity formed by nuclear power plant owners, is responsible for waste management. The Nuclear and Industrial Safety Agency, a unit within Japan's Ministry of Economy, Trade, and Industry, is the independent regulator. The Ministry maintains two funds to cover costs associated with radioactive waste management: nuclear power plant owners pay into a High-Level Waste Fund; owners of reprocessing plants and mixed-oxide fuel fabrication plants pay into a TRU Waste Fund. Commercial spent nuclear fuel from Japan has been reprocessed in France and the United Kingdom; in addition, reprocessing takes place in Japan at a small facility in Tokai. A large new reprocessing facility at Rokkasho Village is expected to open in the next few years pending the results of pre-service testing. Two underground research laboratories to investigate deep geologic disposal (in granite and sedimentary rock) are under construction, but no decision has been reached in terms of selecting a site for a long-term repository. Requirements for such a repository (with regard to health and safety, retrievability, design of engineered barriers, etc.) have also not been established. The Nuclear Waste Management Organization has adopted a transparent, voluntary approach to identifying potential sites—thus, both the mayor of the host community and the governor of the prefecture must agree to participate. Localities that agree to be included in an initial survey can receive up to $18 million; if they subsequently agree to participate in surface-based site investigations they can receive up to $65 million. One town (Toyo-cho) initially agreed to participate but later withdrew. The national government has since indicated that it may play a more proactive role in the site selection process going forward. Japan had been constructing an independent, centralized interim-storage facility at Mutsu in Aomori Prefecture but those plans have been put on hold in the aftermath of the March 2011 earthquake and tsunami. Japan has not projected a date for opening a permanent repository.

Russia: Russia currently has 33 nuclear reactors in operation (including a 600 MWe fast breeder reactor) which together account for nearly 16% of the country's total electricity production. Another 9 reactors are under construction (including a 800 MWe fast breeder reactor). Radioactive waste management and spent fuel waste management are divided into two different programs. Radioactive waste management is the responsibility of the newly created federal state enterprise "RosRAO" within the structure of the federal corporation Rosatom (which runs the country's nuclear power complex) and Rosatom itself. The new Federal Law on Radioactive Waste Management (came into force in 2011) establishes a legal framework for radioactive waste management in Russia and requires creation of a unified state system for radioactive waste management. Among other provisions, the law authorizes a single-purpose organization (so-called "national operator" – currently Rosatom) to conduct main activities related to waste management activities (e.g. receiving, storing, securing and disposing of radioactive waste); decision-making regarding siting, construction, commissioning etc. of waste-management facilities remains the responsibility of the Federal Government. The law also establishes a framework for a new funding mechanism (analogous to the Nuclear Waste Fund in the United States). Some federal budget resources have also been allocated for the program (the total for 2016 to 2020 is $13 billion in U.S. dollars). Meanwhile, a system for managing spent nuclear fuel is being developed by Rosatom. It is not clear whether implementing this system will be the responsibility of Rosatom or one of its subsidiaries. The pending Federal Law on Spent Nuclear Fuel Management will provide the legal framework for the national program. As work continues on drafting this legislation, Rosatom has gone ahead with developing plans for the construction and commissioning of an underground rock laboratory by 2015 and a final repository by 2021. Several sites have been proposed as candidates for such a facility, including a granite site on the Kola Peninsula (in the Murmansk region), Krasnokamenks in Chita (4,300 miles east of Moscow), and the Nignekamensk Rock Mass in the Krasnoyarsk Territory of Siberia. Site selection efforts are currently underway on the Kola Peninsula. Russia plans to close its fuel cycle as much as possible and use plutonium in MOX fuel in fast breeder reactors. However, current reprocessing capacities are limited to about 100 metric tons per year. A new reprocessing plant in the city of Zheleznogorsk (in the Krasnoyarsk Territory) is being redesigned from a previous version and is expected to commence operations in the 2025–2030 timeframe.

Although most of Russia's spent nuclear fuel is being stored at reactor sties, there is a centralized interim wet (pool) storage facility located in Zheleznogorsk. Its storage capacity of 7,200 metric tons was recently expanded to 8,600 metric tons, allowing it to safely store/accept spent VVER-1000 (PWR-1000) fuel through 2025. In addition, a dry storage facility for spent RBMK (BWR) fuel with a total capacity of 8,600 metric tons was commissioned in late 2011, also in Zheleznogorsk, with the first SNF is scheduled to arrive in early 2012.

Low-level radioactive wastes and some intermediate-level wastes are processed and stored at 16 sites in Russia (within the structure of the federal state enterprise RosRAO).

Russia currently has a program to "take-back" spent fuel of Russian origin for reprocessing from commercial and research reactors abroad. However, due to limits on available reprocessing capabilities, the spent fuel that has been accepted under this program is being held in wet (pool) storage.

Spain: Spain has eight operating nuclear power plants, which together account for 18% of the country's total electricity production. Management of nuclear waste is the responsibility of the Spanish National Company for Radioactive Waste, a government-owned corporation. The Nuclear Safety Council is the independent regulator, although the Ministry of Industry, Tourism, and Trade is required by law to make a final decision concerning the disposition of used nuclear fuel. Operators of nuclear power plants pay into a nuclear decommissioning fund that was established to cover the costs of both decommissioning plants and managing radioactive waste. Some used nuclear fuel from Spanish reactors has been reprocessed in the past at the La Hague and Sellafield facilities, but current national policy does not contemplate any further reprocessing. No decision has been made regarding a deep geologic repository for high-level waste and used nuclear fuel, but in 2006 Spain initiated a process to site a centralized temporary facility. That process required voluntary participation by potential host communities and resulted in recent selection of a site for a consolidated storage facility in the town of Villar de Cañas, located in the "autonomous community" (the level of government in Spain roughly equivalent to a state) of Castilla la Mancha.

Sweden: Sweden currently has 10 operating nuclear power plants, which together account for 42% of the country's total electricity production. The Swedish Nuclear Fuel and Waste Management Company, a private corporation formed by nuclear power plant owners, is responsible for waste management. The Radiation Safety Authority within Sweden's Ministry of the Environment is the independent regulator. Owners of nuclear power plants pay fees into a nuclear waste fund. The fees vary from year to year and from plant to plant, depending on the estimated costs of disposing of used nuclear fuel and the level of the fund. Small amounts of used nuclear fuel from Swedish reactors have been reprocessed in the past at facilities in France and England (none of the resulting high-level waste was returned to Sweden), but Sweden's current plans do not include reprocessing. In 2001, the government approved a proposal by the Swedish Nuclear Fuel and Waste Management Company to investigate three potential sites for a long-term geologic repository—at Östhammer, Oskarshamn (Oskarshamn was also the site of an underground research laboratory constructed in the early 1990s) and area in the northern part of Tierp. Later, municipal councils in Östhammer and Oskarshamn consented to further investigation, while Tierp opted-out. The site at Östhammer was selected for a repository in 2009. The value of benefits for communities was estimated as $300 million. The local community at Östhammer, which could have vetoed its selection as a geologic repository site, will receive 25% of the benefits. In addition, the community at Oskarshamn, which was *not* selected, will receive about 75% of the benefits for participating in the siting process. A license application for the Östhammer repository was submitted to the Radiation Safety Authority for review in March 2011. Concurrently, Sweden's Environmental Court will rule on the application. Based on the findings of the Safety Authority and the Court, the Swedish government will decide whether to approve the license application. Regular operation of the repository is expected to begin after several years of trial operation. Current plans call for transporting waste to the site using a specially designed ship and for placing used nuclear fuel in a copper canister that has a cast-iron insert for support and is surrounded by bentonite clay. Details concerning safety standards, post-closure compliance demonstration, and other requirements applicable to the Östhammer repository are available from the NWTRB report and other sources. Sweden currently expects to start repository operations in 2023. Sweden also has an independent, centralized interim-storage facility for used nuclear fuel: the CLAB facility, also located in Oskarshamn, was commissioned in 1985.

United Kingdom: The United Kingdom currently has 19 nuclear reactors that together account for one-sixth of the country's electricity generation. In October 2010, the UK government approved the construction of up to eight new nuclear power stations. All nuclear installations in the UK are subject to regulation by the Office for Nuclear Regulation and by environmental authorities. Responsibility for designing and developing a geological disposal facility for higher activity wastes rests with the Nuclear Decommissioning Authority (NDA). The NDA has a baseline disposal plan that envisions first emplacement of legacy intermediate level waste in 2040, emplacement of legacy high level waste and spent fuels in 2075, emplacement of spent fuel from new reactors in 2130, and commencement of facility closure in 2175.

The UK has accumulated a substantial legacy of radioactive waste from a variety of different nuclear programs, both civil and defense-related. For decades, the UK struggled to find a solution to the problem of long-term radioactive waste management. The nearest the UK came was a planning application for a "Rock Characterisation Facility" as the first step towards geological disposal in Cumbria in 1994. The application went to a public inquiry and was rejected in 1997, largely on the basis of the site selection process used and scientific and technical uncertainties at the time.

Recognizing that the existing approach was unworkable, the government undertook a more fundamental review of options for managing radioactive wastes in the long term. In 2001, the UK government initiated the "Managing Radioactive Waste Safely" (MRWS) program, which provided for public consultation on the waste management issue with the goal of finding a practicable solution for the UK's higher activity wastes. The process was designed to work in an open and transparent way that inspired public confidence, was based on sound science, and ensured the effective use of public monies. Having collected feedback from a public consultation process, an independent body, the Committee on Radioactive Waste Management (CoRWM) was set up to recommend specific program options. In July 2006, CoRWM announced an integrated package of recommendations for pursuing geological disposal, coupled with safe and secure interim storage and a program of ongoing research and development. Following publication of a white paper in 2008, the UK government launched a search for an engineered, underground site to serve as a permanent disposal facility for high-level radioactive wastes. The government invited communities across the country to learn more about what it would mean to potentially host this facility. To date, only a group of communities in West Cumbria, near the Sellafield nuclear site in northwest England, have sought to examine the possibility further. They formed a West Cumbria MRWS Partnership, including a range of local stakeholders, to examine the proposal and make recommendations to the local decision-making bodies on whether to proceed further. A comprehensive local consultation is currently underway to gauge public view prior to submission of the final recommendation whether to proceed or not.

The U.K. has taken a noteworthy approach to providing benefits to potential host communities. One element is an "Engagement Package" which Government agrees upon each year to support the running costs of the MWRS partnership, including all the research, project management, consultants, travel expenses, staff time and public engagement work. In 2011 the support costs were approximately 1.2 million pounds. This kind of Engagement Package is anticipated to continue throughout the whole siting process, and be extended to individual host communities as they enter the process actively, to cover their own costs. Note, however, that the definition of Engagement Package does not cover any 'incentive' type payments - only reimbursing actual costs incurred.

A "Community Benefits Package" will only be paid when a host community has passed the time at which it can withdraw from the process (i.e. when a final planning application is submitted for the actual facility to be built). The Community Benefits Package would, however, be agreed upon well before that point.

A site has not yet been selected so there are no specific agreements to date regarding what amount of money or investment any community would receive for hosting the facility, only a promise in the Government's policy that these kinds of benefits be available to the community that finally agrees to host a repository. Recognizing this, but wanting reassurance at the same time, the current partnership has developed a number of principles for community benefit that have been agreed to by the Government, so that the community's understanding of the type and scale of benefits meets their expectation. These principles will form the basis for any future negotiation.

APPENDIX D
BRC COMMISSIONED PAPERS

1. Joe T. Carter et al., *U.S. Radioactive Waste Inventory and Characteristics Related to Potential Future Nuclear Energy Systems, Rev. 2,* May 2011
2. Peter C. Chestnut et al., *The Role of Indian Tribes in America's Nuclear Future*, April 29, 2011
3. Rodney C. Ewing, *Standards & Regulations for the Geologic Disposal of Spent Nuclear Fuel and High-Level Waste*, March 4, 2011
4. Cliff W. Hamal et al., *Spent Nuclear Fuel Management: How Centralized Interim Storage Can Expand Options and Reduce Costs*, May 16, 2011
5. Elizabeth Helvey, *Overview of the Section 180(c) Program: History, Lessons Learned and Potential Next Steps*, April 18, 2011.
6. Joseph S. Hezir, *Budget and Financial Management Improvements to the Nuclear Waste Fund*, May 2011
7. Judith A. Holm*, Innovative Stakeholder Involvement Processes in Department of Energy Programs: A Selective Accounting*, April 2011
8. Hank Jenkins-Smith, *Public Beliefs, Concerns and Preferences Regarding the Management of Used Nuclear Fuel and High-Level Radioactive Waste*, February 2011
9. Andrew C. Klein, *Nuclear Energy R&D Infrastructure Report for The Blue Ribbon Commission on America's Nuclear Future*, March 16, 2011
10. Jim Lieberman et al., *Overview of the Nuclear Regulatory Commission and Its Regulatory Process for the Nuclear Fuel Cycle for Light Water Reactors*, February 25, 2011
11. Richard C. Moore, *Enhancing the Role of State and Local Governments in America's Nuclear Future: An Idea Whose Time Has Come*, May 2011
12. Michael O'Hare et al., *Nuclear Waste Facility Siting and Local Opposition*, January 2011
13. Scott D. Sagan, *The International Security Implications of U.S. Domestic Nuclear Power Decisions*, April 18, 2011
14. Stoneturn Consultants, *From Three Mile Island to the Future: Improving Worker Safety and Health In the U.S. Nuclear Power Industry*, March 14, 2011
15. Eileen M. Supko and Michael H. Schwartz, *Overview of High-Level Nuclear Waste Materials Transportation: Processes, Regulations, Experience and Outlook in the U.S.*, January 2011.
16. Seth P. Tuler and Roger E. Kasperson, *Social Distrust: Implications and Recommendation for Spent Nuclear Fuel and High-Level Radioactive Waste Management*, January 29, 2011
17. Van Ness Feldman, P.C., *Legal Memorandum, Co-Mingled and Defense-Only Repositories*, updated Dec. 9, 2011
18. Van Ness Feldman, P.C., *Federal Commitments Regarding Used Fuel and High-Level Wastes*, August 13, 2010 (revised November 12, 2010)
19. Gary Vine, *Abridged History of Reactor and Fuel Cycle Technologies Development*, March 15, 2011
20. Thomas Webler et al., *Options for Developing Public and Stakeholder Engagement for the Storage and Management of Spent Nuclear Fuel (SNF) and High Level Waste (HLW) in the United States (Updated)*, June 6, 2011
21. Chris Whipple, *Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste,* September 10, 2010
22. Paul P.H. Wilson, *Comparing Nuclear Fuel Cycle Options: Observations and Challenges*, June 25, 2011
23. R.G. Wymer and A.G. Croff, *Current U.S. Department of Energy Nuclear Energy RD&D Programs and Plans*, January 2011
24. Van Ness Feldman, P.C., *Legal Analysis of Commission Recommendations for Near-Term Actions,* July 29, 2011 (revised October 11, 2011).
25. Van Ness Feldman, P.C., *Legal Background and Questions Concerning the Federal Government's Contractual Obligations Under the "Standard Contracts"* with "Utilities," December 20, 2010

These papers are available at www.brc.gov

ENDNOTES

1. The resulting crisis at the Fukushima Daiichi plant was by no means the most tragic aspect of the disaster that occurred in Japan on March 11, 2011: on the contrary, more than 23,000 people were lost and immense damage was caused by the immediate impacts of the earthquake and tsunami.

2. "Spent fuel" is sometimes also referred to as "used fuel." The difference in terminology in fact reflects a profound policy issue as to whether the material should be seen as a waste or a resource. We use the term "spent fuel" in this report, but, as discussed in chapter 11, we believe it is premature to resolve that policy debate.

3. The Nuclear Power Plant Exporters' "Principles of Conduct" are available at http://nuclearprinciples.org/the-principles/.

4. The inter-temporal, inter-generational dimensions of this ethical obligation have long been recognized in the U.S. context and internationally. The 1996 IAEA "Joint Convention on the Safety of Spent Fuel and Radioactive Waste Management," for example, speaks of the need to avoid "compromising the ability of future generations to meet their needs and aspirations." (See http://www.iaea.org/Publications/Documents/Conventions/jointconv.html.) Put another way, plans for geologic disposal must not impose reasonably predictable impacts on future generations that are greater than those permitted for the current generation.

5. The "Open Government Directive" was sent by Peter Orszag to the heads of executive departments and agencies on December 8, 2009. See: http://www.whitehouse.gov/sites/default/files/omb/assets/memoranda_2010/m10-06.pdf.

6. Atoms of a given element, such as uranium, can exist in different forms or "isotopes," depending on the number of neutrons present in the nucleus of the atom. Different elements are distinguished by their unique atomic number, which reflects the number of protons in the atomic nucleus. Uranium has an atomic number of 92, which means that all uranium atoms have 92 protons. A U-235 atom differs from a U-238 atom in that its nucleus holds three fewer neutrons—143 neutrons instead of 146—in combination with 92 protons.

7. Some reactors – such as the CANDU reactors employed in Canada and elsewhere – can use natural uranium as fuel.

8. There have been around 3,300 truck and rail shipments of spent nuclear fuel in the United States since the mid-1960s (firm numbers before that are not available). There have been a very few barge shipments--most notably from Brookhaven National Laboratory and the Shoreham plant, both on Long Island--but they were multimodal shipments that used truck or rail for most of the distance. Information on shipments to date is taken from National Research Council, *Going the Distance? The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States*, Washington, DC: The National Academies Press, 2006. See Table 3.2 on p. 188.

9. The amount of fission products is roughly proportional to the amount of electricity generated, no matter what fuel cycle is used. As a result, any nuclear energy system produces wastes that will require disposal.

10. The figure shows the composition of a standard PWR fuel assembly which achieved a burnup of 33 gigawatts per ton after ten years of cooling. Adapted from "Fuel Cycles for Sustainable Development and Waste Minimization," presentation by M. Salvatories, CAE/DEN Cadarache, France at World Nuclear University Summer Institute 2007(available at: http://www.world-nuclear-university.org/html/summer_institute/2007/2007SI-lecture%20Materials/0725/0725_Massimo%20SALVATORES_1/0725-1-Massimo%20Salvatores.pdf).

11. People are routinely exposed to low levels of radiation in everyday life. These low-level exposures can come from natural sources (e.g., cosmic rays, certain minerals) and from man-made sources (e.g., building materials, medical procedures such as x-rays, certain cancer treatments, etc.).

12. Riley E. Dunlap, Michael E. Kraft and Eugene A. Rosa, eds., *Public Reactions to Nuclear Waste: Citizens' Views of Repository Siting*, Duke University Press, 1993.

13. Half-life is the time required for half of the initial atoms of a given amount of a radionuclide to decay.

14. Weight (e.g., metric tons) is not the best measure of the nuclear waste challenge. However, it is commonly used, including in federal law, so we adopt the same practice for purposes of this report.

15. Sources for the information shown in the figure include the following: U.S. Environmental Protection Agency, "Radiation Health Effects," available at http://www.epa.gov/radiation/understand/health_effects.html and World Nuclear Association, "Nuclear Radiation and Health Effects," available at http://www.world-nuclear.org/info/inf05.html. See also http://www.naturalnews.com/032136_radiation_exposure_chart.html and http://www.informationisbeautiful.net/visualizations/radiation-dosage-chart/.

16. U.S. Department of Energy, "Supplemental Analysis for the U.S. Disposition of Gap Material – Spent Nuclear Fuel," (DOE/EIS-0218-SA-4), January 2009.

17. U.S. Department of Energy, "Draft Environmental Impact Statement (EIS) for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste (LLRW) and GTCC-like Waste" (DOE/EIA-0375D), 2011. More information available at http://www.gtcceis.anl.gov/.

18. John McKenzie, Presentation to the Blue Ribbon Commission on America's Nuclear Future, March 25, 2010, available at http://www.brc.gov/pdfFiles/NR_Briefing_100325.pdf.

19. The Navy has also designed and built large shipping casks that each hold one loaded spent fuel canister and are designed for shipment by rail. The canisters were intended to be transferred at Yucca Mountain into disposal overpacks and then be directly disposed in the repository.

20. More details on the 1995 Agreement and the 2008 modifications to it can be found in a white paper prepared for the BRC by Van Ness Feldman, P.C.: "Federal Commitments Regarding Used Fuel And High-Level Wastes," August 31, 2010 (Revised November 12, 2010). Available at www.brc.gov.

21. There is a similar agreement with the State of Colorado under which Navy SNF has to be moved out of that state by January 1, 2035. The penalty for non-compliance amounts to $15,000 for each day of delay beyond the deadline.

22. United States Government Accountability Office, *DOE NUCLEAR WASTE: Better Information Needed on Waste Storage at DOE Sites as a Result of Yucca Mountain Shutdown*, GAO-11-230, March 2011.

23. See presentation of Susan Burke, Idaho National Laboratory Oversight Coordinator for the State of Idaho, "Idaho's Perspective on the Blue Ribbon Commission Report," available at http://brc.gov/sites/default/files/meetings/presentations/brc_comments_idahos_perspective.pdfIdaho

24. http://www.brc.gov/sites/default/files/comments/attachments/brc_nrcomentletter.pdf

25. The Atomic Energy Commission was the nation's first overarching nuclear regulatory authority. It was established by the Atomic Energy Act of 1946.

26. The National Academy of Sciences (NAS) was established by an Act of Congress in 1863 to provide independent advice to the U.S. government on matters related to science and technology. The National Research Council, which was created in 1916 to extend the scope of the NAS in its advisory role, conducts much of the research and technical analysis, and issues many of the reports released under NAS auspices. Today, the National Research Council is operated collaboratively by the NAS and by the National Academy of Engineering as the working arm of both organizations. (The NAS, the National Academy of Engineering, and the National Research Council—along with the Institutes of Medicine—together comprise the "National Academies.") For simplicity in this report, we use the acronym "NAS" to encompass work that may be undertaken by, or studies that have been issued by, the National Research Council.

27. In 1957, the NAS published *The Disposal of Radioactive Waste on Land* (Washington, DC: The National Academies Press). This report recommended geological disposal and specifically recommended disposal in cavities mined in salt beds or domes.

28. ERDA, along with the newly formed NRC, took the place of the AEC in 1975. Soon after, in 1977, the functions and responsibilities of ERDA were assumed by the newly formed DOE.

29. A statement by Representative Morris Udall of Arizona, on the floor of the House of Representatives in 1987, summed up the general mood of dismay. Referring to the site selection process in the original NWPA, Representative Udall said, "We created a principled process for finding the safest, most sensible place to bury these dangerous wastes. Today, just 5 years later, this great program is in ruins. Potential host states no longer trust the technical integrity of the Department of Energy's siting decisions."

30. By 1989, DOE was relying on the Negotiator to find an MRS site, with linkages to the repository removed. According to a DOE report to Congress in 1989 concerning the schedule for an MRS facility: "[T]he reference schedule for the MRS facility assumes that (1) a site will be obtained through the efforts of the Nuclear Waste Negotiator and (2) the statutory linkages specified in the Nuclear Waste Policy Amendments Act between the MRS facility and the repository (see Section 4) are modified" (U.S. Department of Energy, *Reassessment of the Civilian Radioactive Waste Management Program: Report to the Congress by the Secretary of Energy*, November 29, 1989, DOE-RW-0247).

31. Keith Schneider, "Grants Open Doors for Nuclear Wastes," *New York Times*, January 9, 1992, available at http://www.nytimes.com/1992/01/09/us/grants-open-doors-for-nuclear-waste.html?scp=2&sq=Office+of+the+nuclear+waste+negotiator&st=cse&pagewanted=print.

32. Several organizations that commented on the BRC Disposal Subcommittee's draft report have pointed out that the Yucca Mountain site was ranked first among candidate sites in the DOE assessments that led up to the 1987 Amendments.

33. See MSNBC, "Store Nuclear Waste on Reservation? Tribe Split," June 26, 2006, accessible at http://www.msnbc.msn.com/id/13458867/.

34. Governor Gary R. Herbert, State of Utah, letter to the Blue Ribbon Commission on America's Nuclear Future, September 13, 2011. Available at www.brc.gov.

35. Richard B. Stewart, "Solving the US Nuclear Waste Dilemma," *Environmental Law and Policy Review* (forthcoming, 2011). See http://www.brc.gov/sites/default/files/meetings/attachments/stewart_elpar_article.pdf.

36. Massachusetts Institute of Technology, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT Study*, Cambridge, MA, 2011, p. 4.

37. See description in Luther J. Carter, *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste*, Washington, D.C.: Resources for the Future, 1987, pp. 84-89.

38. E. Michael Blake, "Where new reactors can (and can't) be built," *Nuclear News*, November 2006, pp. 23-25. Other states, such as Minnesota, have adopted moratoria on new nuclear reactors, but these moratoria are not necessarily tied to the waste issue.

39. U.S. Nuclear Regulatory Commission, 42 FR 34391, July 5, 1977.

40. "Waste Confidence and Waste Challenges: Managing Radioactive Materials," Remarks Prepared for NRC Chairman Dale E. Klein, Waste Management Symposium, Phoenix, Arizona, February 25, 2008.

41. At an August 22, 2007 briefing to the Nuclear Regulatory Commission on new reactor issues ((the briefing was attended by all four NRC commissioners), Marvin Fertel of NEI called for the NRC to reaffirm the waste confidence decision:

> "[W]e believe that it would be prudent and reasonable for NRC to consider reaffirming their waste confidence position that they currently have in rulemaking…The thing that we think would be harmful to decision-making at the companies and then to the licensing process themselves is to have this [uncertainty about when and whether Yucca Mountain would be licensed] become an issue in individual proceedings. We think it would delay proceedings. We think the potential for that could actually impact decision-making by corporate boards… So our recommendation would be for the Commission to look at going forward to update the rulemaking and to have that behind us as soon as possible as this licensing process begins and particularly as the companies make decisions. [F]irm decisions [about moving ahead with new reactors] are still being discussed and evaluated at the Board level. So anything we can do from our standpoint to relieve what people perceive as risks, we think is important and that's one that we do perceive as a risk." In a September 7, 2007 follow-up memo (SRM M070822) on the meeting to the Executive Director for Operations and the General Counsel, the secretary of the Commission reported that the Commission agreed: " The Commission agreed with the nuclear industry view that it was appropriate to update the NRC's waste confidence findings in the near term. Accordingly, the staff should include waste confidence in its proposal to the Commission regarding potential rulemaking to resolve issues that are generic to COL applications, as required by the Staff Requirements Memorandum to COMDEK-07-0001/COMJSM-07-0001." See http://pbadupws.nrc.gov/docs/ML0724/ML072400432.pdf,

42. U.S. Nuclear Regulatory Commission news release No. 10-162, September 15, 2010.

43. Testimony of Jack Spencer, The Heritage Foundation, before the Subcommittee on Energy and Power, Committee on Energy and Commerce, United States House of Representatives, June 3, 2011, http://www.heritage.org/research/testimony/2011/06/the-american-energy-initiative.

44. The NWTRB report presents all of its country-specific information in tables, using alphabetical groupings of three countries at a time.

45. Most ratepayers are, of course, also taxpayers (and vice versa). For clarity, we refer to taxpayers and ratepayers as distinct groups here and in the main body of the report.

46. Spent nuclear fuel and other high-level radioactive waste often also contains toxic or hazardous chemicals, but these are not primary drivers of the disposal concerns and issues that are the subject of the Blue Ribbon Commission's work.

47. In the past, a number of concepts have been advanced periodically in hopes of eliminating the need for long-term nuclear waste disposal options (including permanent repositories). One program at Los Alamos National Laboratory, for example, focused on accelerator-driven systems for transmuting waste; it eventually evolved into a more comprehensive effort known as the Advanced

Fuel Cycle Initiative. Advanced fuel cycle technologies are discussed in chapter 11 of this report.

48. An international review of options for disposal of high-level waste and spent fuel conducted by the National Academy of Sciences specifically examined technologies for separating out and transmuting long-lived radionuclides to produce wastes that have shorter half-lives and that therefore pose less of a challenge for long term disposal. The NAS study concluded that "this option should be considered a supplement to, but not a substitute for, continued surface storage or geological disposition." It also concluded that "Geological disposition followed by closing the repository (geological disposal) is nevertheless the only permanent and final solution to the waste problem." National Research Council, *Disposition of High-Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges*, Washington DC: The National Academies Press, 2001, Chapter 7.

49. For example, see endnotes 52, 53 and 56

50. According to a report issued by the OECD's Nuclear Energy Agency (NEA) in 2008 and titled *Moving Forward with Geological Disposal of Radioactive Waste*:

> "The overwhelming scientific consensus world-wide is that geological disposal is technically feasible. This is supported by the extensive experimental data accumulated for different geological formations and engineered materials from surface investigations, underground research facilities and demonstration equipment and facilities; by the current state-of-the-art in modeling techniques; by the experience in operating underground repositories for other classes of waste; and by the advances in best practice for performing safety assessments of potential disposal systems." See p. 7 of report available at: http://www.oecd-nea.org/rwm/reports/2008/nea6433-statement.pdf and http://www.oecd-nea.org/rwm/documents/FSC_moving_flyer_A4.pdf.

51. On July 19, 2011 the European Commission adopted the "radioactive waste and spent fuel management directive" that had been proposed by the Commission for the European Union on November 3, 2010. That directive supports disposal as the necessary long-term end point for radioactive waste:

> "Temporary storage is an important stage in the overall management of radioactive waste, in particular for spent fuel and HLW, allowing effective cooling and radiation levels to decrease thereby making handling safer. However, there is also a broad consensus that storage of spent fuel and radioactive waste, including long-term storage, is only an interim solution requiring active and permanent institutional controls. In the longer term, only disposal with its inherent passive safety characteristics can guarantee protection against all potential hazards."
>
> See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52010PC0618:EN:HTML:NOT.

52. Massachusetts Institute of Technology, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT Study*, Cambridge, MA, 2011, p. 59.

53. The description in this paragraph is adapted from U.S. Department of Energy, *Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste*, Volume 1, October 1980, DOE/EIS-0046F Volume 1 of 3 UC-70.

54. International Atomic Energy Agency, *Scientific and Technical Basis for Geological Disposal of Radioactive Wastes*, Vienna, 2003.

55. Nuclear Waste Technical Review Board, *Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel: A Report to Congress and the Secretary of Energy*, Washington DC, October 2009, available at http://www.nwtrb.gov/reports/reports.html.

56. A similar conclusion is reached in several submissions made to the BRC (e.g. Hansen, et. al, *Geologic Disposal Options in the USA*, SAND2010-7975C).

57. For a description of different borehole disposal concepts, see Fergus Gibb, "Deep borehole disposal (DBD) methods," *Nuclear Engineering International*, March 25, 2010, at http://www.neimagazine.com/story.asp?storyCode=2055862. See also: Patrick V. Brady, Bill W. Arnold, Geoff A. Freeze, Peter N. Swift, Stephen J. Bauer, Joseph L. Kanney, Robert P. Rechard, Joshua S. Stein, *Deep Borehole Disposal of High-Level Radioactive Waste*, SAND2009-4401, August 2009, at http://www.mkg.se/uploads/Bil_2_Deep_Borehole_Disposal_High-Level_Radioactive_Waste_-_Sandia_Report_2009-4401_August_2009.pdf. In addition, the Commission received a number of public comments about deep boreholes.

58. Chris Whipple, "Disposal of Spent Nuclear Fuel and High-level Radioactive Waste," ENVIRON International Corporation, September 10, 2010, at http://www.brc.gov/sites/default/files/documents/disposal_of_spent_nuclear_fuel_and_high_level_radioactive_waste_rev4.pdf.

59. EPA's existing disposal standards (40 CFR Part 191) apply to any disposal method for SNF and HLW.

60. It is important to recognize that retrievability is not an absolute or binary characteristic—rather it is a relative one. The question is how easy (or difficult) would it be to retrieve materials from a geologic disposal facility and over what time frame. Wastes that were disposed of geologically could always, if absolutely necessary, be recovered somehow—although different methods of disposal could make it more or less expensive to do so.

61. The OECD/NEA's International Project on Reversibility and Retrievability defines retrievability as "the possibility to reverse the step of waste emplacement" and reversibility as a term that "implies a disposal programme that is implemented in stages and that keeps options open at each stage, and provides the capability to manage the repository with flexibility over time." See: *International Understanding of Reversibility of Decisions and Retrievability of Waste in Geological Disposal* at http://www.oecd-nea.org/rwm/rr/documents/RR_Leaflet.pdf.

62. Specifically, current regulations stipulate that the option of waste retrieval must be preserved throughout the period of waste emplacement and thereafter until the completion of a performance confirmation program and subsequent NRC review.

63. Bill W. Arnold, Peter N. Swift, et al, "Into the Deep," *Nuclear Engineering International*, March 25, 2010. http://www.neimagazine.com/story.asp?storyCode=2055856.

64. U.S. Department of Energy, "Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program, Fiscal Year 2007," (DOE/RW-0591),Washington DC, July 2008.

65. U.S. Department of Energy, "Fiscal Year 2007 Civilian Radioactive Waste Management Fee Adequacy Assessment Report," (DOE/RW-0593), Washington DC, July 2008.

66. Electric Power Research Institute, *Industry Spent Fuel Storage Handbook*, July 2010, available at http://my.epri.com/portal/server.pt?Abstract_id=000000000001021048.

67. The figure is from a presentation to the Blue Ribbon Commission by Dr. John Kessler of EPRI. In his presentation, Dr. Kessler predicted that utilities "will continue with on-site storage on a plant-by-plant basis—barring clear, compelling national guidance."

68. It is worth noting that the NRC's 2010 Waste Confidence finding is being challenged in court by three states; it is also worth noting that the NRC took care to reaffirm as part of this finding its view that final disposal in a mined repository will still be necessary.

69. See study conducted for the BRC by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring and titled "Spent Nuclear Fuel Management: How centralized interim storage can expand options and reduce costs," May 16, 2011, available at http://brc.gov/sites/default/files/documents/centralized_interim_storage_of_snf.pdf. See also Massachusetts Institute of Technology, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT* Study, Cambridge, MA, 2011, p. 50.

70. Derived from U.S. Department of Energy, *Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites* (DOE/RW-0596), December 2008. This table contains updated information from reactor site managers as of January 2012.

71. Nevada Nuclear Waste Task Force, "Comments on the: Transportation and Storage Subcommittee Draft Report to the Full Commission," June 9, 2011.

72. "Because the NWPA required DOE to enter into contracts with the owners and generators of SNF, rather than merely create a statutory program, changes in the program, even if directed by a statutory change, can potentially cause further breaches of contract, which then can create additional monetary liability." Statement of Michael F. Hertz, Deputy Assistant Attorney General Civil Division, before the Blue Ribbon Commission on America's Nuclear Future, February 2, 2011, pp. 10-11.

73. Van Ness Feldman P.C., "Legal Background and Questions Concerning the Federal Government's Contractual Obligations Under the 'Standard Contracts' with 'Utilities,'" Memorandum prepared for the BRC, revised Dec. 20, 2010, at pp. 22-23.

74. In March, 2011, the Department of Justice offered all remaining SNF litigants a New Framework settlement agreement that would be applicable to the 78 nuclear power reactors covered by a Standard Contract that had not previously entered into a settlement agreement. Under this framework, which uses a higher acceptance rate for determining the government's performance liability than has been used in previous settlements, there is no "crossover point" at which the government will have caught up with its acceptance obligations. Rather, the government's liability for spent nuclear fuel storage costs will continue until the spent fuel is removed from reactor sites covered by a

New Framework settlement agreement. As of October 6, 2011, eight utilities have accepted the New Framework settlement agreement. See memorandum provided by David K. Zabransky, Director, Office of Standard Contract Management Office of General Counsel, to Steve Isakowitz, Chief Financial Officer, DOE on October 26, 2011 and available at http://www.brc.gov/index.php?q=generalcomment/response-brc-request-information.

75. NWPA, Sections 144-149.

76. The regulations cover multiple types of dry cask technologies as well as dry vaults. While no ISFSIs using pools have been proposed, there is little doubt that pools – the storage technology for which there is most experience – would not raise any new technical issues.

77. This would be consistent with common practice in Sweden and France, where fuel is removed from reactor pools within a year after discharge and moved to central pool storage pending later disposition. (In Sweden, the fuel is stored for disposal; in France it is stored for reprocessing.)

78. It is worth noting that nearly 60 percent of the fuel discharged from the six reactors at Fukushima prior to the earthquake and tsunami had already been transferred into a shared pool, leaving relatively small inventories of spent fuel (compared to U.S. practice) in the reactor pools. This shared pool appears to have survived the disaster relatively unscathed.

79. The MRS Review Commission concluded that "in view of the continuing delay in the building of a repository… it would be in the national interest to have available a safety net of storage capacity for emergency purposes, such as an accident at a nuclear power plant, which would make it advantageous to have the plant's spent fuel pool available for decontamination of affected parts of reactors and for storage of debris." The Review Commission recommended construction of a Federal Emergency Storage (FES) facility with a capacity limit of 2,000 metric tons. See U.S. Monitored Retrievable Storage Review Commission, *Is there a need for federal interim storage? Report of the Monitored Retrievable Storage Commission*, University of Michigan Library, 1989. Accessible at http://www.brc.gov/sites/default/files/documents/is_there_a_need_for_interim_storage_s.pdf

80. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *1987 OCRWM Mission Plan Amendment* (DOE/RW-0128), June 1987, p. 116.

81. It is worth noting that the opportunity to host an R&D facility of this type might itself be among the inducements for a community interested in being considered for a consolidated storage facility. A national center for ongoing research on all aspects of the storage of spent fuel could be a significant ancillary benefit for a community willing to host a storage facility.

82. "If standardization is not mandated by the Federal government, then an MRS facility that accepts waste early could promote standardization by reducing the variety of spent fuel forms and packages to be handled and limiting the number of reactors providing storage for other than intact, unpackaged spent fuel." U.S. Monitored Retrievable Storage Review Commission, *Is there a need for federal interim storage? Report of the Monitored Retrievable Storage Commission*, University of Michigan Library, 1989, p. 97. More generally, actions that could be taken now or in the near term to specify standardized requirements for SNF package designs could be of substantial value to the waste management program, and to utilities and cask vendors, in the future. Standardization would help ensure that SNF and HLW would not need to be re-packaged before being shipped and emplaced at a storage or disposal facility. See for example, Nuclear Waste Technical Review Board, *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs*, Washington DC, June 2011, p. 44.

83. The MRS Review Commission evaluated occupational doses to workers in the no-MRS, linked MRS, and unlinked MRS systems and concluded that the unlinked MRS system would result in the lowest doses because of "greater reliance on remote operations and remote handling facilities" at the MRS. U.S. Monitored Retrievable Storage Review Commission, *Is there a need for federal interim storage? Report of the Monitored Retrievable Storage Commission*, University of Michigan Library, 1989, p. 13.

84. The MRS Review Commission explicitly evaluated the argument that a system using dual-purpose storage/transportation casks for storage at reactors would provide as much flexibility as a system including a centralized MRS facility and concluded that it would not because they could not be certain "that a dual-purpose cask could be developed that could be used for prolonged storage and then transported without having to be returned to a spent fuel pool or opened." Ibid., p. 95.

85. The recent MIT fuel cycle study (titled *The Future of the Nuclear Fuel Cycle*; full cite given in previous endnotes and available at http://web.mit.edu/mitei/docs/spotlights/nuclear-fuel-cycle.pdf) refers to storage on the order of a

century. The NRC is evaluating the implications of storage for a period of up to 300 years. As noted in the main text, the fact that storage periods of this length are being evaluated should not be taken as an indication that storage over multi-century timeframes would be desirable or even defensible from either a cost or risk management standpoint.

86. A.C. Kadak and K. Yost, *Key Issues Associated with Interim Storage of Used Nuclear Fuel*, MIT, 2010, pp. 27-28.

87. Staged development of a centralized storage facility is discussed in a paper developed for the BRC by Cliff W. Hamal, Julie M. Carey and Christopher L. Ring and titled "Spent Nuclear Fuel Management: How centralized interim storage can expand options and reduce costs," *May 16, 2011*, pp. 48-50. Available at http://brc.gov/sites/default/files/documents/centralized_interim_storage_of_snf.pdf.

88. American Physical Society, *Consolidated Interim Storage of Commercial Spent Nuclear Fuel: A Technical and Programmatic Assessment*, American Physical Society Panel on Public Affairs, February 2007

89. It is possible that the contractual obligation for waste acceptance would remain with DOE for some time and perhaps indefinitely—even after a new waste management organization is established.

90. Eileen M. Supko and Michael H. Schwartz, *Overview of High-Level Nuclear Waste Materials Transportation: Processes, Regulations, Experience and Outlook in the U.S.*, Energy Resources International, Inc., ERI-2030-1101, January 2011, p. 74.

91. While the Standard Contract allows DOE to give priority to fuel at shutdown sites, the Department has declined to consider this option in the past because of concerns about equity impacts on contract holders. U.S. Department of Energy, *Report to Congress on the Demonstration of the Interim Storage of Spent Nuclear Fuel from Decommissioned Nuclear Power Reactor Sites* (DOE/RW-0596), Dec. 2008, p. 3.

92. This chart uses GAO's estimate of $4.5 million/year M&O costs for stranded fuel at a shutdown site. While the figure indicates a repository, the estimates would apply to any facility capable of accepting spent fuel in 2030.

93. Some of the data used in preparing this chart were derived from the following report: Government Accountability Office, *Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives,* GAO-10-48, November 2010.

94. This cost analysis is based on capacity for either interim storage or disposal being available for spent fuel.

95. U.S. Nuclear Regulatory Commission SECY-11-0137, "Prioritization of Recommended Actions To Be Taken in Response to Fukushima Lessons Learned," Oct. 3, 2011 (available at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0137scy.pdf).

96. In the course of the BRC's deliberations, Commission members with appropriate clearances were briefed by officials from DOE, NRC, and other agencies regarding issues of fuel storage and transportation safety and security. These briefings also covered related research efforts and the additional security measures that have been implemented at some sites. We are confident that the NRC's current analytical and regulatory processes are adequate to make needed assessments, and to adapt as appropriate.

97. Over time, spent fuel "cools" thermally and radioactively and requires less shielding to be handled directly. In this way it loses some of the characteristics that would make it difficult to remove and transport for unauthorized purposes. Depending on burnup, spent fuel may no longer be self-protecting after a century or so of storage.

98. Material for this section was developed from presentations to the BRC Transportation and Storage Subcommittee by Mr. Philip Brochman, NRC Office of Nuclear Security and Incident Response, Sept.23, 2010 (available at http://www.brc.gov/index.php?q=meeting/open-meeting-4.).

99. Electronic mail from Dr. Brittain Hill, NRC, to Alex Thrower, BRC staff, Feb. 23, 2011 (available at http://www.brc.gov/sites/default/files/comments/attachments/post_9-11steps_b_hill.pdf).

100. Additional background about NRC's security programs is available at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/security-enhancements.pdf).

101. U.S. Nuclear Regulatory Commission Staff Requirements Memorandum dated Aug. 26, 2010 (SECY-10-0014 Enclosure 1, found at http://wba.nrc.gov:8080/ves/view_contents.jsp).

102. U.S. Nuclear Regulatory Commission paper dated Aug. 26, 2010 (SECY-10-0114, Enclosure 1), found at https://adamsxt.nrc.gov/WorkplaceXT/getContent?id=release&vsId=%7B1214CFFE-E9C0-4742-B109-74DCD84A1B84%7D&objectStoreName=Main.__.Library&objectType=document.

103. Robert Alvarez et al., "Reducing the Hazards from Stored Spent Fuel Power-Reactor Fuel in the United States," *Science and Global Security* 11: 1-51, 2003.

104. Allan S. Benjamin et al., *Spent Fuel Heatup Following Loss of Water During Storage*, Sandia National Laboratory (NUREG/CR-0649, SAND77-1371), 1979.

105. Robert Alvarez et al., "Reducing the Hazards from Stored Spent Fuel Power-Reactor Fuel in the United States," *Science and Global Security* 11: 1-51, 2003, p. 21.

106. U.S. Nuclear Regulatory Commission, "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States," *Science and Global Security*, Vol. 11, pp. 203–211.

107. National Research Council, Committee on the Safety and Security of Commercial Spent Nuclear Fuel in Storage, *Safety and Security of Commercial Spent Nuclear Fuel Storage*, Washington DC: The National Academies Press, 2006, p. 5 (accessible at http://www.nap.edu/catalog.php?record_id=11263).

108. Ibid.

109. Ibid at p. 3

110. The term "hardened on-site storage" is not currently defined in regulations, and is not commonly used by the industry.

111. Michelle Boyd, "Principles for Safeguarding Nuclear Waste at Reactors," submission to the BRC, May 11, 2010 (the principles may be found at http://www.citizen.org/documents/PrinciplesSafeguarding2009.pdf).

112. Charles W. Pennington, "Storage and Transportation of Spent Fuel: Does Storage/Transport System Hardening Enhance Safety and Security," submission to the BRC Transportation and Storage Subcommittee, Sept. 2010 (accessible at http://www.brc.gov/sites/default/files/meetings/presentations/c_pennington_presentation_final.pdf). Mr. Pennington subsequently submitted a detailed critique of the HOSS proposal as presented by Mr. David Kraft at the subcommittee meeting in Chicago, IL on Nov. 2, 2010. Mr. Kraft's submittal can be found at http://www.brc.gov/sites/default/files/meetings/presentations/panel_present_to_brc_11-2-10.pdf. Mr. Pennington's critique was submitted to the BRC on January 20, 2011 and is available at http://brc.gov/sites/default/files/comments/attachments/recapitulating_and_expanding_upon_safety_of_dry_storage_-_final.pdf.

113. Nuclear Energy Institute [NEI 06-12, Revision 2), "B.5.b Phase 2 & 3 Submittal Guideline." This document was initially designated for Official Use Only – Security Related Information, and so is unavailable to the public. However, it was made publicly available on May 9, 2011 and can be found on NRC's ADAMS system at http://www.nrc.gov/reading-rm/adams.html with accession number ML070090060.

114. See remarks in the comments of Bill Borchardt, Executive Director for Operations of the Nuclear Regulatory Commission, and Anthony Pietrangelo, Senior Vice President and Chief Nuclear Officer of the Nuclear Energy Institute, in the transcript of the March 29, 2011 meeting of the Senate Committee on Energy and Natural Resources on the accident at the Fukushima Daiichi reactor complex, accessible at http://dpwsa.powergenworldwide.com/index/display/wire-news-display/1389933775.html.

115. Michelle Boyd, "Principles for Safeguarding Nuclear Waste at Reactors," submission to the BRC, May 11, 2010 (the principles may be found at http://www.citizen.org/documents/PrinciplesSafeguarding2009.pdf).

116. Another country that has grappled with the siting issue is Germany, which in the late 1990s commissioned an expert committee (not unlike the BRC) to look at the problem of nuclear waste. The German committee developed a relatively straightforward plan in which the siting organization was to do an initial screening of the entire country for geologically suitable sites, based on a short set of criteria. From the subset of potentially suitable sites, weighted criteria were to be used to reduce the number of potential locations to five. At that point, the five affected municipalities were to be asked whether they wished to go forward with a more detailed evaluation. The hope was that at least two sites would survive this next cut, and assuming approval could be obtained from the local communities, the plan was to build two underground facilities for further technical analysis in preparation for a final decision. However, because of a change of government, the German plan was never implemented.

117. According to a March 2010 document issued by the NEA's Forum on Stakeholder Confidence: "History shows that the search for sites for radioactive waste management facilities has been marred by conflicts and delays. Affected communities have often objected that their concerns and interests were not addressed. In response, institutions have progressively turned away from the traditional "decide, announce and defend" model, and are learning to "engage, interact and co-operate." This shift has fostered the emergence of partnerships between the proponent of the

facility and the potential host community, as shown in a recent NEA study. Working in partnership with potential host communities enables pertinent issues and concerns to be raised and addressed, and creates an opportunity for developing a relationship of mutual understanding and mutual learning, as well as for developing solutions that will add value to the host community and region. Key elements of the partnership approach are being incorporated into waste management strategies, leading increasingly to positive outcomes." See: http://www.oecd-nea.org/rwm/fsc/docs/FSC_partnership_flyer_US_letter.pdf.

118. Under Finland's Nuclear Energy Act of 1987, the consent of the host municipality is required for any major nuclear installation (including reactors as well as repositories). Thus, local acceptance was a necessary prerequisite for any decision in principle to approve the Olkiluoto repository. Interestingly, when a proposal for the Olkiluoto repository first came up for a vote by the local town council, it was vetoed. See http://www.finlex.fi/fi/laki/kaannokset/1987/en19870990.pdf.

119. Like the U.S. program, the Finnish program included a siting schedule. However, that schedule allowed considerably more time than in the U.S. case. The schedule set by Finnish government in 1983 called for repository construction to begin in 2010, and targeted 2020 as the date when spent fuel would begin to be accepted for final disposal. See http://www.worldenergy.org/documents/p000915.pdf.

120. The Swedish Act on the Management of Natural Resources gives municipalities a veto over siting permits. While the government has the right, under certain circumstances, to disregard such vetoes, neither SKB nor the Swedish Parliament favored siting a repository without the consent of the selected municipality. The government's choice not to exercise its override authority, in other words, represents a discretionary policy decision. See SKB RD&D Programme 1998, p. 30 (accessible at http://www.skb.se/upload/publications/pdf/RD&D98webb.pdf) and Rolf Lidskog & AnnCatrin Andersson, "The management of radioactive waste: A description of ten countries" (accessible at http://www.edram.info/en/edram-home/joint-activities/status-report-skb-report/index.php), p. 71.

121. Claes Thegerström (CEO of the SKB), "Comment on Disposal Subcommittee Draft," submission to the full Commission on June 29, 2011 (available at: http://www.brc.gov/sites/default/files/comments/attachments/brb-text_5_sweden.pdf).

122. See "Next phase for French geological disposal," January 5, 2012, at http://www.world-nuclear-news.org/WR-Next_phase_for_French_geological_disposal-0501127.html.

123. In a presentation before the Commission, Liz Dowdeswell, former President of the NWMO, summarized the organization's perspective this way: "We believed that fundamentally the selection of an approach for long-term management was really about developing a contract between science and society, a contract that would allow all of us to continue to benefit from technology, but also would mitigate risk and, most importantly, would respect the values of our citizens."

124. This siting process was described to the Blue Ribbon Commission at its September 20, 2010 meeting. See http://www.brc.gov/sites/default/files/meetings/presentations/alvaro_rodriguez_usa_21-09-10.pdf and http://www.brc.gov/sites/default/files/meetings/attachments/alvaro_atc_articulo_para_la_ens.pdf

125. National Research Council, *Disposition of High-Level Waste and Spent Nuclear Fuel: The Continuing Societal and Technical Challenges, Summary*, Washington DC: The National Academies Press, 2001. An even earlier National Academies study, issued in 1990 and titled *Rethinking High-Level Radioactive Waste Disposal*, likewise called for an adaptive approach. According to the abstract: "This alternative approach emphasized flexibility; time to assess performance and a willingness to respond to problems as they are found, remediation if things do not turn out as planned, and revision of the design and regulations if they are found to impede progress toward the health goal already defined as save disposal. To succeed, however, this alternative approach will require significant changes in laws and regulations, as well as in program management."

126. In follow-on study sponsored by DOE, the National Academies elaborated on this central conclusion by describing two approaches to staging: (1) "Linear staging, involving a single, predetermined path to a well-defined end point, with stages viewed as milestones at which cost and schedules are reviewed and modified as needed" (this is the approach that in the Academies' view characterized the current U.S. program); and (2) "adaptive staging, which emphasizes deliberate continued learning and improvement and in which the ultimate path to success and the end points themselves are determined by knowledge and experience gathered along the way." The report, which was issued in 2003, concluded by recommending that adaptive staging should be the approach used in geologic repository

development. See: National Research Council, *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, Washington DC: The National Academies Press, 2003.

127. The *One Step at a Time* report argues strongly for the use of a periodically-revised safety case as a central feature of adaptive staging: "Two primary roles of the safety case are: (1) to guide the work of the implementer while adapting the program at each stage, and (2) to provide the implementer with a vehicle for making the safety arguments understandable by a wide audience."

128. The concept of a broad "safety case" that integrates all available lines of evidence supporting the safety of a repository, including institutional as well as technical factors, has become increasingly prominent internationally over the last decade. See International Atomic Energy Agency And The OECD Nuclear Energy Agency, *Geological Disposal Of Radioactive Waste: Safety Requirements*, No. Ws-R-4, International Atomic Energy Agency, Vienna, 2006, sections 3.40-3.53 (available at www-pub.iaea.org/MTCD/publications/PDF/Pub1231_web.pdf).

129. The Commission recognizes that many arguments for the safety of the repository are distributed throughout the regulatory process in the regulations and the justification documents supporting them, in requirements for reporting, and elsewhere. See EPRI comments on the BRC Disposal Subcommittee's Draft Report to the Full Commission, July 1, 2011 available at http://www.brc.gov/sites/default/files/comments/attachments/epri_comments_on_the_brc_disposal_subcommittee_draft_report_-_final_0.pdf.

130. "Complex performance assessments may be necessary for licensing, but the public and policy-makers may not find them easy to understand. The probabilistic performance assessment methods and results developed for Yucca Mountain are a state-of-the-art achievement and very valuable. They verge on being incomprehensible because of their complexity, however, except perhaps to organizations able to afford a large cadre of experts. Future repository programs still may have to produce complex performance assessments for compliance purposes, but they also must produce more-realistic, less-complex performance assessments for non-regulators. As experience with the Yucca Mountain program clearly shows, not only the regulators decide the fate of a repository program. The audience for the safety case is much broader." See Nuclear Waste Technical Review Board, *Technical Advancements And Issues Associated With The Permanent Disposal Of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs*, Washington DC, June 2011.

131. "If adopted, Adaptive Staging would lead DOE to …Focus more strongly on achieving the degree of technical and societal consensus needed to begin waste emplacement, rather than on the emplacement of all waste." National Research Council, *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, Washington DC: The National Academies Press, 2003, pp. 7-8.

132. Ibid., pp. 22-23.

133. Unless the provisions of an agreement would require additional legislative authorizations not already provided in the law establishing the waste management organization.

134. This is very well demonstrated in Sweden's repository program which began by establishing an underground rock laboratory.

135. A similar approach has just been adopted in a recent directive of the European Commission requiring members of the European Community to develop programs and schedules for developing disposal facilities: "Member States will have to draw up national programmes and notify them to the Commission by 2015 at the latest. The Commission will examine them and can require changes. National programmes have to include plans with a concrete timetable for the construction of disposal facilities, as well as a description of the activities needed for the implementation of disposal solutions, costs assessments and a description of the financing schemes. They will have to be updated regularly." Source: "Nuclear waste: Commission welcomes adoption of radioactive waste directive," Brussels, 19 July 2011, accessible at http://ec.europa.eu/energy/nuclear/waste_management/waste_management_en.htm.

136. This contention is supported by a 2008 report of the National Academy of Sciences, which concluded: "When done well, public participation improves the quality and legitimacy of a decision and builds the capacity of all involved to engage in the policy process. It can lead to better results in terms of environmental quality and other social objectives. It also can enhance trust and understanding among parties. Achieving these results depends on using practices that address difficulties that specific aspects of the context can present." See National Research Council, *Public Participation in Environmental Assessment and Decision Making*, Washington, DC: The National Academies Press, 2008.

137. For this reason, the BRC provided funding for key NGO and community stakeholders to travel to its deliberative meetings.

138. For example, the waste management organization could provide funding for independent monitoring and testing on a candidate repository site, provided that these activities do not interfere with other site development activities or compromise the site's integrity. In fact, Section 116 of the NWPA provides for grants to states and affected units of local governments for a number of purposes, including "any monitoring, testing, or evaluation activities with respect to site characterization programs with regard to such site," while Section 117 adds the proviso "except that such monitoring and testing shall not unreasonably interfere with or delay onsite activities." Funding for monitoring, testing, or evaluation activities is also provided for affected tribes. Under these provisions, over $4 million was provided to Inyo County, CA for the Inyo Regional Ground Water Monitoring Program, and over $31 million was provided to Nye County, NV for a Science & Verification Program that included the Nye County Early Warning Drilling Program, which provided data used in the Yucca Mountain project (Office of Civilian Radioactive Waste Management Office of Business Management, "Summary of Program Financial & Budget Information as of January 31, 2010").

139. For example, a report from 1980 on the subject pointed out that states have a "constitutional responsibility to ensure the health and safety of their citizens," as well as "jurisdiction over local authorities and land use," and that states therefore believed "it is both undesirable and impartial for disposal procedures to be wholly federally determined." See Pat Choate and John Bowman, *Radioactive Waste Management: State Concerns, A Report to the Office of Technology Assessment from the Academy for Contemporary Problems*, 1980, p. 3.

140. Ibid p. 11.

141. An absolute state veto had been opposed by the State Planning Council established by President Carter to provide advice on intergovernmental relations, as well as by others. See U.S. Congress Office of Technology Assessment, *Managing the Nation's Commercial High-Level Radioactive Waste*, (OTA-O-171), March, 1985, p. 180.

142. The state of Nevada's strong opposition to the proposed Yucca Mountain repository is well known, but other examples abound. In Utah, efforts to site a private centralized storage facility were blocked when the Utah delegation successfully pushed for congressional designation of a wilderness area that prevented access to the proposed site. Utah took this action despite its tradition of hostility toward past federal efforts to designate wilderness lands and national monuments within the state.

143. The Commission recognizes that more than one community, state, or tribe might be affected by a proposed repository. The waste management organization should therefore be directed to consult with any state, affected unit of local government, or Indian tribe that it determines may be so affected and to include any reasonable and appropriate provisions relating to their interests in negotiated agreements, as the Nuclear Waste Negotiator was directed and empowered to do under Section 403(b) of the NWPA.

144. In one notable instance—the NRC Agreement States program—regulatory authorities of the federal government under the Atomic Energy Act have been delegated to states. Although the current Agreement States program does not cover licensing of a repository, it does suggest a similar enforcement model might give a host state or tribe sufficient regulatory oversight to assure a meaningful public safety role. Alternative approaches through memoranda of understanding or other binding agreements may also be acceptable and should be explored as part of the negotiating process.

145. For instance, the Western Governors' Association (WGA) adopted a definition of consent-based siting for spent fuel storage facilities as part of its Resolution 11-3. The resolution requires the written consent of the governor of the hosting state. Members of the WGA's WIEB High-Level Waste Committee also believe that written consent should be required for all future disposal and storage decisions. For details see WGA's comments, dated September 13, 2011, on the BRC draft report.

146. Mixed waste is waste that contains, in addition to radioactive materials, materials that are defined as hazardous under RCRA (e.g., a chemical such as toluene).

147. Current federal law—including aspects of the Atomic Energy Act, the Commerce Clause, and the doctrine of intergovernmental immunity on federal reservations—has the effect of preempting almost all forms of state regulation over a high-level waste facility.

148. Elements that were essential to the success of the Environmental Evaluation Group have been summarized by the two scientists who served as director of the organization. See R.H. Neill and M.K. Silva, "EEG's Independent Technical Oversight on WIPP, a TRU Waste Geologic Repository" in the conference proceedings of the 9th International High Level

Radioactive Waste Management Conference, Session T-1, Las Vegas, NV, April 29–May 3, 2001.

149. The article quotes Sullivan as stating that "the same problems that existed 20 years ago still exist today. Among them is the lack of trust that western states have of the federal government to either follow through on a long-term policy or to actually work in a state's own interest." See: http://wyofile.com/2011/02/sullivan-i-was-right-to-veto-nuclear-waste/.

150. Peter C. Chestnut et al., *The Role Of Indian Tribes In America's Nuclear Future*, BRC Commissioned paper April 29, 2011, available at: http://www.brc.gov/sites/default/files/documents/the_role_of_indian_tribes_in_americas_nuclear_future-2011-04-29_final.pdf

151. See, for example, Executive Order 13175 "Consultation and Coordination with Indian Tribal Governments" available at: http://www.epa.gov/fedreg/eo/eo13175.htm.

152. Peter C. Chestnut et al., *The Role of Indian Tribes in America's Nuclear Future*, BRC commissioned paper April 29, 2011, accessible at http://www.brc.gov/sites/default/files/documents/the_role_of_indian_tribes_in_americas_nuclear_future-2011-04-29_final.pdf. According to this paper, "It is critical to remember that any entity created by the federal government…must have a formal working relationship directly with all potentially affected Indian Tribes. An example of a formal working relationship with Indian tribes is the Memorandum of Agreement between the Tennessee Valley Authority (TVA) and the Tennessee State Historic Preservation Officer of Knox County, TN. This Agreement calls for consultation with federally recognized Indian tribes that are participants or invited signatories to the Agreement."

153. In France, direct financial benefits for the region surrounding the proposed repository are spelled out in law. In addition, a range of other programs to promote development are being provided. While the particular government—utility mechanism that is used for this purpose may be unique to the French situation, the concept of promoting regional development through activities that go beyond financial benefits and waste-management-related employment is worthy of careful examination.

154. For example, the authorization of federal funds to build a new road so that shipments of transuranic waste could bypass Santa Fe (known as the Santa Fe bypass) was important in the WIPP context.

155. In the past, DOE often did not make the most of these opportunities. For example, WIPP was managed for years by DOE personnel located in Albuquerque rather than at an office in Carlsbad near the facility. It was only late in the process that DOE relocated its top WIPP management to Carlsbad. Likewise, the TRANSCOM tracking system used in the transportation program was originally based out of Oak Ridge, Tennessee. It was later relocated to Albuquerque and finally moved to Carlsbad in 2005.

156. Benefits provided by the current NWPA include cash payments of up to $20 million per year (Section 171) and special consideration for selection for DOE research projects (Section 174).

157. Provisions for evaluating and providing compensation are contained in Sections 116 and 118 of the NWPA.

158. Throughout this report we use the term "management" to refer to these three activities (i.e., transportation, storage, and disposal).

159. Outside of the United States and Germany, the implementing organizations are all dedicated public or private entities rather than a ministry or department of the national government.

160. In 2010, Senator Voinovich introduced the "United States Nuclear Fuel Management Corporation Establishment Act of 2010" (S. 3322), co-sponsored by Senators Alexander and Murkowski, and Representative Upton introduced a companion bill (H.R. 5979) in the House. There was no legislative activity on these bills in the 111th Congress.

161. *Report of the Advisory Panel on Alternative Means of Financing and Managing Radioactive Waste Management Facilities (AMFM Panel): A Report to the Secretary of Energy*, December 1984 (transmitted to Congress in April 1985), in the BRC library at http://www.brc.gov/sites/default/files/documents/amfm_1984_s.pdf.

162. Belgium, France, Japan, Spain, and United Kingdom have established public companies to implement high level waste management programs. In Canada, Finland, Sweden, and Switzerland, waste producers have set up implementing bodies to undertake these tasks. Only the United States and Germany have assigned the job to a government department. See International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), *Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries*, June 2005, available at http://www.edram.info/fileadmin/edram/pdf/EDRAMWGonWOwnershipFinal_271005.pdf.

163. The TVA board provides an example of how the need for expertise and stakeholder representation might be balanced. It has nine members appointed by the President and confirmed by the Senate. Key qualifications specified in law include "management expertise relative to a large for-profit or nonprofit corporate, government, or academic structure" and "support for the objectives and missions, of the Corporation, including being a national leader in technological innovation, low-cost power, and environmental stewardship." That is, Board members must be both capable of and invested in ensuring that the Corporation achieves its mission. In appointing members of the Board, the President must consider recommendations from governors of states in the service area; individual citizens; business, industrial, labor, electric power distribution, environmental, civic, and service organizations; and the congressional delegations of the states in the service area. Furthermore, the President must "seek qualified members from among persons who reflect the diversity, including the geographical diversity, and needs of the service area of the Corporation."

164. Section 302(d) of the NWPA limits use of the Waste Fund to "non-generic research, development, and demonstration activities under this Act." An example of such non-generic research is the OCRWM Science and Technology program initiated by OCRWM in 2002 to improve existing technologies and develop new technologies so as to achieve efficiencies and life-cycle cost savings in the waste management system (transportation, waste handling, and disposal) and to increase confidence in repository performance. Robert J. Budnitz, "Status of OCRWM's New Science and Technology Program," presentation to the National Research Council's Board on Radioactive Waste Management, December 12, 2002.

165. This could include addressing the need for complex adjustments to the nuclear waste fee schedule if spent nuclear fuel becomes a feedstock.

166. In our proposal, responsibility for the treatment and storage of defense waste would remain with DOE.

167. Based on an evaluation conducted by DOE pursuant to the NWPA and titled *An Evaluation of Commercial Repository Capacity for the Disposal of Defense High-Level Waste*, (DOE/DP/0020/1), Washington DC, 1985.

168. This general approach, in which government and not the implementing organization defines the policy framework that will guide future waste management activities is common to most countries with a significant waste management program. A review of 11 countries that are members of the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM) shows that in all cases general waste management policy is set by government, rather than the implementing organization. International Association for Environmentally Safe Disposal of Radioactive Materials, *Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries*, June 2005.

169. For example, "the economic and social well-being of the people living in [the Tennessee] river basin" is one of the general purposes identified in the legislation that established TVA [48 Stat. 69, 16 U.S.C. sec. 831v]; consequently, TVA sees economic development of the region as a key part of its mission and has an economic development program for that purpose (http://www.tva.com/econdev/index.htm). Similarly, ENRESA, which is Spain's national corporation for radioactive waste management, has established the ENRESA Foundation to promote social welfare and socio-economic development, the environment, education, and culture in areas that host ENRESA facilities.

170. The NWPA already requires annual audits of the activities of OCRWM by GAO, a comprehensive annual report by OCRWM on its activities and expenditures, and an annual report to Congress from the Secretary of the Treasury (after consultation with the Secretary of Energy) on the financial condition and operations of the Waste Fund.

171. Spain, for example, may offer a useful model: the government provides policy direction to the waste management organization, ENRESA, through ministerial review and approval of a General Radioactive Waste Plan that is revised and resubmitted every four years.

172. The CRA requires federal agencies that promulgate rules to submit certain information to each House of Congress and the General Comptroller about the rule. Generally, major rules may not become effective until 60 days after submission to Congress. During those 60 days, Congress could pass a joint resolution to disapprove the major rule. The President could veto a congressional joint resolution of disapproval. In that case Congress would have 30 days to override the President's veto. If Congress does not override the veto, the rule becomes effective. In legislation establishing the waste management organization and setting nuclear waste policy direction, Congress could provide itself CRA-like authority to review the organization's Mission Plan update.

173. These ten countries are Belgium, Canada, France, Germany, Japan, Spain, Sweden, Switzerland, Taiwan, and the United Kingdom.

174. The AMFM Panel recommended that a "Waste Fund Oversight Commission" be established for the specific purpose of ensuring that NWF fees are being used cost-effectively and to approve or disapprove proposed changes to the level of the fee. In its 2001 update of the AMFM study, DOE instead recommended that the Federal Energy Regulatory Commission (FERC) serve this purpose.

175. The National Academies' *One Step at a Time* report also recommended a stakeholder advisory board.

176. Waste management facilities include disposal and interim storage facilities as well as any new transportation infrastructure required to construct, operate or decommission a geologic repository or interim storage facility.

177. The NWPA does provide (in a separate section) for local government representation on a review panel that would advise DOE in the context of a negotiated "benefits agreement" between the federal government and a state or tribe hosting a repository or MRS facility. However, local interests account for only a small part of the representation on this panel.

178. Clinch River MRS Task Force, "Position on the Proposed Monitored Retrievable Storage Facility," October 10, 1985.

179. The Voinovich/Upton bill deals with this issue by providing that contracts and settlements remain the liability of DOE until 10 years after termination of the license of the reactor involved. The new federal corporation would take liability under the existing contracts no later than 10 years after license termination; it would also be liable for all new contracts and for any negotiated transfer of liability between DOE and the corporation.

180. For more details see "R&D Activities for Used Nuclear Fuel Disposition Storage, Transportation & Disposal," by William Boyle, Director, Office of Used Nuclear Fuel Disposition Research & Development, DOE Office of Nuclear Energy, presented to the NWTRB winter meeting, February 16, 2011 and accessible at http://www.nwtrb.gov/meetings/2011/feb/boyle.pdf.

181. The "polluter pays" principle for high-level waste disposal was first established by the AEC in 1970 when it established rules for the solidification and disposal of high-level wastes from reprocessing. However, the waste generators were going to pay when they actually delivered the waste for disposal, leaving the federal government to come up with the funds needed to develop a disposal system before the government could be reimbursed for this expense by the waste generators. In the NWPA, Congress departed from this approach and opted for an up-front fee to generate the revenues to build the system without having to rely on taxpayer funds, to ensure that adequate funds were available as needed.

182. U.S. Congress Office of Technology Assessment, *Managing the Nation's Commercial High-Level Radioactive Waste*, OTA-O-171, March, 1985, p. 93, pp. 106-107.

183. Opening Statement of Senator J. Bennett Johnston, Chairman, at a hearing before the Senate Committee on Energy and Natural Resources, March 1, 1994.

184. Data Source: U.S. DOE Office of Civilian Radioactive Waste Management, Office of Business Management "Summary of the Program Financial & Budget Information," as of January 31, 2010.

185. Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, UK, and United States.

186. International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM), *Report on Radioactive Waste Ownership and Management of Long-Term Liabilities in EDRAM Member Countries*, June 2005, Tables 7.4 and 7.5, accessible at http://www.edram.info/fileadmin/edram/pdf/EDRAMWGonWOwnershipFinal_271005.pdf.

187. See extended discussion in Joseph S. Hezir, "Budget and Financial Management Improvements to the Nuclear Waste Fund (NWF): Background Report to the Blue Ribbon Commission on America's Nuclear Future," May 2011. Accessible at http://brc.gov/sites/default/files/documents/brc_hezir_nwfbudget_051511.pdf.

188. This specific combination of measures was identified as one of four feasible interim steps for dealing with the funding problem in DOE's 2001 update of the AMFM report. See U.S. Department of Energy, *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program* (DOE/RW-0546), August 2001.

189. Data source: U.S. Department of Energy, Office of Civilian Radioactive Waste Management Office of Business Management, "Summary of Program Financial & Budget Information" as of January 31, 2010.

190. U.S. Department of Energy, *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program* (DOE/RW-0546), August 2001, Fig. 3. The proposal was not accepted by the utilities because the quid pro quo was their agreement not to seek damages for delay in waste acceptance.

191. Legal analysis performed for the BRC concluded that it may be possible to amend the Standard Contract in this way without a rulemaking proceeding to amend the rule that established the contract in the first place (10 C.F.R. § 961). See Van Ness Feldman, P.C., "Legal Analysis of Commission Recommendations for Near-Term Actions," October 11, 2011, http://www.brc.gov/sites/default/files/documents/vnf_legal_authorities_memo_legal_authorities_memo_revised_20111011_final_clean_1.pdf.

192. In proposing this approach, Secretary of Energy Peña stated that this "can be accomplished promptly within [DOE's] current authority." (See letter from Secretary of Energy Federico Peña to Alfred William Dahlberg, Chairman, President, and Chief Executive Officer, Southern Company, May 18, 1998.) Under the NWPA, the Secretary of Energy has existing authority to establish procedures for the collection and payment of the fees. In addition, the principle that fee payments can be deferred until wastes are accepted has an existing precedent in the form of the one-time fee payment imposed on utilities for spent fuel generated before the Act was passed. See Van Ness Feldman, P.C., "Legal Analysis of Commission Recommendations for Near-Term Actions," October 11, 2011, accessible at http://www.brc.gov/sites/default/files/documents/20111011_legal_authorities_memo_revised_final_clean_1.pdf.

193. The original PAYGO requirements in the Budget Enforcement Act of 1990 have since been modified in the Statutory Pay-As-You-Go Act of 2010. The requirements apply to proposed legislation (and not administrative actions) and require that OMB maintain a "PAYGO Scorecard" of the average annual cost over a 5-year period and the annual average cost over a 10-year period of newly enacted legislation. If, at the end of the Congressional session, there is a net increase in budget costs, an across-the-board sequestration of an equal offsetting amount is triggered. Legislation that increases direct spending also is subject to points of order under the Congressional Budget Act and the rules of the House and Senate. For example, the 112th Congress adopted a Cut-As-You-Go (CUTGO) rule (part of H. Res. 5) that establishes a point of order against any legislation that increases net mandatory spending for the period of the current fiscal year, the budget year, the four fiscal years following the budget year or the nine fiscal years following the budget year. There also is a point of order against any legislation that increases mandatory budget costs in excess of $5 billion in any of the first four consecutive 10-year fiscal-year periods following the period covered by an applicable budget resolution. **It should be emphasized that PAYGO and CUTGO rules apply to legislative and not administrative actions.**

194. Joseph S. Hezir, "Discussion of Timing of Payment of NWF Fees," presentation to the BRC Subcommittee on Transportation and Storage, January 3, 2011, Washington, D.C. If this change were a DOE-initiated proposal, rather than implementation by DOE of policy direction from the Administration, it might be subject to review under the administrative PAYGO requirements for agency proposals affecting mandatory spending established by the Bush Administration in 2005 through OMB Memorandum M-05-13 and supported by the Obama Administration in the FY 2011 budget. (The extent of its use in practice is unclear – a report by the Congressional Research Service, "OMB Controls on Agency Mandatory Spending Programs: 'Administrative PAYGO' and Related Issues for Congress," documented only a single instance where administrative PAYGO was applied.) However, the proposed renegotiation of contracts might not fall within the scope of the administrative PAYGO guidelines in any event, and even if it did, it should be subject to the provision for exceptions "…in light of extraordinary need or other compelling circumstances." In this case, the need for assured funding for the used/spent nuclear fuel management program to mitigate the magnitude of further federal budget liability to the Judgment Fund, plus the fact that reduced receipts in the near term would be offset by higher-than-projected receipts in the long term when the escrow accounts are drawn down to meet the costs of constructing and operating waste management facilities, would provide a compelling argument.

195. Ibid.

196. The original classification of the fee receipts as mandatory and program expenditures as discretionary was a judgment made by OMB based on general budget principles rather than on clear legislative requirements. See Hezir, op. cit.

197. See U.S. Department of Energy, *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program*, (DOE/RW-0546), August 2001.

198. The Financial Report shows $19.1 billion of unpaid damages and $30 billion of unspent fees and interest that are categorized as "unearned revenue" (money received in advance of providing goods or services).

199. The Bush Administration addressed precisely this issue in a statement by DOE to Congress explaining the Administration's proposed legislation to reclassify the revenues from the nuclear utility fees as offsetting collections "so they can be used in the way that was intended when

the Nuclear Waste Policy Act was passed: to develop a repository for disposal of high-level radioactive waste and spent nuclear fuel." The specific stated objective was the same as that of our non-legislative proposal: "to ensure that Congress can focus its appropriations decisions on ensuring that the funds are used effectively and efficiently to meet the objectives of the Act, without having to worry about the impact on the funding of other programs within the Energy and Water Development appropriation." In that testimony, DOE noted: "[T]the principle supported by the proposal is specific to the highly unusual contractual arrangement required by the Nuclear Waste Policy Act, and is unlikely to be relevant to many other federal activities. Simply stated, whenever the Federal government, pursuant to an explicit statutory requirement, makes a legally binding contractual commitment specified by that statutory requirement to perform a well-defined service in exchange for payments that cover the costs of that service, it should treat those payments in a way that ensures that they are used for the statutorily-specified contracted purpose. It is hard to see how anyone could disagree with that principle. Likewise, it is hard to see how such distinctive-if not unique-statutory obligations could threaten the ability of Congress to weigh competing demands for appropriations in other, unrelated areas." Testimony by Robert G. Card, Under Secretary of Energy, before the hearing on "A Review of the Department of Energy's Yucca Mountain Project, and Proposed Legislation to Alter the Nuclear Waste Trust Fund (H.R. 3429 and H.R. 3981)," held by the Subcommittee on Energy and Air Quality of the House Committee on Energy and Commerce, March 25, 2004.

200. For a summary of proposals to change the Nuclear Waste Fund (NWF) funding structure from 1994 through 1999, see Figure 3 in U.S. Department of Energy, *Alternative Means of Financing and Managing the Civilian Radioactive Waste Management Program*, (DOE/RW-0546), August 2001. More recently, Senator Hagel introduced a bill in 2007 with provisions specifying that "funds from the Nuclear Waste Fund will not be subject to allocations for discretionary spending under Section 302(a) of the Congressional Budget Act or suballocations of appropriations committees under Section 302(b)." To address the issue of budget neutrality, the Hagel bill would have further required that adjustments be made "In the allocation of new budget authority to appropriate committees in amounts equal to the fees reclassified as discretionary as a result of the above provision." Legislation introduced by Senator Domenici in 2008 under the title "Strengthening Management of Advanced Recycling Technologies Act" (or SMART Act) would have established a revolving fund using $1 billion of the current NWF, as well as the annual interest on the Fund. The remaining 95 percent of the current waste Fund, as well as all future fees, would be placed in a legacy fund for the purposes of constructing a geologic repository. Expenditures from the revolving fund for the provisions of the Act could be made without further appropriations but would be subject to limitations in appropriations acts. In this way, the revolving fund could be put to use without being subject to the uncertainty of the annual appropriations process while still retaining the authority of Congress to oversee the NWF. The recent Voinovich/Upton legislation would establish two funds—an operating fund and a reserve fund—for the new waste management organization. The unexpended balance of already appropriated funds, plus accounts receivable and future revenues from NWF fees and appropriations would go to the operating fund. The corpus of the NWF would be transferred as an unfunded asset to the reserve fund (accruing interest from the NWF would go to the operating fund).

201. This would need to take account of the current Cut-As-You-Go (CUTGO) rules that establish a point of order against (1) any legislation that increases net mandatory spending for the period of the current fiscal year, the budget year, the four fiscal years following the budget year or the nine fiscal years following the budget year, and (2) any legislation that increases mandatory budget costs in excess of $5 billion in any of the first four consecutive 10-year fiscal-year periods following the period covered by an applicable budget resolution.

202. Testimony by Robert H. Card, Under Secretary of Energy, before the hearing on "A Review of the Department of Energy's Yucca Mountain Project, and Proposed Legislation to Alter the Nuclear Waste Trust Fund (H.R. 3429 and H.R. 3981)," held by the Subcommittee on Energy and Air Quality of the House Committee on Energy and Commerce, March 25, 2004.

203. Section 302(b)(4) stipulates that "No high-level radioactive waste or SNF generated or owned by any department of the United States …. may be disposed of by the Secretary in any repository constructed under this Act… unless such department transfers to the Secretary, for deposit in the NWF, amounts equivalent to the fees that would be paid to the Secretary under the contracts referred to in this section if such waste or spent fuel were generated by any other person." In practice, funds for the defense wastes have been appropriated directly to the program for use each year, with no surplus to be deposited in the Fund.

204. 52 FR 31508.

205. U.S. Department of Energy, “Fiscal Year 2007 Civilian Radioactive Waste Management Fee Adequacy Assessment Report,” DOE/RW-0593, July 2008.

206. Mark Gaffigan, Managing Directorof Natural Resources and Environment, “NUCLEAR WASTE: Disposal Challenges and Lessons Learned from Yucca Mountain,” statement before the Subcommittee on Environment and the Economy, Committee on Energy and Commerce, House of Representatives, June 1, 2011.

207. Information provided by DOE to the BRC. See http://brc.gov/sites/default/files/correspondence/blue_ribbon_request_1-6-2010_final.pdf.

208. Just as the fees paid by utilities to date are credited in determining whether they are fully “paid up” for purposes of being able to begin delivering waste for disposal, so should the defense waste appropriations to date be credited in determining when the defense share has been fully paid.

209. Recent court decisions upholding the government’s obligation to accept spent fuel are backed by a long history of case law regarding the contractual obligations of the federal government, even in times of severe economic and budget crisis. In one Depression-era case involving an effort to stop payment on government-issued insurance policies, the Supreme Court concluded: “No doubt there was in March, 1933, great need of economy. In the administration of all government business economy had become urgent because of lessened revenues and the heavy obligations to be issued in the hope of relieving widespread distress. Congress was free to reduce gratuities deemed excessive. But Congress was without power to reduce expenditures by abrogating contractual obligations of the United States. To abrogate contracts, in the attempt to lessen government expenditure, would not be the practice of economy, but an act of repudiation.” Lynch v. United States, 292 U.S. 571, 580 (1934).

210. The courts have ruled that “acceptance” includes the obligation to remove spent fuel from reactors. We use “accept” and “acceptance” in this broader sense.

211. Yankee Atomic Electric Co. v. United States, 536 F.3d 1268 (Fed. Cir. 2008); Pacific Gas & Electric Co. v. United States, 536 F.3d 1282 (Fed. Cir. 2008); Sacramento Municipal Utility District v. United States, Nos. 2007-5052, -5097, 2008 WL 3539880 (Fed. Cir. Aug. 7, 2008).

212. Department of Justice, “Response to Request for Information from the Blue Ribbon Commission on America’s Nuclear Future”, December 20, 2011. Available at http://www.brc.gov/sites/default/files/comments/attachments/doj_response.12.20.11_0.pdf.

213. “Because the claims of a substantial number of utilities are not substantially affected by issues that require resolution at the appellate level, it may be possible to implement an administrative claims process with these utilities that is less expensive and more efficient than litigation and that achieves largely the same results.” Testimony of Michael F. Hertz, Deputy Assistant Attorney General, Civil Division, on “Budget Implications of Closing Yucca Mountain, before the Committee on the Budget, U.S. House of Representatives, July 27, 2010.

214. Department of Justice, “Response to Request for Information from the Blue Ribbon Commission on America’s Nuclear Future”, December 20, 2011. Available at http://www.brc.gov/sites/default/files/comments/attachments/doj_response.12.20.11_0.pdf.

215. National Research Council, *Going the Distance: The Safe Transport of Spent Nuclear Fuel and High-Level Waste in the United States*, Washington DC: The National Academies Press, Aug. 2006.

216. Presentation of Earl Easton, U.S. Nuclear Regulatory Commission Office of Spent Fuel Storage and Transportation, to the BRC Subcommittee on Transportation and Storage, Nov. 2, 2010.

217. Examples of recommendations from the 2006 NAS report that have not been implemented include full-scale cask testing, more systematic examination of social or societal risk and risk perception, making planned shipment routes publicly available, shipping stranded spent fuel from shutdown reactor sites first, and executing technical assistance and funding under NWPA, Section 180(c).

218. Including the Pipeline and Hazardous Materials Safety Administration, the Federal Motor Carrier Safety Administration, and the Federal Railroad Administration.

219. Burnups greater than 45 gigawatt-days per metric ton (45GWd/MTU) are now common.

220. In addition, the Departments of Homeland Security and Transportation adopted regulations in 2008 to enhance the safety and security of rail shipments of hazardous materials, including spent nuclear fuel (49 CFR 172, 179, 209, 1520, 1580). The rules designated 46 High Threat Urban Areas (HTUAs) that require a chain of custody and control procedures. They also require rail route evaluations using 27 risk factors, including

proximity to densely populated areas, iconic targets, and places of congregation. These rules have not been applied to large-scale spent nuclear fuel shipping campaigns; in fact, a number of observers have noted that doing so on a nationwide basis could be problematic. See presentation of Robert Halstead to the BRC Transportation and Storage Subcommittee, Sept. 23, 2010 (available at http://www.brc.gov/sites/default/files/meetings/presentations/d_halstead_final_sep23.pdf).

221. Ibid at p. 8.

222. BRC staff met with NRC/NSIR staff on January 11, 2011, and reviewed the classified versions of the NAS reports, as well as NRC summaries of the actions it has taken to address the issues identified. NRC staff also briefed cleared staff and Commissioners on Feb. 3, 2011.

223. Presentation of Lisa Janairo, Midwest Council of State Governments, to the BRC Transportation and Storage Subcommittee, Nov. 2, 2010 (accessible at http://www.brc.gov/index.php?q=meeting/open-meeting-3).

224. Ibid.

225. Presentation of Gary Lanthrum, Principal Engineer, RAMTASC to the Blue Ribbon Commission, Oct. 20, 2011 (available at http://brc.gov/index.php?q=meeting/public-meeting-solicit-feedback-draft-commission-report-washington-dc).

226. Western Governors' Association, "Policy Resolution 11-5, Transportation of Radioactive Waste, Radioactive Materials, and Spent Nuclear Fuel," 2011 (available at http://www.westgov.org/policies).

227. Ken Niles and Rick Moore, *The WIPP Transportation Program at 10 Years: Making the Case for Above-Regulatory Procedures*, Waste Management Symposium, March 2009, at p. 4 (available at http://www.brc.gov/sites/default/files/comments/attachments/above-regulatory_transport.pdf).

228. Elizabeth Helvey, Complex Systems Group, "Overview of the Section 180(c) Program: History, Lessons Learned and Potential Next Steps," April 2011 (available at http://www.brc.gov/sites/default/files/documents/nwpa_section_180c_paper_final.pdf).

229. EPA also has sole responsibility for regulating non-radiological environmental impacts.

230. 10 CFR 51.23(a). The Waste Confidence decision is important because it avoids the need to resolve the issue of long-term disposition of spent fuel in each individual licensing action. See, for example, Nuclear Energy Institute press release, "Industry Applauds NRC Approval of revision of Waste Confidence Rule," Sept.15, 2010 (found at http://www.nei.org/newsandevents/newsreleases/industry-applauds-nrc-approval-of-revision-of-waste-confidence-rule).

231. Matthew L. Wald, "3 States Challenge Policy on Storing Nuclear Waste," New York Times, Feb.15, 2011 (available at http://www.nytimes.com/2011/02/16/nyregion/16nuke.html?_r=1&scp=2&sq=Nuclear&st=cse).

232. The NRC has been careful to note that despite these actions, it is not endorsing indefinite storage at reactor sites and continues to believe a mined geologic repository is necessary; in addition, the NRC has expressed "reasonable assurance" that such a repository "will be available in the foreseeable future." See Nuclear Regulatory Commission, "Staff Requirements Memorandum", Sept. 15, 2010 (found at http://www.nrc.gov/reading-rm/doc-collections/commission/srm/meet/2010/m20100915.pdf).

233. Notably, the IAEA goes on to state that "The aim of geological disposal is not to provide a guarantee of absolute and complete containment and isolation of the waste for all time."

234. The NEA is an agency of the Organisation for Economic Cooperation and Development (OECD), which includes the world's major industrialized economies.

235. EPA's general standard also applies to WIPP and is currently in use there.

236. The change came in response to a legal challenge charging that EPA was required by law to follow the recommendation issued by the NAS in 1995 that compliance should be measured at the time of peak dose within the period of geologic stability for Yucca Mountain, which the NAS found to be on the order of 1 million years.

237. 40 CFR § 197.20 (Yucca Mountain standards): "What standard must DOE meet? (a) The DOE must demonstrate, **using performance assessment**, that there is a reasonable expectation that the reasonably maximally exposed individual receives no more than the following annual committed effective dose equivalent from releases from the undisturbed Yucca Mountain disposal system: (1) 150 microsieverts (15 millirems) for 10,000 years following disposal; and (2) 1 millisievert (100 millirems) after 10,000 years, but within the period of geologic stability. (b) The DOE's performance assessment must include all potential pathways of radionuclide transport and exposure."

238. “We have recognized the strong consensus in the international radioactive waste community that dose projections extending many tens to hundreds of thousands of years into the future can best be viewed as qualitative indicators of disposal system performance, rather than as firm predictions that can be compared against strict numerical compliance criteria. In fact, international organizations have treated such numerical criteria in a more flexible way and supported their application in conjunction with other qualitative considerations in applying them to regulatory determinations over very long time frames. Further, we agree that confidence in the way the projections were performed, and the consideration of supporting qualitative information, may be more important to an overall judgment of safety at longer times.” U.S. Environmental Protection Agency (EPA), Preamble to 40 CFR Part 197, *Public Health And Environmental Radiation Protection Standards For Yucca Mountain, Nevada, Final Rule*, 73 FR 61266, October 15, 2008.

239. Canada’s regulations, for example, call for developing a long term safety case that combines a safety assessment with complementary arguments based on (1) appropriate selection and application of assessment strategies, (2) demonstration of system robustness, (3) the use of complementary indicators of safety, and (3) any other evidence available to provide confidence in the long term safety of the proposed system. Similarly, Finnish regulations call for a safety analysis that includes (1) a description of the disposal system and definition of barriers, (2) an analysis of the future evolution of the system, (3) definition of performance targets for individual barriers, (4) functional description of the disposal system by means of conceptual and mathematical modeling, (5) analysis of activity releases and resulting doses from radionuclides that penetrate the barriers and enter the biosphere, (6) estimates of the probabilities of activity releases and radiation doses arising from unlikely disruptive events, (7) uncertainty and sensitivity analyses, and (8) comparison of the outcome of the safety analysis with safety requirements.

240. See endnote 238.

241. See, for example, Rodney C. Ewing, “Standards & Regulations for the Geological Disposal of Spent Nuclear Fuel and High Level Waste,” prepared for the Blue Ribbon Commission on America’s Nuclear Future, March 4th, 2011 and available at http://www.brc.gov/library/commissioned_papers/EWING%20BRC%20white%20paper%20FINAL.pdf.

242. Jukka Laaksonen (Director General, Radiation and Nuclear Safety Authority (STUK), Finland), “Regulatory Aspects of Radioactive Waste Disposal – the Finnish Approach,” presented at the Conference on Geological Repositories: A Common Objective, a Variety of Paths, October 15 – 17, 2007, Berne, Switzerland.

243. Rodney C. Ewing, “Performance Assessments: Are They Necessary or Sufficient?” in *Uncertainty Underground: Dealing with the Nation’s High-Level Nuclear Waste Policy and Scientific Issues*, R. Ewing and A. Macfarlane, eds., MIT Press, 2006, p. 76.

244. U.S. Nuclear Waste Technical Review Board, *Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes: Lessons Learned from Yucca Mountain and Other Programs*, Washington DC, June 2011. Available at http://www.nwtrb.gov/reports/technical%20lessons.pdf.

245. U.S. Nuclear Regulatory Commission “Comments on the Blue Ribbon Commission July 2011 Draft Report to the Secretary of Energy.” Available at http://www.brc.gov/sites/default/files/comments/attachments/nrc_comments_on_draft_brc_report.pdf.

246. 66 Federal Register 55746, November 2, 2001.

247. Organisation for Economic Development, *Joint NEA-IAEA International Peer Review of the Yucca Mountain Site Characterisation Project’s Total System Performance Assessment Supporting the Site Recommendation Process, Final Report*, December 2001.

248. Rodney C. Ewing, “Standards & Regulations for the Geological Disposal of Spent Nuclear Fuel and High Level Waste,” prepared for the Blue Ribbon Commission on America’s Nuclear Future, March 4th, 2011 and available at http://www.brc.gov/library/commissioned_papers/EWING%20BRC%20white%20paper%20FINAL.pdf.

249. Nuclear Energy Institute v. Environmental Protection Agency, 373 F. 3d 1251 (D.C. Cir 2004).

250. Notably, the statements of secondary performance standards – groundwater protection in parts 191 and 197, and human intrusion in 197 – do not include performance assessment as part of the standard, and use of performance assessment to demonstrate compliance with those standards is not absolutely required. E.g. 40 CFR § 197.30 “What standards must DOE meet? The DOE must demonstrate that there is a reasonable expectation that, for 10,000 years of undisturbed performance after disposal, releases of radionuclides from waste in the Yucca Mountain disposal system into the accessible environment will not cause the level of radioactivity in the representative volume of

ground water to exceed the limits in the following Table 1:" Another example of a more flexible approach is found in EPA's regulations for uranium mill tailings, which allow the 1000-year quantitative standards to "be implemented through analysis of the physical properties of the site and the natural processes over time……. Computational models, theories, and prevalent expert judgment may be used to decide that a control system design will satisfy the standard." 40 CFR § 192.20.

251. In issuing its initial repository standards, EPA stated that "unequivocal proof of compliance is neither expected nor required because of the substantial uncertainties inherent in such long-term projections."

252. International Atomic Energy Agency and the OECD Nuclear Energy Agency, *Geological Disposal of Radioactive Waste: Safety Requirements*, WS-R-4, Vienna, 2006 (available at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1231_web.pdf).

253. EPA's position on reasonable expectation was challenged as being arbitrary and capricious in the lawsuit that led to the remand of parts of 40 CFR 191 in 1987. Nevertheless, EPA's position was upheld by the Court: "Given that absolute proof of compliance is impossible to predict because of the inherent uncertainties, we find that the Agency's decision to require "reasonable expectation" of compliance is a rational one. It would be irrational for the Agency to require proof which is scientifically impossible to obtain. Any such purported absolute proof would be of questionable veracity, and thus of little value to the implementing agencies. Nor can we say that this provision is arbitrary and capricious because it will afford the implementing agencies a degree of discretion, since such imprecision is unavoidable given the current state of scientific knowledge" (Natural Resources Defense Council v. U.S.E.P.A., 824 F.2d 1258).

254. "As a historic matter, differences in the NRC and EPA standards are rooted in the two agencies' philosophical approach to setting limits. EPA has tended to set very aggressive goals (often based on best technology) but has been very forgiving when best efforts at compliance with the goals are made (thus: "Reasonable Expectation"). The NRC, on the other hand, has set more achievable, science-based, standards and has been very strict in enforcing the standards once set (thus: "Reasonable Assurance")." *Report of the American Nuclear Society on the EPA proposed standard for the Yucca Mountain High Level Waste Repository*, November 1999, http://www.ans.org/pi/news/sd/944200800-report.html.

255. National Research Council, *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*, Washington DC: National Academies Press, 2003, available at http://www.nap.edu/catalog/10611.html, pp. 130-131.

256. Ibid, p. 92.

257. Ibid, p. 91.

258. In Appendix E of its recent "Plan for Integrating Spent Nuclear Fuel Regulatory Activities," the NRC identifies "Development of an assessment tool ("Flexible Performance Assessment"–FPA) that allows a scoping-level evaluation of the regulatory and technical aspects of various spent fuel and HLW disposition scenarios that may be identified by the Blue Ribbon Commission on America's Nuclear Future," as one of several activities to be completed by the end of FY 2010.

259. In 1990, in the midst of ongoing debates about the EPA and NRC repository regulations, the National Research Council warned against the risks of establishing excessively rigid regulatory requirements before data on actual sites were available. National Research Council, *Rethinking High-Level Radioactive Waste Disposal*, Washington DC: National Academies Press, 1990.

260. According to a statement submitted by Steve Frishman: "The regulatory arena associated with deep geologic disposal of highlevel radioactive waste and used nuclear fuel has been subject to an array of policy changes, changes in philosophy, and internal struggles within and between the two affected regulatory agencies – the NRC and the EPA. The interested and affected public often has been confused about the roles of the respective agencies, and the motivation, scope and meaning of the regulations proposed, while being confined in their responses to the review and comment provisions of the Administrative Procedures Act (APA), and ultimately the federal courts. Having been a participant in this process, at the affected state government level, for its entire nearly 30-year history, has been frustrating, to say the least." Summary of Statement by Steve Frishman, Consultant, Agency for Nuclear Projects, State of Nevada, presented at the public meeting focused on the issues to be addressed in development of new generic regulations for radioactive waste disposal in deep geological repositories," held by the Disposal Subcommittee of the BRC, September 1, 2010, in Washington D.C. (accessible at http://www.brc.gov/sites/default/files/meetings/attachments/summary_of_steve_frishamn_to_the_disposal_subcommittee.pdf).

261. At a hearing in Maine concerning spent fuel stored at the shutdown Maine Yankee reactor site, an elected official described open disagreement between EPA and NRC about whether the final cleanup standard for decommissioning of the site should be 15 mrem or 25 mrem. According to this official, her constituents did not understand the technical basis for the disagreement, but the simple fact that there was a dispute between the regulatory agencies undermined public confidence in the regulatory system and the ability to safely store spent fuel at the Maine Yankee site. This ongoing dispute between the EPA and NRC was also mentioned in a paper prepared for the Commission by Dr. Rodney Ewing and described in a GAO report in 2000 (see U.S. General Accounting Office, RADIATION STANDARDS: Scientific Basis Inconclusive, and EPA and NRC Disagreement Continues, GAO/RCED-00-152, June 2000).

262. Presentation to the BRC Subcommittee on Disposal by Robert Neill, September 1, 2010. Available at http://www.brc.gov/sites/default/files/meetings/attachments/summary_of_bob_neill__statement_to_the_disposal_subcommittee.pdf.

263. For example, the BRC's Subcommittee on Disposal has also heard a proposal that would involve forming a panel of experts from each agency and from academia or the private sector to conduct a process in accord with the Administrative Procedures Act. The aim would be to produce a report that could be used as the basis for an integrated set of disposal safety regulations to be adopted by both EPA and NRC, as was proposed by Steven Frishman at the Disposal Subcommittee meeting on September 1, 2010 (see: http://www.brc.gov/sites/default/files/meetings/attachments/summary_of_steve_frishamn_to_the_disposal_subcommittee.pdf). Other options such as regulatory negotiations might be possible.

264. Current NRC regulations for geologic disposal provide requirements for physical protection (10 CFR 60.21(b)(3) and 63.21(b)(3), Part 73) and material control and accounting (10 CFR 60.78 and 63.78). The NRC is currently conducting a rulemaking to enhance these requirements.

265. The "President's Offer" first put forward by President Lyndon Johnson, offered to place all U.S. nuclear facilities under IAEA safeguards except those of direct national security significance. This is intended to assure non-nuclear weapons states that they will not be discriminated against in having to supply information and undergo IAEA inspections and reports. For more details see Scott D. Sagan, "The International Security Implications of U.S. Domestic Nuclear Power Decisions," paper prepared for the Blue Ribbon Commission on America's Nuclear Future, April 18, 2011. Available at http://www.brc.gov/sites/default/files/documents/sagan_brc_paper_final.pdf.

266. Stoneturn Consultants: "From Three Mile Island to the Future: Improving Worker Safety and Health in the U.S. Nuclear Power Industry," March 14, 2011. In concluding that the record of occupational health and safety performance for the civilian nuclear power industry is very good (and indeed comparable to that of non-energy sectors like insurance and finance), the Stoneturn report relied on performance indicators in nuclear power plants, occupation radiation dose, and occupational injury and illness rates compared to workers in other industries.

267. During the construction of WIPP, one construction worker was fatally injured in 1984 when he fell 1000 feet down a 6-foot diameter borehole. See: "Safety Violations Led to WIPP Worker's Death," *Albuquerque Journal*, July 4, 1984, p. D-2. Overall this was the one traumatic fatality in an estimated 17,000 person-working years needed to construct the facility. SInce WIPP opened in 2000, there have been no significant accidents involving workers. In the case of Yucca Mountain, concerns were raised about the adequacy of the industrial hygiene procedures in place to protect workers from silica exposure. A study of some 413 individuals (out of almost 3000) who worked at Yucca Mountain between 1993 and 2002 found three individuals with silicosis, however all of these individuals had previously worked in mines and two of them had been diagnosed before working at Yucca Mountain, so it was difficult to determine whether and to what extent exposures at Yucca Mountain might have contributed to their condition. The other case was a new diagnosis, but that worker also reported previous mining experience so it was not possible to attribute his disease solely to exposure at Yucca Mountain. The study was performed between 2003 and 2005 out of almost 3000 individuals who had been known to have worked in some capacity at Yucca Mountain in during the study. (See *An Investigation into the Silica Exposure of Yucca Mountain Project Workers*. Special Hearing before a Subcommittee of the Committee on Appropriations, US Senate, Las Vegas, March 15. 2004. Available at http://www.gpo.gov/fdsys/pkg/CHRG-108shrg94749/pdf/CHRG-108shrg94749.pdf.) In contrast to Yucca Mountain, the WIPP facility is mined out of halite (salt) deposits. There has not been any study of whether mining halite has had any adverse health impact on workers at WIPP, even though there are significant salt dust exposures in the facility and even though exposure to salt dust is considered a risk factor for cardiovascular, gastric and kidney diseases.

268. Note that these are not the precise legal definitions. Links or citations to the legal definitions may be found in the supplementary materials posted on the BRC website (www.brc.gov).

269. R. H. Jones Jr., *Engineering Alternative Studies for Separations: NEPA Data Input Report*, EAS-Q-NEP-G-00001 Revision 4, June 2008, p. 3.

270. Kennedy, J.E. 2010. "Potential Changes to the U.S. LLW Regulatory Framework," U.S. Nuclear Regulatory Commission Regulatory Information Conference 2010, March 11, 2010, Washington D.C. http://www.nrc.gov/public-involve/conference-symposia/ric/past/2010/slides/th31kennedyjpv.pdf.

271. As Secretary Chu pointed out at the March 2010 Commission meeting, the once-through fuel cycle, as currently practiced in the United States with reactor technology that dates back to the 1970s and 1980s, uses only about 1 percent of the energy content of mined uranium. Noting the impact of future nuclear technology advances Secretary Chu said, "Your committee should be looking at these possibilities because if you can reduce the lifetime of the waste by factors of hundreds to thousands, if you can reduce the amount of the waste by factors of tens to hundreds, that also can change things. And what you do in the interim is then an open question." See transcript of March 25, 2010 meeting at http://www.brc.gov/sites/default/files/meetings/transcripts/0325scur.pdf.

272. Massachusetts Institute of Technology, *The Future of the Nuclear Fuel Cycle: An Interdisciplinary MIT Study*, Cambridge, MA, 2011.

273. For example, see (1) Bunn, et al., *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, 2003). http://www.publicpolicy.umd.edu/files.php/faculty/fetter/2003-Bunn-repro.pdf, (2) Dixon, et al. *Dynamic Systems Analysis Report for Nuclear Fuel Recycle*, December 2008, INL/EXT-08-15201 Rev., http://www.inl.gov/technicalpublications/Documents/4310613.pdf, (3) U.S. DOE, *Advanced Fuel Cycle Initiative Comparison Report*, FY 2003,(Updated 2004, 2006), http://www.ne.doe.gov/pdfFiles/AFCICompRpt2003.pdf, (4) EPRI, *Nuclear Fuel Cycle Cost Comparison Between Once-Through and Plutonium Single-Recycling in Pressurized Water Reactors*, #1018585, 2009, http://my.epri.com/portal/server.pt?, (5) EPRI, *Advanced Nuclear Fuel Cycles – Main Challenges and Strategic Choices*, #1020307, 2010, http://my.epri.com/portal/server.pt?, (6) MIT, *The Future of Nuclear Power*, 2003 (Updated 2009), http://web.mit.edu/nuclearpower/, (7) MIT, *The Future of the Nuclear Fuel Cycle*, 2011, http://web.mit.edu/mitei/research/studies/nuclear-fuel-cycle.shtml, (8) Shropshire, *Advanced Fuel Cycle Economic Tools, Algorithms, and Methodologies*, 2009, INL/EXT-09-15483, http://www.inl.gov/technicalpublications/Documents/4247163.pdf, (9) Wigeland, *AFCI Options Study*, 2009, INL/EXT-10-17639, http://www.inl.gov/technicalpublications/Documents/4480296.pdf, (10) Wilson, *Comparing Nuclear Fuel Cycle Options: Observations and Challenges*, 2011, http://brc.gov/sites/default/files/documents/wilson.fuel_.cycle_.comparisons_final.pdf, (11) U.S. NWTRB, *Nuclear Waste Assessment System for Technical Evaluation (NUWASTE): Status and Initial Results*, 2011.

274. Mixed oxide fuel (MOX) consists of a mix of recycled plutonium and uranium.

275. DOE is currently planning to build a demonstration plant of this type, called the Next Generation Nuclear Plant, at the Idaho National Laboratory. The reactor would be cooled with helium gas, moderated with graphite, and use low-enriched uranium fuel. It would be capable of generating electricity as well as supplying process heat.

276. This endnote summarizes key assumptions underlying table 4. As noted in the first paragraph in section 11.2, many of the comparisons are qualitative because the available technical literature is not comparable or consistent due to different assumptions and the current status of the technologies differs widely (LWR systems are deployed, fast reactors require more development and demonstration, and gas-cooled reactors even more).

Table 4 compares four nuclear energy systems: (1) a once-through LWR system using high-burnup uranium dioxide system [at least 45 GWd/metric ton] representative of near-term technology, (2) a modified-open cycle (MOC) in which eight high-burnup uranium dioxide fuel assemblies are reprocessed to make one high-burnup MOX fuel assembly which is irradiated for one cycle and then managed as waste, (3) a high-temperature [~600 C] helium-cooled reactor (HTGR) operated on a once-through basis using very-high-burnup uranium dioxide fuel in a graphite matrix to produce electricity or process heat, and (4) a closed sodium-cooled fast reactor system involving sustained reprocessing and recycle of MOX fuel. The comparisons in the table are based on a hypothetical system in which all nuclear power is produced by each system, i.e., transition effects are ignored. Each of the systems is assumed to produce the same amount of electric power. The once-through LWR system is considered to be the baseline against which the other systems are compared.

Noteworthy assumptions for some of the criteria that are not already stated in the table are as follows:

- Uranium utilization: uranium recovered in the MOC system is assumed to be recovered and re-enriched to make fresh uranium dioxide (UOX) fuel and the MOX fuel replaces uranium dioxide fuel. In the closed cycle uranium is recovered and recycled but with ~1% losses during each recycle.
- Global climate and energy security: HTGR is planned to achieve temperatures that make it possible to displace fossil fuel use in energy-intensive non-electric sectors.
- Non-proliferation and counter-terrorism: Once-through systems would be sending plutonium in SNF to a repository after relatively short cooling times. MOX and closed cycle systems keep much more plutonium in reprocessing plant, MOX fabrication plant, and reactor storage.
- Disposal safety: Once-through systems about the same given uncertainties in HTGR burnup and fuel composition. Reduction of TRU in MOC based on ORIGEN2 calculation. Reduction of TRU in closed cycle based on literature and staff calculations with caveats concerning duration stated. The MOC system includes disposal of intact MOX fuel after one irradiation cycle. Reduction in fuel cycle risk from MOC and closed cycles based on scaling results given in G. E. Michaels, *Impact of Actinide Recycle on Nuclear Fuel Cycle Heath Risks*, ORNL/M-1947 (June 1992) and OECD Nuclear Energy Agency, Radiological Impacts of Spent Nuclear Fuel Management Options: A Comparative Study, (2000).
- Waste volume: Volume requiring repository disposal and volume acceptable for near-surface disposal (A-B-C LLW plus uranium mill tailings plus depleted uranium) are addressed separately. Unit waste volumes are based on staff estimates using literature data.
- Repository space: Assume 40%+ thermal efficiency for HTGR. Space requirements for MOC wastes (UOX HLW plus intact MOX fuel) based on integrated decay heat using ORIGEN2 results.

277. Although the safety evaluation of the once-through fuel cycle is marked as the baseline, this does not presuppose that safety is perfect. Even given consistent and approved safety design standards across fuel cycles, there is still room for improvement in this system.

278. "No existing deterministic cost study of full recycling is credible, because there has been no engineering demonstration of full recycling." Testimony received from Geoffrey Rothwell at the meeting of the Subcommittee on Reactor & Fuel Cycle Technology on August 30, 2010.

279. The table compares nuclear energy systems in the long-term which means the R&D has been successfully completed, the fuel cycle in question has been adopted, and the transition phase is over so that the US is relying on just that system.

280. Assumption: Depleted uranium is deemed acceptable for near-surface disposal. If repository disposal is required the volume of repository waste increases ranging from 3 to 30 times for all but the closed fuel cycle, although decay heat and toxicity are not affected for 100,000 years. Note also that volume is less important for mined repositories than for other potential disposal options, notably boreholes.

281. President's Council of Advisors on Science and Technology (PCAST). *Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy*. November 2010. Available at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf.

282. The ESBWR (or Economic Simplified Boiling Water Reactor) is a reactor design marketed by GE Hitachi Nuclear Energy. It is considered a generation III+, passively safety design.

283. M. Anastasio et al., *A Sustainable Energy Future: the Essential Role of Nuclear Energy*, August 2008, page 4, http://www.ne.doe.gov/pdffiles/rpt_sustainableenergyfuture_aug2008.pdf.

284. World Association of Nuclear Operators (WANO), "A Post-Fukushima WANO – Applying Lessons Learned,"available at http://www.wano.info/press-release/wano-press-release-3/.

285. World Association of Nuclear Operators (WANO), "WANO after Fukushima– Strengthening Global Nuclear Safety: A Question and Answer Document," available at http://www.wano.info/wp-content/uploads/2011/10/Q-A-Document-for-Press-Pack.pdf.

286. See http://nuclearprinciples.org/the-principles/

287. Ibid.

288. Scott D. Sagan, *The International Security Implications of U.S. Domestic Nuclear Power Decisions*, 2011. Commissioned paper for the BRC, available at http://www.brc.gov/sites/default/files/documents/sagan_brc_paper_final.pdf.

289. "The Treaty on the Non-proliferation of Nuclear Weapons," United Nations, available at http://www.un.org/disarmament/WMD/Nuclear/pdf/NPTEnglish_Text.pdf.

290. Scott D. Sagan, "Shared Responsibilities for Nuclear Disarmament," *Daedalus* 138:4 (Fall 2009):157-68.

291. International Atomic Energy Agency, "The Safeguards System of the International Atomic Energy Agency," see http://www.iaea.org/OurWork/SV/Safeguards/.

292. See http://www.nti.org/h_learnmore/npttutorial/chapter02_02.html.

293. International Atomic Energy Agency, "Model Protocol Additional to the Agreements Between States and the IAEA for the Application of Safeguards," INFCIRC/540, available at http://www.iaea.org/Publications/Documents/Infcircs/1997/infcirc540c.pdf.

294. From http://www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html, accessed May 5, 2011.

295. Testimony before the BRC by Edwin Lyman on October 12, 2010.

296. The IAEA currently has 151 member states; its budget in 2011 was $447 million. The United States provided approximately 25% of that figure.

297. Regional Nuclear Fuel Cycle Centers study (1975-1977), International Nuclear Fuel Cycle Evaluation study (1977-1980), Expert Group on International Plutonium Storage (1978-1982), IAEA Committee on Assurances of Supply (1980-1987), United Nations Conference for the Promotion of International Cooperation in The Peaceful Uses of Nuclear energy (1987).

298. World Nuclear Association - http://www.world-nuclear.org/info/reactors.html, update for Dec 1, 2011.

299. International Atomic Energy Agency, *Multilateral Approaches to the Nuclear Fuel Cycle: Expert Group Report submitted to the Director General of the International Atomic Energy Agency*, INFCIRC/640, 22 February, 2005. Available at http://www.iaea.org/Publications/Documents/Infcircs/2005/infcirc640.pdf.

300. The Fund was seeded by NTI and supplemented by voluntary donations from the European Union, Kuwait, Norway, the United Arab Emirates, and the United States, according to a December 2, 2010 statement made to IAEA Board of Governors by Glyn Davies, U.S. Ambassador to the IAEA (see http://vienna.usmission.gov/101203nfs.html).

301. Incorporated as a joint venture between Russia's Tekhsnabeksport and Kazakhstan's Kazatomprom.

302. The fuel bank consists of two 1,000 megawatt-reactor loads of LEU.

303. Seen as a "virtual assurance mechanism that would facilitate access to nuclear energy to avoid the huge cost and technical challenge involved in establishing a nuclear fuel cycle." Statement made at the 2010 IAEA General Conference by Charles Hendy, Minister of State for Energy and Climate Change of the United Kingdom; see http://www.iaea.org/About/Policy/GC/GC54/Statements/uk.pdf.

304. Spent fuel take-away arrangements are broadly defined as negotiated agreements for governments with fuel cycle capabilities to assume liability for supplied or obligated fuel and develop permanent disposition solutions for managing used fuel in concert with countries seeking nuclear energy.

305. U.S. Department of State – website, Principles of the Global Initiative to Combat Nuclear Terrorism, http://www.state.gov/t/isn/c37071.htm.

306. Official U.S. Department of State blog - Secretary Clinton, Foreign Minister Lavrov Sign Plutonium Disposition Protocol, posted April 13, 2010 http://blogs.state.gov/index.php/site/entry/clinton_lavrov_plutonium_disposition_protocol.

307. In 2010, The U.S. returned Russian-origin HEU from Poland, Czech Republic, Serbia, and the Ukraine. GTRI Fact Sheet, http://nnsa.energy.gov/mediaroom/factsheets/reducingthreats.

308. Kenneth N. Luongo, "The Urgent Need for a Seoul Declaration: A Roadmap for the 2012 Nuclear Security Summit and Beyond," *Arms Control Today*, Washington, D.C., April 2012.

309. According to the IAEA, 1,773 confirmed incidents of illegal possession, movement or attempts to illegally trade in or use nuclear material or radioactive sources occurred between January 1993 and December 2009. Information taken from the IAEA's Illicit Trafficking Database at http://www-ns.iaea.org/security/itdb.asp.

NOTES

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Certificate of Service

On March 14, 2017, the Original Petition and Appendix were filed with the Clerk of Court via CM/ECF. Counsel further certifies that: (1) any required privacy redactions have been made in compliance with Fifth Circuit Rule 25.2.13; (2) the electronic submission is an exact copy of the paper document in compliance with Fifth Circuit Rule 25.2.1; and (3) the document has been scanned with the most recent version of Symantec Endpoint Protection and is free of viruses. Counsel further certifies that pursuant to Fed. R. App. P. 25(c) a copy of this Petition will be personally served on:

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