The Back-End of the Nuclear Fuel Cycle: Establishing a Viable Roadmap for a Multilateral Interim Storage Facility

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Cover image: The dry-cask storage hall of the Zwilag radioactive waste interim storage facility in Würenlingen, Switzerland. The hall—which is sixty-eight meters long and forty-one meters wide—is used to store vitrified high-level waste and spent-fuel elements from Swiss nuclear power and reprocessing plants. At full capacity, the hall can store around two hundred standing casks. © Zwilag Zwischenlager Würenlingen AG.

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Acknowledgments

There is growing interest worldwide in using civilian nuclear power to meet our increasing energy demands. But the spread of nuclear technology, in the absence of rigorous safety and security regimes, presents unique risks, from the potential proliferation of weapons capabilities to new states and subnational and terrorist groups to catastrophic accidents. As we have learned from incidents such as the accident at Japan's Fukushima Daiichi nuclear power site, a nuclear incident anywhere affects the prospects of nuclear power everywhere.

The Academy's Global Nuclear Future (GNF) Initiative is working to prevent such incidents by identifying and advocating for measures that promote strong safety cultures and limit the security and proliferation risks raised by the growing global appetite for nuclear energy. The GNF Initiative has created an interdisciplinary and international network of experts who are working together to devise and implement nuclear policy for the twenty-first century.

To help reduce the risks resulting from the global expansion of nuclear energy, the GNF Initiative addresses the following key policy areas: the international dimension of the nonproliferation regime, the entirety of the fuel cycle, the physical protection of nuclear facilities and materials, and the interaction of the nuclear industry with the nonproliferation community and national regulatory structures. Each of these areas presents specific challenges and opportunities, and each requires informed and thoughtful policies if we are to reach a comprehensive response to the risks posed by the spread of nuclear technology.

We would like to acknowledge the contributions of Dr. Stephen M. Goldberg, who was instrumental in helping to define the directions of the work on internationally supervised consolidated interim storage in the earlier phases of our project. The GNF Initiative itself was founded through the joint efforts of Steven E. Miller and former project codirector Scott D. Sagan.

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Foreword

Robert Rosner

Dealing with used fuel produced by civilian nuclear power plants has proven to be a politically charged issue for virtually all nations that have embraced nuclear power. Debates about the ultimate disposal of this material range from concerns surrounding safety and security to disagreements about the value of the used fuel: is it to be regarded as waste, to be disposed of permanently, or should it be viewed as a valuable commodity, capable of being reused as nuclear fuel after appropriate processing?

The few extant examples of successful siting of civilian nuclear waste repositories—such as by the Swedish Nuclear Fuel and Waste Management Company in Sweden—clearly point to the critical importance of clarity and transparency in the processes leading to site selection and construction, as well as to the central role of *willing* local participation in these processes. These characteristics are key to repository siting that is perceived as fair and that speaks directly to the safety and security fears that inevitably surround any discussion of nuclear technology. There is, however, another key element common to all extant successful siting exercises: a prior agreement between all concerned parties about the nature of the repository. Is the site intended for retrievable disposition or for permanent storage?

In the cases of many of the countries that are "newcomers" to nuclear power, a further constraint is the feasibility of repositories: both the technical suitability of in-country sites (for example, is the local geology sufficiently well characterized and sufficiently stable to allow for safe disposal?) and the financial burden of building and maintaining the type of repository the nation desires. Newcomers may resolve these problems by partnering with likeminded countries pursuing nuclear power; such partnerships can potentially ease the search for suitable geological repositories (by enlarging the search area) and ease the cost burdens (by distributing the fixed costs over a larger user base). But critical to these partnerships is a shared vision of the nature of the repository: is the spent fuel retrievable or not? This requirement has proven problematic in practice. In our discussions with stakeholders in a number of newcomer states, it has become evident that there is no universal agreement on this point. But without agreement, it is difficult to imagine a pathway toward multilateral nuclear repository storage.

With this conundrum in mind—and acknowledging the increasing urgency of dealing with used-fuel storage, especially in certain "legacy" nations where little progress has been made in dealing with the nuclear waste currently accumulating at reactor sites—Stephen Goldberg, James Malone, and I developed a concept for internationally supervised consolidated interim storage.[1] The fundamental idea was to get past the obstacle of making a choice about the nature of the repository by moving used fuel from the cooling pools located in the vicinity of the reactors to a consolidated dry-cask storage facility as soon as practicable. This facility would be operated under international supervision, would be located in a willing partner state according to the multilateral interim storage agreement, and ownership of the used fuel would remain with the states that produced it. Thus, the used fuel could be stored safely and securely for tens of decades and could be, in principal, retrievable. Moreover, there would not be a need for the partner states to agree on the economic value of the used fuel; and by actively seeking partners that include both newcomers and legacy states, it might be possible to devise an economically feasible implementation plan.

This publication serves the purpose of fleshing out this concept. The first chapter, by Lenka Kollar, describes in substantial depth the various issues of governance and liability that arise when implementing a multilateral consolidated interim storage facility. The second chapter, by James Malone, provides a detailed discussion of the economics of such a facility; that is, it builds a business plan for multilateral consolidated interim storage. In both contributions, the authors focus not only on the final state—that is, the operation of such a facility—but also on the processes that will lead to it (as well as the challenges that stand in their way). This is an important point: many ideas in the nuclear domain capably describe a future nirvana but come to grief when faced with the task of outlining their implementation—the transition from the "here and now" to the desired state. It is our hope that—with the addition of these two discussions—conversations regarding multilateral consolidated interim storage can move forward to the next stage: namely, concrete discussion of potential legal frameworks that will allow implementation of the storage concept.

1. Stephen M. Goldberg, Robert Rosner, and James P. Malone, *The Back-End of the Nuclear Fuel Cycle: An Innovative Storage Concept* (Cambridge, Mass.: American Academy of Arts & Sciences, 2012).

Chapter 1

Back-End of the Nuclear Fuel Cycle: Governance and Liability

Lenka Kollar

EXECUTIVE SUMMARY

As countries continue to delay the management and disposal of used nuclear fuel, there is growing interest in a multilateral approach to the back-end of the nuclear fuel cycle. States are interested in multilateral storage facilities to consolidate used fuel until a permanent repository has been constructed or a fuel recycling technology that presents less of a proliferation risk is developed. If executed correctly, this multilateral interim storage proposal will have many benefits for the international community. In this chapter, issues pertaining to stakeholders, governance, and liability for the multilateral approach are discussed. We offer the following recommendations to make this proposal a success:

- The host state needs to volunteer to host the facility and the community in which the facility is sited must be chosen by a consent-based approach. Clear economic, technical, and political incentives should be presented to attract a host.
- Customer states will also need to agree to participate in the multilateral facility, which must attract business on the strength of the political and technical benefits it offers.
- A host state should meet the same International Atomic Energy Agency (IAEA) standards of safety and security as are required of states that want to become nuclear powers and thus needs to have developed the human and technical capital necessary for compliance.

- The facility should include a research and development (R&D) program to explore storage integrity and new technologies for fuel recycling that lower proliferation risk.
- All participating states should be in good standing with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and other nuclear-related conventions, and have a safeguard agreement with the IAEA. Participating states should also implement the IAEA's Additional Protocol and work with the IAEA from the beginning of the facility design in order to establish robust safeguards.
- The facilitating entity to manage the multilateral used-fuel storage facility will need to be able to make decisions quickly and effectively while also remaining transparent, credible, and accountable to customers and the international community.
- The facility should be regulated by an independent organization and also allow for oversight by the IAEA and international community.
- Customers should remain the owners of the used fuel, which will be returned to them upon completion of the period outlined in the storage agreement. As part of the agreement, customers are required to have a used-fuel management and disposition policy in place. This plan should include the laws, regulations, and procedures to site and construct a permanent disposal repository, as well as a timeline that customers must adhere to, lest they be fined. By strictly requiring this of participating states, the multilateral facility forces states to plan for disposing of their used fuel far in advance.

BACKGROUND

The storage and permanent disposal of used nuclear fuel has been an issue for nuclear states and their advocates since nuclear power was first harnessed to generate electricity for public consumption in the mid-1950s. Although the technical means to build repositories exist, siting a permanent location in which to dispose of nuclear material for thousands of years is difficult and often inspires significant pushback from politicians and the public. After efforts to establish a permanent civilian nuclear waste repository in the United States failed, President Obama organized the Blue Ribbon Commission on America's Nuclear Future (BRC) to reevaluate the repository siting process and also make recommendations for the future of nuclear energy in the United States.[1] Similar situations in which governments have invested substantial resources to research and choose

1. Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy," January 2012, http://www.energy.gov/sites/prod/files/2013/04/f0/brc_finalreport_jan2012.pdf.

a disposal site only to later be rejected by the public (or other parties) have occurred in such nuclear power states as Germany and the United Kingdom. Other states, such as France and Japan, are reprocessing fuel and storing vitrified high-level waste in interim storage facilities to delay the need for permanent waste repositories. Finland and Sweden have successfully sited geologic repositories, but the facilities are still under construction and are not currently open.

In the case of countries that are now in the process of embarking on a civilian nuclear energy program, the question of what to do with the nuclear waste that will be produced remains open to discussion. In response, the American Academy's Global Nuclear Future (GNF) Initiative has focused on advancing effective policies and procedures that help minimize the international security and nonproliferation concerns associated with the spread of nuclear energy, including an emphasis on the back-end of the nuclear fuel cycle. This chapter explores the governance and liability issues associated with the innovative used-fuel storage concept proposed by the GNF Initiative.[2] This multilateral interim used-fuel storage concept is designed as a consensus-based approach to the back-end that would limit proliferation risks by consolidating nuclear waste generated by power plants in an internationally supervised interim storage facility. The facility will attract participants from both the facility's immediate region and around the world and will allow for international oversight by the International Atomic Energy Agency (IAEA). Using existing dry-cask storage technology, such a facility would store up to ten thousand metric tons of used nuclear fuel (on a relatively small footprint) for time scales on the order of one hundred years.

Due to the growth of nuclear energy and the mix of legacy and newcomer civilian nuclear power states in the region, South Asia, East Asia, and Southeast Asia are the primary targets of this back-end storage arrangement. Although other regions are also experiencing growth in nuclear energy, the Asian nations appear to have the most aggressive plans, and some, such as Vietnam, are currently seeking contracts and putting the regulatory infrastructure in place.[3] The storage concept is designed to prevent the debilitating arguments about "spent" fuel reprocessing that now stand in the way of moving toward internationally supervised nuclear waste consolidation; and it allows for the possibility that if recycling technology advances to provide a more proliferation-resistant and economically advantageous fuel cycle, the stored used fuel could become a valuable commodity.[4] In addition, the agreements made with the storage facility can even accelerate the siting and construction of repositories by requiring customers to have the policies in place and to adhere to a timeline to

2. Goldberg, Rosner, and Malone, *The Back-End of the Nuclear Fuel Cycle*.

3. World Nuclear Association, "Emerging Nuclear Energy Countries," February 2014, http://www.world-nuclear.org/info/Country-Profiles/Others/Emerging-Nuclear-Energy-Countries/.

4. The question of whether to reprocess fuel is currently both a question of economics and of proliferation concerns, given the current state of reprocessing technologies that separate out plutonium. Whether this will continue to be the case depends on future technological developments, and a key aspect of this interim storage strategy is to buy time while simultaneously moving toward internationally supervised nuclear waste consolidation.

dispose of the used fuel. While repositories are constructed, the international community can be assured that used fuel is stored in a safe and secure manner at an internationally supervised storage facility.

GOVERNANCE OF THE MULTILATERAL INTERIM STORAGE FACILITY

As already alluded to, the multilateral used-fuel interim storage concept presents many challenges, including: 1) preserving the inalienable right of a state to pursue nuclear energy technology as a customer or provider of services; 2) making the proposal economically attractive to potential customers; 3) attracting a state to host an interim storage facility; and 4) fusing together interests that run the gamut from immediate fuel recycling with current technology to a permanent ban on any current or future advanced partitioning and potential recycling technology.[5]

The multilateral back-end approach must provide ample flexibility to attract customers, appeal to a host state, and benefit stakeholders. The primary benefit for customers is to minimize the immediate need for local interim used-fuel storage and to avoid the need to make immediate decisions about reprocessing.[6] Newcomers to the nuclear energy sector will primarily benefit from a multilateral used-fuel storage option. Most legacy states have yet to develop a concrete solution to the back-end of the nuclear fuel cycle and would benefit from a longer-term interim storage facility while they build a permanent repository or develop more economically plausible and more proliferation-resistant recycling technology. The host state of the facility would experience economic benefits in the form of monetary incentives and infrastructure development.[7] The international community benefits from multilateral used-fuel storage facilities by providing incentives for states to forgo their right to reprocess and ensuring that the used fuel is stored in an internationally supervised and secure manner. The latter has been a particular concern of the international community of late, due to the risks associated with the build-up of onsite pool used-fuel storage, as evidenced by the 2011 disaster at the Fukushima Daiichi plant in Japan.

The IAEA and members of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) are especially interested in used-fuel management methods that increase safety and security. There are many opinions within the international community on the effectiveness and strategy of multilateral nuclear facilities. In 2005, the Multinational Approaches (MNA) Expert Group set up by the IAEA

5. Goldberg, Rosner, and Malone, *The Back-End of the Nuclear Fuel Cycle.*

6. In other words, countries that already view nuclear waste as a potential energy resource can avoid committing to building retrievable repositories while the technologies for reprocessing remain economically questionable and problematic from the proliferation perspective.

7. See Chapter 2, “Back-End Governance and Liability Business Plan,” in this publication.

outlined a set of approaches that seeks to increase nonproliferation confidence while preserving assurances of supply and services in nuclear energy. It reads:

1. Reinforcing existing commercial market mechanisms on a case-by-case basis through long-term contracts and transparent suppliers' arrangements with government backing. Examples would be: fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks.

2. Developing and implementing international supply guarantees with IAEA participation. Different models should be investigated, notably with the IAEA as guarantor of service supplies, e.g., as administrator of a fuel bank.

3. Promoting voluntary conversion of existing facilities to MNAs, and pursuing them as confidence-building measures, with the participation of NPT non-nuclear-weapon States and nuclear-weapon States, and non-NPT States.

4. Creating, through voluntary agreements and contracts, multinational and, in particular, regional MNAs for new facilities based on joint ownership, drawing rights or co-management for front-end and back-end nuclear facilities, such as uranium enrichment; fuel reprocessing; disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.

5. The scenario of a further expansion of nuclear energy around the world might call for the development of a nuclear fuel cycle with stronger multilateral arrangements—by region or by continent—and for broader cooperation, involving the IAEA and the international community.[8]

The very nature of the multilateral interim used-fuel storage approach introduces governance and liability issues. To ensure the success of this venture, the interests of all stakeholders—including the host state, legacy holders, newcomer states, and the international community—must be leveraged to provide benefits to all parties. The following sections discuss the involved stakeholders, structure of the corporate entity, stages of governance during the storage facility operation, liability issues, and nonproliferation and security issues. This discussion is followed by recommendations on the governance and liability of the back-end fuel cycle storage facility.

8. 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, February 22, 2005, http://www.iaea.org/sites/default/files/publications/documents/infcircs/2005/infcirc640.pdf.

Stakeholders

Host State

The used-fuel storage facility will be located in the host state. This state will have jurisdiction of the facility and responsibility for its regulation, either by an existing or newly formed independent government entity. The host state is also the primary stakeholder to ensure the safety and security of the facility. The host government will have a unique relationship with the entity that owns the storage facility. This entity may be state-owned, a federal corporation, a commercial corporation, or an international consortium. In addition, the host government will need to negotiate the applicable bilateral arrangements with customer states. States have various export control laws that need to be upheld in the case of transfer of nuclear technology and material.

The proposed back-end concept outlines incentives for a state to serve as a host to a multilateral storage facility. The economic incentives include fee payments from customers, infrastructure development, and the growth of high-quality employment. In addition, the host state benefits from technical advancement and research and development (R&D) programs. There may also be political benefits: used-fuel management is a prominent nuclear energy and nonproliferation issue and any country that can provide an international solution will gain a positive reputation in the nonproliferation regime. It is imperative that these incentives are realized by the host state and that provisions, such as fees and payments by customers, are agreed to before the construction and opening of the facility.

The primary requirement for a host state is for it to be in good standing with the NPT, the IAEA safeguards agreement, and other international conventions in the nonproliferation regime. States in "good standing" with their international safeguards agreements have been verified by the IAEA to have not diverted any nuclear material to a weapons program, as reported in the annual Safeguards Implementation Report. "Good standing" with the NPT, and even other international nonproliferation conventions, is more difficult to discern. Requirements for achieving and remaining in good standing with the NPT should be outlined in any agreements made with host and customer states. Whether the host state is experienced in nuclear energy and the nuclear fuel cycle or a newcomer to nuclear technology, all international guidelines for nuclear safety and security need to be enforced by the state and facility. The IAEA has a series of safety standards for radioactive waste management, including standards for used-fuel storage.[9] In addition, the IAEA has guidelines

9. International Atomic Energy Agency, "Safety Standards: Radioactive Waste Management," http://www-ns.iaea.org/standards/documents/topics.asp?sub=170.

for states for the development of a national infrastructure for nuclear power.[10] A state that wishes to become a host should meet the same standards of safety and security (and thus technological readiness) as do states that want to become nuclear power states under IAEA guidelines. Therefore, the host does not need to have reactors (and so does not need to be either a legacy or a newcomer state); but it does need to have developed the human and technological capital that the IAEA outlines. If not already a member, the host state should also consider joining the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which is the first legal instrument to directly address these issues on a global scale.[11] Discussions on multilateral used-fuel storage facilities through the Joint Convention are discussed later in this chapter.

Crucial to the success of a robust governance and liability arrangement is that the host state be a *willing* participant in the international back-end fuel services. The state must volunteer as a host and the facility should be sited by a consent-based approach. This approach was recommended by the BRC after lessons were identified from the successes and failures of radioactive waste management enterprises in the United States (see "The Consent-Based Approach for Site Selection," page 23).[12] A prime example is the Yucca Mountain Nuclear Waste Repository, which was proposed to be the site of commercial used-fuel disposal by the U.S. Department of Energy (DOE), but failed to become operational due to pushback from the State of Nevada, despite the support of the immediate local community. The site was mandated by law and not chosen on a consent-basis. Another example is the Pangaea Resources proposal, in which a United Kingdom–based company identified areas around the world that they found to have the most appropriate geological features for an international nuclear waste repository, one of which was located in the Australian outback. This proposal was not well-received by the Australian public and government, and the Western Australian parliament even passed legislation to make it illegal to dispose of foreign high-level waste in the province.[13]

Beyond consent, the host state must also have the opportunity for a back-end R&D program to research storage integrity and recycling techniques that lessen proliferation risks, as described in the supplementary section "Used-Fuel

10. International Atomic Energy Agency, *Milestones in the Development of a National Infrastructure for Nuclear Power* (Vienna: International Atomic Energy Agency, 2007), http://www-pub.iaea.org/books/IAEABooks/7812/Milestones-in-the-Development-of-a-National-Infrastructure-for-Nuclear-Power.

11. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management," INFCIRC/546, December 24, 1997, http://www.iaea.org/sites/default/files/publications/documents/infcircs/1997/infcirc0546.pdf.

12. Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy."

13. World Nuclear Association, "International Nuclear Waste Disposal Concepts," April 2012, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/International-Nuclear-Waste-Disposal-Concepts/.

R&D Program." Funding for this program will be drawn from customer storage fees, and customers may allow for the use of their fuel for such R&D activities. The R&D program benefits both the host state and the customers. The host state will benefit from technical infrastructure developed by the R&D program, which would include laboratories, equipment, and quality employment.[14] The customers benefit in the long term from a back-end R&D program that may lead to the development of more robust technologies for fuel recycling, storage, and disposal. Agreements must outline that the results of the R&D program are available to all participants of the multilateral storage facility.

A key question faced by the consolidated interim storage concept is how to ensure that the facility indeed does function as an *interim* storage facility. How can the host nation ensure that the storage facility located within its borders does not in time morph into a permanent repository? One proposal to address this problem is to structure the bilateral fuel storage agreements between the host and the customers as time-limited arrangements: after a certain period of time (for example, fifty or one hundred years), the stored fuel either must have already been moved to a repository or reprocessing facility or have been returned to the customer. In this way, the customer country is deeply incented to make a decision regarding the permanent disposal of its nuclear waste; and by implication, ownership of the stored nuclear waste would remain with the customer state.

Customers

The customers of the multilateral storage facility are divided into legacy holders and newcomers (as described below). Much like the host state, customer states will participate in the multinational back-end arrangements on a voluntary basis. The present legal framework of the NPT does not allow for the requirement of a state to participate in multinational arrangements.[15] Therefore, a newcomer state, for example, cannot be required to participate in international fuel cycle services or forgo development of any fuel cycle technology in order to develop a nuclear power program. It is furthermore not guaranteed that if a state participates in fuel cycle services then it will not develop fuel cycle technology, such as enrichment and reprocessing. This is an important consideration in gaining customer and international support for a multilateral storage facility. Ultimately, the proposed interim storage concept must "sell" on the strength of its economic, political, and technical arguments. A shared interim facility allows sharing of expensive storage and transportation infrastructure and allows for the postponement of decisions regarding reprocessing. Both the customer state's public and the international public will see this facility as an internationally certified safe and secure path for nuclear waste. This concept allows technological developments to blossom without forcing anyone's hand about making potentially irreversible decisions in the here and now.

14. See Chapter 2, "Back-End Governance and Liability Business Plan."

15. International Atomic Energy Agency, "Multilateral Approaches to the Nuclear Fuel Cycle."

Although the IAEA cannot mandate it, the multilateral arrangement itself can require that certain parameters be met by a state in order to participate as customers in the storage facility agreement. Such parameters should be identical to the requirements for the host state mentioned above. First and foremost, the customer needs to be in good standing with the NPT and its international safeguards agreement.[16] In addition, all international guidelines for nuclear safety and security need to be followed by the state: namely, the IAEA safety standards for radioactive waste management.[17] If not already a member, the customer should also consider joining the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.[18]

Another major requirement for customer states needs to be an assurance to the host state that there is a final disposal plan in place for the used fuel upon its return to the customer. Even if the fuel is recycled, a plan must still be in place for the resulting radioactive waste. This interim storage facility must not serve as a de facto disposal facility or a mechanism for states to delay dealing with the "used-fuel problem." Customer states can ensure that there is a permanent disposal plan in place by embracing the necessary laws, regulations, and procedures for selecting, siting, and constructing a radioactive waste repository. Although this does not guarantee that a repository will be open by the time the used fuel is returned to the customer, it does put in place an obligation to do so; thus, pressure from the host state and international community will keep the customer accountable.

The differing needs and issues of customer states should also be considered on a regional basis. For example, Asian legacy fuel holders such as Japan and South Korea have a very different perspective than European legacy holders,[19] and the ASEAN (Association of Southeast Asian Nations) newcomer states have a very different view of the nuclear order than newcomer states in the Middle East and Africa (MENA).[20] While the framework of the multilateral arrangement should be beneficial to all customers, the terms used to attract customer states can be tailored to states' particular interests. ASEAN newcomer states are each looking to build a relatively small number of reactors and are thus interested in consolidating used-fuel storage in the region. On the other hand, MENA states may be more interested in multilateral storage to reduce proliferation risk.

16. States that are not party to the NPT but have a safeguards agreement with the IAEA (India, Pakistan, and Israel) should be considered as customers on a case-by-case basis.

17. International Atomic Energy Agency, "Safety Standards: Radioactive Waste Management."

18. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management."

19. With the exception of France, which generally shares opinions with Japan and South Korea.

20. ASEAN has already declared the region a nuclear weapons–free zone, but MENA states are at a high risk of proliferation due to political tensions and existing unofficial nuclear-weapons states in the region.

Legacy Holders

Legacy holders are states with existing nuclear energy programs that already have an inventory of used fuel in interim pool and dry storage. With the exception of the few states that have sited permanent disposal repositories (such as Norway and Sweden) or that already reprocess their fuel (France), the majority of nuclear power states have a build-up of used fuel. Most of this fuel is stored on-site at nuclear power plants either in pools or in dry storage if the pools are nearing capacity. Many states are waiting for the large nuclear power states, such as the United States, to go through the process of disposing of used fuel before they venture down this complex path. Some states may also be allowing time for a more proliferation-resistant recycling technology to be developed. There are also states that have yet to make a firm decision or policy on the issue of used fuel. For these reasons, a multilateral interim storage facility is attractive to states that are having difficulty disposing of used fuel or waiting for better options.

As the first customers of the multilateral interim storage facility, legacy states—which need the storage facility more urgently than newcomer states—will provide the funding to build the facility. The organization of the operating entity will need to appeal to legacy states in order to attract them as the first customers. Further, the legacy states' existing relations with the host state must not be a deterrent. Legacy states are concerned about the integrity, safety, and security of the used fuel being stored in another state. The host needs to ensure that the used fuel is stored in a manner so that it can later be returned to the customer.

Legacy states also have existing export control laws that need to be considered when transferring nuclear material and technical information about the material. Some states require a bilateral nuclear agreement, the negotiation of which may depend on the good standing of the host state within the nonproliferation regime. All major nuclear power states are members of the Nuclear Suppliers Group and model their export control laws accordingly. Most important, the host state needs to assure its customers that their used fuel will not be used for a nuclear weapons program.

Newcomer States

States currently constructing, planning, or exploring their first nuclear power plants are newcomers to the nuclear industry. Although not in immediate need of storage solutions, these states are nonetheless interested in assured back-end services for their future used fuel. Many of these states have limited expertise in nuclear technology and will only construct a small number of nuclear reactors. Multilateral back-end services are attractive in that the newcomer state will not need to further develop interim storage. Used-fuel storage has become a major nuclear issue in many legacy states, but assured back-end services would alleviate these concerns for newcomer states.

Therefore, newcomer states are most concerned about the guarantee of back-end services if they do not develop back-end technology themselves. For example, what happens when a state develops a nuclear energy program with the plan to store used fuel at a multilateral storage facility, but when it comes time to store the fuel, the facility is full or shut down? This would present a major problem to a state that does not have the nuclear R&D program or technology to develop the back-end of the fuel cycle. How can the host state and operating entity ensure that back-end services will be there when newcomer states start unloading used fuel? The contract must therefore have provisions that allow for agreed-to storage capacities that are legally enforceable under international trade laws so that the performance obligation belongs to the host state.

Newcomer states will also have the same safety and security concerns for their used fuel as legacy states. Moreover, they will likely need assistance with transporting the fuel to the facility. (Ownership during the transportation phase is discussed more in later sections.) Finally, newcomers will need to have a plan in place for the used fuel once it is returned, after the duration of the storage agreement.

International Community

The international community is a major stakeholder in this concept and includes all states and organizations that are involved in the nonproliferation regime and nuclear industry. The international community is interested in multilateral storage facilities in order to mitigate the safety concerns and the risk of proliferation from the back-end of the fuel cycle. By providing back-end services, it is less likely that a state will pursue current reprocessing technology to reuse the material in the fuel.[21] At the same time, multinational back-end services encourage the growth of nuclear power, especially for newcomer states that are concerned about used-fuel disposal. The growth of nuclear energy is favorable for nuclear supplier states.

As the leading international organization for nuclear technology and the nonproliferation regime and also as a supporter of international fuel cycle services, both front-end and back-end, the IAEA has taken particular interest in this venture. As mentioned previously, the international treaty on the safety of spent-fuel and radioactive-waste management produced by the IAEA in 1997 requires that any national or multinational facility meet the highest national and international standards. The convention affirms the importance of bilateral and multilateral mechanisms to enhance the safety of radioactive-waste and spent-fuel management and also in assisting less developed nations with the obligations of the convention.[22] Although multilateral and regional facilities have been mentioned in past meetings of the convention,[23] the summary of

21. For example, see PUREX and its aqueous variants, which separate out plutonium and are thus problematic from the proliferation perspective.

22. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management."

23. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: Third Review Meeting of the Contracting Parties," JC/RM3/02/Rev2, Article 20, May 2009, http://www-ns.iaea.org/downloads/rw/conventions/third-review-meeting/final-report-english.pdf.

the most recent meeting in 2012 states that "the long term management of spent fuel and high-level radioactive waste remains a challenging and difficult topic with considerable areas for improvement" and that it must be taken "into account from the very beginning of any nuclear activities, such as in expanding nuclear power programmes."[24]

The IAEA should take some part in the formation and management of the interim storage facility and governing entity. The IAEA will also be responsible for supervising the implementation of safeguards for the used fuel at the facility. The material at the storage facility and that used in the R&D program will be eligible for international safeguards measures and inspections according to the safeguards agreements of both the host state and the customers. Although the fuel will remain under the ownership of the customer, its location in the host state will complicate international safeguards obligations.

Other international organizations that may be stakeholders in back-end fuel cycle services include regional nuclear and nonnuclear organizations, such as the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), the European Atomic Energy Community (EURATOM), and the Arab Atomic Energy Agency (AAEA). Other international organizations may also be consulted: the World Institute for Nuclear Security (WINS) for security considerations; the Nuclear Suppliers Group (NSG) for export control guidelines; and the World Association of Nuclear Operators (WANO) for safety best practices.

Structure of the Facilitating Entity

Once the host state is identified, the actual entity that will manage the facility should be formed. The structure of this entity may be state-owned and -run, a federal corporation, a commercial corporation, or an international consortium. Each type of organization presents different advantages and disadvantages in governing and operating the facility. In order for a multilateral fuel storage facility to be a success, the facilitating entity must be able to do the following effectively:

- Attract and negotiate with customer states;
- Assist in forming the necessary bilateral and/or multilateral agreements between the host state and customer states;
- Have the technical expertise to manage the transportation, transfer, and storage of used fuel;
- Be independently regulated by national or international authorities;
- Have open communication and a working relationship with the host state;
- Have the ability to operate protective security forces;

24. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: Fourth Review Meeting of the Contracting Parties," JC/RM4/04/Rev.2, May 2012, http://www-ns.iaea.org/downloads/rw/conventions/fourth-review-meeting/summary-report-english.pdf.

- Accept international safeguards on nuclear material;
- Make decisions quickly in response to safety or security issues;
- Remain transparent, credible, and accountable;
- Maintain operational stability even in times of national, regional, or global instability; and
- Accept input from members, customers, and the international community.

The degree of implementing authority that this entity has is crucial to the success of the facility, especially when safety or security concerns arise. An organization that is too bureaucratic or has too many stakeholders with authority cannot make and implement decisions in a timely or effective manner. An international consortium could be designed to ensure that all members have input and influence, while still being structured to enable quick and effective decision-making. The facilitating entity can have a board of directors in which representatives of the regional and international community are present. In addition, the IAEA and/or regional nuclear authority need to have a seat at the table in order to ensure that the highest standard of safety and security guidelines are followed. The entity needs to be transparent, credible, and have political authority.

While a state-owned and -run facility is a possibility, past experience has shown that existing government organizations are not necessarily the most effective at managing used-fuel storage. This was yet another lesson learned from the BRC, which recommends that a new organization be formed (separate from the DOE) to implement the waste management program. Further, this should be a federal organization with the sole purpose of waste management "to provide the stability, focus, and credibility" and possess a "substantial degree of implementing authority and assured access to funds." Finally, the organization needs "rigorous financial, technical, and regulatory oversight" by the appropriate government agencies.[25]

When considering the structure of the facilitating entity and associated customer contracts, existing international fuel cycle arrangements can be consulted for best practices. For example, France reprocesses fuel from other countries and then sends the material (MOX[26] and radioactive waste) back to the customer. Russia provides fuel-leasing services to other countries, wherein Russia remains the owner of the fuel. These arrangements are further discussed in the supplementary secion, "Case Studies of International Fuel-Conditioning and Fuel-Leasing Arrangements."

In the case of an international storage facility, oversight may be provided by an existing international organization, such as the IAEA, or by a newly formed international or regional organization. The host state's existing independent nuclear regulator should provide safety and security regulation and oversight.

25. Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy."

26. Mixed uranium-oxide plutonium-oxide fuel.

The differences between laws governing federal and commercial corporations vary from state to state and should be taken into account when forming this entity. The ownership of the entity will impact its ability to implement and make decisions and also its ability to attract customer states. There must be confidence in the facilitating entity for customer states to trust the host with used-fuel storage for a significant period of time.

The long timeline for this facility—one storage agreement can last for up to about one hundred years—also introduces the issue of regional stability, especially considering how often borders have changed in the past century. For example, Slovenia's current capital, Ljubljana, has politically been part of seven different countries in just the last century. Revolutions and coups d'état are now occurring in states around the world. Civil wars and regional tensions in the future can have a significant impact on the safety and security of a storage facility. This may increase the importance of an independent governing entity and oversight by an international authority. A multilateral arrangement can protect the facility against political situations in a customer or host state; thus, the facility oversight should not belong to a single state. While the host state may be the sole or main owner of the facility, oversight and additional stakeholders should include other nations, companies, and international organizations. Procedures implemented by a multinational or international entity need to be formally established in case the facility location is compromised by changing borders, war, natural disaster, or other causes.

Stages of Governance during the Storage Facility Operation

Transportation to and from the Storage Site

The storage of used fuel in a multilateral facility begins with the transfer of that fuel from the customer to the facility in the host state. Agreements need to outline which party will be responsible for the transportation of the fuel at which phases, including loading the fuel into transportation casks from pool or dry storage. This endeavor is complicated and involves technology that a newcomer state or a state with a small nuclear program may not possess. Therefore, the host entity should assist with or completely handle transportation of the used fuel to the storage site. The multilateral storage facility is only economical if all of the costs of the infrastructure for transportation are spread among the participants.

Transportation regulations for radioactive material in the customer state, host state, and any states within the travel path must be taken into account. Although nuclear material has been transported internationally for many decades, there may still be significant hold-up and delays in processing radioactive material at border crossings. The IAEA publishes many international safety regulations for the transportation of nuclear material.[27] If not done already,

27. International Atomic Energy Agency, "Transport Safety: Published Safety Standards," http://www-ns.iaea.org/standards/documents/topics.asp?sub=250.

the integrity of all transportation routes needs to be inspected according to national regulations. Some countries and locales also maintain a nuclear-free zone, which—depending on the specific legislation—may or may not apply to the transportation of high-level radioactive materials. Piracy in international waters must also be considered a risk for the transportation of used fuel. If not already in place, the host state will need to establish sound infrastructure for accepting and transporting used fuel at ports and through borders on roadways and railroads. These same considerations must be taken into account when transporting the used fuel offsite either to a disposal or recycling facility or back to the customer.

Governance at the Storage Facility

The question of who owns the used fuel when it is stored at the multilateral facility is important. In this storage concept proposal, the customer maintains ownership of the fuel and the host state returns the fuel at the end of the storage agreement. However, the host entity manages the fuel in the facility and therefore is liable for the safety and security of the material, which is discussed later in this chapter. The main concern here is how much input the customers and the international community have in the management of the used fuel onsite. The character and extent of customer involvement will be outlined by the nature of the host entity and the contracts to which the participants agree.

Ownership and Liability at the End of the Storage Agreement

Since this proposal involves a multilateral interim storage (not disposal or repository) facility, used-fuel storage agreements will be for a finite time period, after which the used fuel is sent back to the customer state, who must have the means to deal with it domestically. A major fear is that states will use the multilateral storage facility as a cop-out and will not take steps to ensure that they can dispose of or recycle the used fuel once it is returned. As discussed previously, the storage agreement should require the customer to have a policy and plan in place for how the used fuel will be managed once it is returned. This plan should include the laws, regulations, and procedures to site and construct a permanent disposal repository. Even if the customer decides to recycle the fuel, disposal will be needed for the subsequent radioactive waste. Including this plan in the storage agreement will allow the host state and multilateral entity to pressure the customer into following through with the plans.

The storage agreement should include financial and/or political penalties in the event that the customer does not have a proper used-fuel strategy in place at the conclusion of the agreed storage period. One option is for the customer to set forth a timeline with milestones for used-fuel disposition that is included in the storage agreement. If the milestones are not met by the proposed dates, the multinational storage facility can fine the customer. For example, if the customer agrees to have a repository sited by 2050 and does not follow through, then the customer state will be fined yearly until the repository is sited. This will encourage customers to adhere to their used-fuel policies and remain accountable to the terms set forth in the storage agreement. Returning the used fuel to the customer at the end of the storage agreement will also be punishment in itself if they do not have the means to handle it. There would be public outcry and the government would be pressured to immediately take action to store or dispose of the fuel. In severe cases, if the customer does not take back the fuel or pay the associated fines, the international community can enforce embargos and sanctions until the state has an action plan to handle and dispose of the used fuel. This strategy might not work in states with isolated economies, and this issue needs to be addressed further.

Some envision that in the future we could develop a recycling technology that is more proliferation-resistant and is thus welcomed by the nuclear nonproliferation community. In that case, the used fuel in storage could be viewed as a commodity: fuel whose recycled uranium and plutonium could be reused in reactors for energy. Such a recycling facility could be built in the host state and customers could opt to have their fuel recycled there. In this case, nuclear material and the associated radioactive waste would still need to be returned to the customer. There may be a case in which the customer country no longer has a nuclear power program and opts to sell its recycled nuclear material. Even in this case, again, the associated radioactive waste from the recycling process would still be returned to the customer. Therefore, in any scenario, the customer must have a plan for the final disposal of high-level radioactive waste, as outlined in the storage agreement.

If such recycling technology does exist in the future, then used fuel may be seen as a commodity and valuable resource: the uranium and plutonium within it may be used to produce energy. A situation may arise in which the host state chooses not to return the fuel to its customer, thus breaching their contract, and instead recycles it for profit or to satisfy its own fuel needs. Since this used fuel will be under IAEA safeguards, withholding the transfer of the fuel back to the customer can be seen as a diversion of nuclear material and therefore a breach of the host's safeguards agreement. While international pressure and sanctions may prevent or resolve such a situation, this scenario also requires further exploration.

Another scenario worth considering is if a multinational permanent repository for used fuel were to open while the storage facility is still operating. In this case, customers may opt to have their used fuel or radioactive waste from recycling disposed of in this facility. This does not mean that customers should not have their own plans in place for a permanent repository. But if a multinational repository is planned before customers send their used fuel to the interim storage facility, there can be an option of using the multinational repository instead of the customers' own.

Liability Issues

In the case of an accident or security breach, the host-customer contract must clearly state who is liable and to what extent. One such scenario may involve the loss of integrity in the cladding of used-fuel assembly over time. If an accident occurs, who is responsible for the cleanup? In addition, accidents may occur during transportation, while transferring assemblies, or even due to a natural disaster. Security breaches may involve the attempted theft or destruction of the material. Such situations need to be taken into account when negotiating contracts and insurance for the storage of the used fuel.

Such liability issues also need to be taken into account when designing the structure of the facilitating entity. If the host country and entity do not agree to take full liability for the nuclear material during transportation and once it is on-site, agreements need to outline the terms of liability for possible future events. International oversight by the IAEA, for example, may need to determine liability in some cases; however, it should be noted that the host entity needs to have authority to immediately take action in the event of an accident or security breach in order to mitigate unwanted outcomes and deal with the situation.

Liability and insurance are not new issues to the nuclear industry. For example, these same challenges are present in the United States, where fresh fuel is manufactured and shipped by different companies, not by the owner of the fuel. Similarly, fresh fuel is shipped across international borders, raising a number of questions about liability. There is also experience in shipping used fuel internationally, as with France's international recycling operations.[28] These arrangements should be referenced when considering liability and insurance for shipment to and storage of the used fuel in the multilateral interim storage facility.

Nonproliferation and Security Issues

While one of the goals of multilateral interim used-fuel storage is to mitigate proliferation risks, there are still some nonproliferation issues that need to be considered in this proposal. First of all, all nonnuclear-weapons states party to the NPT are subject to international safeguards according to agreements made with the IAEA. Nuclear material is safeguarded according to state ownership and not necessarily the physical location of the material. For example, used fuel from a nonnuclear-weapons state sent to a nuclear-weapons state for reprocessing is still subject to safeguards under the origin state's agreement. With a multilateral facility accepting material from different states, it may be difficult for the IAEA to implement safeguards according to each state's agreement. In particular, some states are implementing the Additional Protocol (AP) while others are not or are still in the beginning phases.[29] If a state's used fuel is stored

28. See "Case Studies of International Fuel-Conditioning and Fuel-Leasing Arrangements."

29. International Atomic Energy Agency, "Status of Additional Protocols," November 2014, http://www.iaea.org/safeguards/protocol.html.

in another location, it may be more difficult for the IAEA to reach the "broader conclusion" and determine that there is no clandestine nuclear activity in that state. Therefore, safeguards approaches for the storage facility should be considered prior to design and construction of the facility to allow for ease of inspections and accounting. Not only will the IAEA need to verify fuel assemblies, it will verify that they belong to the declared state of origin. IAEA access to the facility and nuclear material can also be limited if the host state or participating states have not implemented the AP, which allows IAEA inspectors full access to any nuclear-related facilities in a state and the ability to employ a variety of safeguards measures, such as environmental sampling and open-source analysis. If the host state has implemented the AP but one of the customer states has not, inspectors may not be able to employ the full set of safeguards measures on that facility. Further complications may arise if a state has a safeguards agreement but is not party to the NPT (India, Pakistan, and Israel currently fit this description). The host state and facilitating entity need to work with the IAEA to develop a safeguards plan prior to constructing the facility and also include safeguards provisions in agreements with customer states.

In addition to safeguards issues, the multilateral agreement faces nuclear export control issues, which are complicated by the varying export control laws in each state. As discussed earlier, it may be necessary for the host state to negotiate bilateral and multilateral nuclear trade agreements with customer states in order to legally transfer nuclear material and technical information. In some cases, bilateral agreements need to be made with the state in which the technology was originally developed. For example, South Korea uses nuclear technology from the United States, and any such technology transfer between South Korea and another state must also be sanctioned by the United States via a bilateral agreement. Any technical assistance with regards to safety, training, and operations is also subject to export control.

Experts from outside of the host state should be recruited to take advantage of the best expertise in interim storage design and operation at the facility. This is especially important if the host state is a newcomer to nuclear energy or not as experienced in interim storage. Given the structure of the multinational facility, there will also likely be international personnel from contracting and owner companies. So it is important for the facilitating entity and regulatory agency to have strict policies that mitigate the risk of insider threats within the facility that may be presented by both national and international personnel. These provisions include background checks, security surveillance, and personnel screening tests. Such practices are already common in the nuclear industry worldwide because of the sensitive technology. However, policies should not be so strict as to discourage international participation and recruitment of expertise from around the world.[30]

30. For more on insider threats, see Matthew Bunn and Scott D. Sagan, *A Worst Practices Guide to Insider Threats: Lessons from Past Mistakes* (Cambridge, Mass.: American Academy of Arts & Sciences, 2014).

Significantly, if it can be shown that the international consolidated interim storage concept is both economically advantageous and—on the basis of international standards—demonstrably safe and secure, then individual states that are potential customers may face considerable public pressures to join, should they be offered the opportunity. Furthermore, this concept presents a more politically palatable way for states to behave as if they had signed a 123 Agreement, without actually having entered into one.[31]

CONCLUSION & RECOMMENDATIONS

The proposed multilateral approach to the back-end of the nuclear fuel cycle will have many benefits for the international community if executed correctly. States are interested in multilateral interim storage facilities to consolidate used fuel until a permanent repository has been constructed or fuel recycling technology that presents less of a proliferation risk is developed. Governance and liability issues need to be taken into account in order to create a successful multilateral approach to a storage facility. This chapter discussed the issues pertaining to stakeholders, governance, and liability, and presented recommendations for the multilateral approach.

The first key to making this proposal a success is that all stakeholders must be willing participants in the multilateral arrangement. Many approaches to managing used fuel around the world have failed due to backlash from the public and participating communities. It is imperative that the host state volunteers to host the facility and that the community is chosen by a consent-based approach. Clear economic, technical, and political incentives should be presented to attract a host. A host state should meet the same standards of safety and security as do states that want to become nuclear power states under IAEA guidelines. Thus, the host state need not necessarily have an experienced nuclear power program, though it should have developed the IAEA-outlined human and technological capital required of the project.

Customer states must also be willing participants in the multilateral facility, which will have to sell itself on the basis of the economic, political, and technical benefits it offers. All participating states should be in good standing with the NPT and other nuclear-related conventions and have a safeguards agreement with the IAEA. States should also have signed and placed into force the Additional Protocol to allow for more robust international safeguards. Because of the complications of safeguarding a facility containing material from multiple countries, the IAEA should be involved in the facility design from inception.

The facilitating entity to manage the multilateral used-fuel storage facility will need to be able to make decisions quickly and effectively and remain trans-

31. In particular, the concept offers states the opportunity to commit to not reprocessing used nuclear fuel within their borders.

parent, credible, and politically accountable. In addition, the facility should be regulated by an independent organization while also allowing for oversight by the IAEA. The host state and entity will negotiate contracts with customers and manage the transportation and storage of the used fuel. However, the customers remain the owner of the fuel and it will be returned to them at the end of the storage agreement. In order to prevent the storage facility from becoming a disposal facility, the storage agreement should require the customer to have a policy and plan in place for how the used fuel will be managed once it is returned. This plan should include the laws, regulations, and procedures to site and construct a permanent disposal repository, along with a timeline—enforced by a system of fines—to which the customer must adhere. By strictly requiring this of participating states and thus forcing states to take action, plans for disposing of used fuel may move more quickly than they would without the multilateral facility.

One of the biggest concerns surrounding the development and expansion of nuclear energy, as expressed by policy-makers and the global public, is the issue of used fuel. The multinational interim used-fuel storage proposal is meant to provide customer states with a facility to store used fuel while permanent repositories are built and/or better recycling technologies are developed. The program may even accelerate the siting and construction of repositories by requiring customers to have long-term policies in place and to adhere to an agreed upon timeline. Finally, the international community can be assured that the used fuel is stored in a safe and secure manner in an internationally supervised storage facility.

The Consent-Based Approach for Site Selection

CANADA'S PLAN FOR THE LONG-TERM MANAGEMENT OF USED FUEL

In 2007, the government of Canada devised a plan for the long-term management of used fuel entitled the "Adaptive Phased Management" approach. It involves an informed and willing host community and the development of a large infrastructure project by the Nuclear Waste Management Organization (NWMO).[32] This approach is very similar to that recommended by the BRC in that a site is chosen on a consent-basis and an independent organization implements the project. For this multilateral storage facility, Canada recommends that a similar approach be used for selecting a host state and community.

The Adaptive Phased Management approach is a multistep process whose implementation began with the open publication of its strategy. That first step—launching a program to provide information to the public—initiated the facility siting process. Communities then identified their interest in learning more about becoming a host of the repository. In 2013, *at the request of the community*, feasibility studies were conducted for eight of the twenty-one interested communities. Moving forward from the present, communities with confirmed suitable sites will decide whether they are willing to accept the project, and the NWMO will enter into a formal agreement with the preferred host. Furthermore, regulatory authorities will review the safety of the project through a public process. After the successful construction and operation of a demonstration facility, construction and operation of the repository will begin in continuing partnership with the host community.[33]

The following guiding principles of the project also exemplify that this is a consent-based and transparent site selection process:

- Safety, security, and protection of people and the environment are first and foremost.
- The host community must be informed and willing to accept the project.
- Communities will only be considered for this project if they willingly enter the process.
- Communities that decide to participate have the right to end their involvement at any point up to and until a final agreement is signed.

32. Nuclear Waste Management Organization, "Canada's Plan for the Long-Term Management of Used Fuel: Step 1. Initiate Process," http://www.nwmo.ca/sitingprocess_theprocess.

33. Nuclear Waste Management Organization, "Canada's Plan for the Long-Term Management of Used Fuel: Review the Steps," http://www.nwmo.ca/sitingprocess_thesteps.

- The host community has a right to benefit from the project.
- The questions and concerns of surrounding communities and those on the transportation route must be addressed.
- The NWMO will involve all potentially affected provincial governments.
- The siting process will respect Aboriginal rights and treaties and will take into account unresolved claims between Aboriginal peoples and the Crown.[34]

USED-FUEL MANAGEMENT IN SWEDEN AND FINLAND

Used-fuel management strategies in Sweden and Finland can also provide some lessons learned for the consent-based approach in siting a used-fuel repository. The Swedish nuclear utility SKB began its final disposal process by sending letters to municipalities across the nation asking them to voluntarily apply to host a repository. Two communities agreed to participate in a feasibility study but had trouble gaining public support for continuing the siting process. SKB then decided instead to approach communities that already had a history of supporting nuclear installations, mainly municipalities with existing nuclear power plants in the area. Two sites were found to be suitable and polls showed support from the residents. SKB then applied for a license to construct a repository near the Forsmark nuclear plant in Östhammar. The BRC acknowledged Sweden's process as a good example of a consent-based approach to siting a repository.[35]

Finland followed Sweden's approach in choosing potential sites before engaging with local citizens and also in using a nongovernmental entity to manage the used fuel. While there was some pushback from the local community, an agreement that included repository requirements and the provision to move the fuel if it did not meet those requirements was finally reached. In both Sweden and Finland, the economic benefit to the local communities was successfully used as a selling point because these communities were already benefitting from existing nuclear infrastructure. Sweden and Finland are the farthest along in opening the first commercial used-fuel repositories in the world.[36]

34. Nuclear Waste Management Organization, "Canada's Plan for the Long-Term Management of Used Fuel: Overview: Selecting a Site," http://www.nwmo.ca/sitingprocess_overview5.

35. Nuclear Energy Institute, "Other Countries Provide Lessons for U.S. in Managing Used Nuclear Fuel," February 13, 2014, http://www.nei.org/News-Media/News/News-Archives/Other-Countries-Provide-Lessons-for-US-in-Managing.

36. Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy."

Used-Fuel R&D Program

The opportunity to host a back-end R&D program is part of the benefits package to attract states to become hosts of the multilateral storage facility. The purpose of the R&D program will be to research storage integrity and recycling techniques that have less of a proliferation risk than current practices. Funding for this program will be derived from customer storage fees, and customers may allow for the use of their fuel for R&D activities. These research activities may include, but are not limited to, the design and development of enhanced:

- Used-fuel storage containers and their integrity over time;
- Containers for the final disposal of used fuel and radioactive waste;
- Transportation of used-fuel storage containers;
- Safeguards techniques for used fuel in dry storage;
- Detectors and equipment for safeguarding used fuel;
- Chemical and other separation techniques for radioactive material; and
- Used-fuel recycling technology that is less of a proliferation risk.

The host state will benefit from the technical infrastructure developed by the R&D program, which will include laboratories, equipment, and quality employment. The customers benefit in the long term from a back-end R&D program that may develop more robust technologies for fuel recycling, storage, and disposal. Agreements must outline that the results of the R&D program are available to all participants of the multilateral storage facility.

Case Studies of International Fuel-Conditioning and Fuel-Leasing Arrangements

International fuel-leasing arrangements have proven popular with some states both because they do not require customers to build indigenous fuel cycle capabilities and because the suppliers can benefit economically. Some arrangements allow customers to completely avoid the issue of dealing with used fuel in-country, which is especially attractive to states with small nuclear power programs. The downside of these arrangements is energy security: customers must usually depend on only one supplier.

INTERNATIONAL USED-FUEL RECYCLING IN FRANCE

International back-end fuel cycle services already exist in the form of used-fuel reprocessing. A prime example is the service provided by France to reprocess used fuel from other countries and return it as MOX (mixed uranium-oxide plutonium-oxide) fuel and vitrified waste. France has reprocessed fuel from The Netherlands, Belgium, Switzerland, Japan, and Germany. The structure of the agreements between France, customer states, and the IAEA can be used as an example for multilateral arrangements for interim used-fuel storage. When France enters into an agreement with another state to treat its used fuel, a date by which the waste must be returned to the customer state is agreed upon. The customer owns the material through the entire process. This is not uncommon in the nuclear industry; for example, nuclear power plant utilities in the United States purchase uranium and then send it to various facilities—owned by different companies—for enrichment and fuel fabrication, though the utilities maintain ownership of the material throughout the processes.

The international safeguards agreement between France and the IAEA also outlines the provisions for safeguarding nuclear material that belongs to non-nuclear-weapons states while it resides in France. This material is subject to safeguards measures and inspections and France must declare all material received from and sent to other states. The location of this material while in France must also be declared.[37] When designing a safeguards approach for the multilateral interim storage facility, lessons can be learned from how safeguards are applied to foreign-owned nuclear material.

37. International Atomic Energy Agency, "Protocol Additional to the Agreement between France, the European Atomic Energy Community and the International Atomic Energy Agency for the Application of Safeguards in France," INFCIRC/290/Add.1, February 2005, http://www.iaea.org/sites/default/files/publications/documents/infcircs/1981/infcirc290a1.pdf.

RUSSIAN FUEL-LEASING ARRANGEMENTS

Russia has long provided fuel to states that have reactors based on Russian technology and it is one of the strongest proponents of international fuel banks and fuel-leasing arrangements. Russia already has fuel-leasing arrangements with several states in which it provides fresh fuel, leases it to the state while it is burned in the reactor, and then takes back the fuel for treatment. If the fuel is reprocessed, the waste must be returned to the lessee, according to Russian law. However, current practices are to take back Russian-origin used fuel without waste return. This arrangement especially appeals to newcomer states without a nuclear fuel cycle infrastructure.[38]

38. World Nuclear Association, "International Nuclear Waste Disposal Concepts."

Chapter 2

Back-End Governance and Liability Business Plan

James P. Malone

THE BACKGROUND AND THE ISSUES

Nuclear power has several vulnerabilities in the forum of public opinion, but the "back-end" of the nuclear fuel cycle may be the most vexing: no nation has managed to deal with this issue without encountering well-organized public opposition (although Russia and France have not experienced public opposition to reprocessing). Further, none of the solutions put forth have won broad international acceptance.

The dual influence of politics and technology complicates the situation for nations with nuclear programs in the early stages of development. Rather than select a permanent used-fuel management solution, it is in the best interest of developing nuclear power programs to choose a back-end strategy that provides safe and cost-effective used-fuel management without requiring a commitment to either an open or closed fuel cycle.

Delaying the selection of an open or closed fuel cycle allows developing nuclear programs to make more informed choices later on: political issues related to used-fuel management can mature; nonproliferation issues can be addressed; and used-fuel management technology can continue to advance. However, in the interim it is prudent to offer nuclear states and states with nuclear ambitions a temporary solution that permits delaying the final decision on back-end technology.

Regionalized interim storage offers a potential buffer between the time that fuel is discharged from the reactor and such time that a permanent solution is selected by the state where the fuel was used. Establishing regionalized storage will require a combination of political, diplomatic, and technological prowess. Prerequisites include infrastructure, technology selection, regulatory oversight, International Atomic Energy Agency (IAEA) oversight, on-site management, effective communications, and commercial agreements ratified by all participants.

All of these requirements must be addressed in a business plan, which also functions as a project plan for the opening stages of the interim storage program. Once construction begins on facilities and infrastructure, the business plan splinters into strategies tailored for each individual site. Segmented and organized temporally, our business plan begins with the first organizational steps and proceeds along a timeline that culminates in commercial operation of a regional interim storage facility.

Financial support of the plan is required prior to when owners of used fuel held in storage at existing nuclear power plants, known as legacy fuel, enter into a regional storage agreement. The investment is needed both to form the regional entity that will provide storage and to begin marketing the concept to potential customers. The business plan calls for opening funding of $10 million to $20 million for this work. The proposed source of the funds is a nongovernmental organization (NGO) whose investments will be returned upon receipt of payment from the owners of the legacy fuel or by proceeds from a commercial fundraising effort.

BUSINESS PLAN PHASE ONE

The first steps of the business plan include creating interest in the project, establishing a commercial entity to legally operate the business, developing a service contract covering transportation and storage of the used fuel, and establishing a regional entity to manage political negotiations and interactions. Once these foundations are in place—or nearly so—it is then appropriate to solicit interest from countries who may consider serving as hosts to the interim storage facility. These conversations require that the business entity negotiate a package of benefits that the country will receive in return for its willingness to host the facility.

After a host country has accepted its role, the next step is to establish bilateral agreements between the host and each country that seeks to send fuel to the interim storage facility.

ESTABLISHING INITIAL INTEREST

The first customers will be the nuclear power plant operators who are storing used fuel at their reactor sites. This legacy fuel has been discharged from the power plant and cooled for at least five years and is thus available to be shipped to the regional interim storage facility. Establishing interest will require meeting with the owners of used fuel in order to introduce the regional storage concept to them. To attract their interest, the following advantages of central interim used-fuel storage should be stressed:

- The fuel is removed from their power plants at a cost that is competitive with the current cost of storage;
- The cost of security to safeguard the used fuel is no longer the responsibility of its owner;
- The regulatory oversight burden is shifted to the interim storage provider and the host country;
- The proliferation threat inherent to the fuel owner having access to potentially weaponizable material is eliminated; and
- In the case of permanent disposal in the host country or another country, the used fuel would not have to be returned to the country of origin.

The project will incur legal fees, regulatory fees, managerial fees, and travel and overhead expenses. There are also costs associated with convening meetings to discuss the concerns of potential participants. The cash to cover these fees is best provided by the owners of the legacy fuel via their initial payments as customers of the project.

The establishment of a business entity to manage the interim storage facility will also incur several expenses. Upfront cash will be needed to support:

- The establishment of a regulatory agency in the host country;
- The preparation and submission of a license application;
- Infrastructure (dock facilities, roads, rail, communication);
- The initial incentive payments to the host country; and
- The legal work to establish a standard service contract.

While negotiating contracts with prospective customers, the business entity will also negotiate supply contracts for establishing the storage facility. The supply contracts will include the storage facility, rail and road improvements, sea transportation arrangements, and harbor facility improvements. Construction of the storage facility is a substantial challenge, but before engineering work can commence, the local licensing authority must be established and must put regulations—covering all aspects of design and construction—in place.

Establishing a regulatory agency would be a substantial undertaking for a host country that does not have a nuclear power program already in place. A host country that *does* have a nuclear program may still lack the expertise to establish the regulatory regime for centralized used-fuel storage. Both time and money are required to establish this expertise. The initial focus of the regulatory regime should be site qualification. Qualification depends on satisfactory seismic data and sufficient drill cores to characterize the substrata beneath the proposed site for both the storage pad and any necessary heavy-load pathways. To avoid the potential for claims of conflict of interest related to the site's characteristics and the data obtained by drilling, it is prudent to establish the criteria for acceptable site parameters prior to investigating the location. The cost of site characterization will be covered by phase two of the project.

BUSINESS PLAN PHASE TWO

Phase two of the business plan is directed at the initial project financing. The opening stages of phase two will include refining the draft contracts for transportation and storage, as well as detailing the design of the regional interim storage facility. Drafting plans for the transportation of the fuel to the interim storage location is also part of this phase.

Finalizing the standard contracts for transportation and interim storage is a key step: they will supply the basis for the commercial arrangements that, in turn, will provide the financial community with the confidence it needs to support the concept. The transportation contract is a simpler arrangement than the storage contract since the technology required to provide the transportation service is well-known and has been used for many years. There are no insurmountable issues related to the transportation contract. But finalizing the storage contract is not so straightforward. One issue in particular requires resolution prior to the facility accepting any used fuel for interim storage: liability for an event that may occur in the future. A storage facility with a lifetime of more than one hundred years could very well outlive the corporations that entered into the agreement. Should an event occur that results in harm to individuals or the environment after a signatory corporation ceases to exist, there must be a way to determine liability for the event.

Establishing an insurance pool is one method to provide the financial means to protect against a future event. Conducting an analysis of possible event scenarios will help insurance experts assign probabilities to and make estimates of the liabilities associated with these events. The appropriate funding level for the insurance pool can be determined based on the results of such analysis. Resolution of the long-term liability issue is likely to be a precondition for current owners of used fuel to agree to store fuel at the regional facility.

Establishing the insurance pool requires a relatively complete facility design; and the facility design and operating procedures will provide the framework for insurance policies. In addition, the facility design and operating procedures will support advance contracting for the holders of legacy fuel, who—critically—will be the first to sign contracts for transportation and storage. The commercial storage contract for legacy-fuel owners will require advance payments totaling $100 million to $300 million in aggregate. The regional authority will use this income for completing the construction and licensing of the facility. The advance payments from legacy-fuel owners will also serve to provide confidence in the project for international financial institutions who may also invest in the facility.

The incentives package model for the host country must be in place before an agreement can be reached, and the details of the package can be negotiated with each country that expresses interest in hosting a facility. The incentives package can include infrastructure improvements such as rail and road facilities, harbor improvements, water purification systems, upgraded electrical distribution, and other needs for operation of the storage facility. The infrastructure improvements are anticipated to cost approximately $230 million. This amount can be amortized over the first ten years of operation. Based on the cost of the infrastructure improvements, the storage fee should be set at $0.0006 per kilowatt hour of electricity generated by the fuel.

However, the incentives should not be limited to the needs of the facility. If necessary, additional incentives can be offered to induce a country to host the facility. These incentives may include a personnel training center that provides a broad range of training subjects, many of which can be applied to other enterprises in the host country. A materials research facility could be established to support the used-fuel storage facility, a potential disposal facility, and other businesses. Conducting research on a disposal facility would not commit the host country to also hosting the disposal site, though it would not rule it out either. Partnerships with universities recognized for their excellence in research would also serve the facility and host country as a whole.

The incentives could also address needs that are particular to a certain country. For example, a water desalination facility could appeal to coastal countries. The possibilities are quite broad and should be the subject of detailed research, with the stated goal of providing facilities that will benefit the host country in a variety of ways over the long term. Because construction of these benefits facilities will require significant cash—which will ultimately come from income related to operation of the interim storage facility—the incentives must be carefully considered.

Preparing an incentives package that also highlights the safety and soundness of the business and nonproliferation guidelines will bring comfort to potential lenders. A compelling presentation illustrating the cash-flow model will help convince the financial community that the project will be self-sustaining over the long run and will increase the likelihood that investors will front the money for the host country's infrastructure improvements. The business entity should strive to pay back any loans as quickly as possible. This will inspire further confidence in the financial community and perhaps assist in future financing negotiations.

BUSINESS PLAN PHASE THREE

Phase three of the plan primarily concerns implementation. Infrastructure and relationships from prior phases must be in place before the implementation phase can begin. Not least among these is the regulatory agency for the host country, which must be up and running and have already approved construction of the facility. The composition of the regulatory body should also be a subject of discussion. There may be a temptation to employ a regional regulatory body; however, this concept is not workable. The host country must have an independent regulatory authority.

The construction for the used-fuel storage facility will provide storage for 10,000 MTU (metric tons of uranium). According to the World Nuclear Association's 2013 market report, about 11,000 MTU are discharged annually from the world's nuclear power reactors.[1] There are economies of scale related to the size of the facility and advantages related to being able to store approximately two hundred and fifty reloads. Currently licensed technology is capable of storing thirty-seven pressurized water reactor or eighty-seven boiling water reactor used-fuel assemblies.[2] The thirty-seven pressurized water reactor fuel assemblies have a uranium mass of about 17 MTU; the eighty-seven boiling water reactor fuel assemblies have a uranium mass of about 15 MTU.

The IAEA has reported that the Republic of Korea in 2006 held a used-fuel inventory of 7,286 MTU. This inventory has since grown, and South Korea may now be considered a legacy-fuel holder candidate. In the same period, Japan held 13,000 MTU of used fuel.[3] Due to the disaster at Fukushima Daiichi, Japan may have an additional incentive to store legacy fuel at an alternative regional facility.

There are practical limits to the amount of used fuel that can be held at a regional storage facility. The shipping capacity is a significant limiting factor. The ability to unload the used-fuel canisters from the ship and transfer them to a rail car is another limitation. Likewise there is a limit to the quantity of used fuel that can be delivered to the regional facility and processed for long-term storage. These limits are related to the availability of qualified personnel as well as to the availability of the necessary equipment (such as transfer casks).

Due to the large quantity of legacy fuel available to be transferred to the regional facility, the initial 10,000 MTU capacity can be reached relatively quickly. Once capacity is met, expansion of the facility is not difficult; the expansion may take place while the initial 10,000 MTU storage facility is operating. And once the legacy fuel is accounted for and has been transferred to storage, there would be continuous used-fuel input to the regional storage facility as plants are refueled. The flow of material to the facility needed to reach equilibrium of operation is expected to be 40 MTU per reload. The number of reactors participating in the interim storage program will determine the speed at which the facility must be expanded.

Growth of the storage facility is an important parameter for the business since it determines the income stream that will contribute to the ongoing obligations of the host country's incentive package. Income is based on the number

1. World Nuclear Association, *The Global Nuclear Fuel Market: Supply and Demand 2013–2030* (London: World Nuclear Association, 2013).

2. NAC International, "The MAGNASTOR System: The New Generation in Multipurpose Storage," http://www.nacintl.com/magnastor.

3. The International Atomic Energy Agency, "Estimation of Global Inventories of Radioactive Waste and Other Radioactive Materials," IAEA-TECDOC-1591, June 2007.

of MTU in storage; based on the estimated income of $25,000 per year per storage cask, the estimated annual storage fee is $1,600 per MTU. Basing the storage fee on MTU rather than the number of casks will enable equitable pricing into the future: storage cask technology continues to improve and it would not be equitable for the newer higher-capacity casks to command the same fee as the earlier-generation casks.

CASH FLOW PARAMETERS AND ANALYSIS

The underlying premise behind cash flow calculations for the interim storage facility is that the business receives income from two fees. The first fee is referred to as the used-fuel acceptance fee: $0.0006 per kilowatt hour electric generated by the fuel. The price was selected to be less than the fee charged to U.S. utilities by the U.S. Department of Energy (DOE); it is 60 percent of the fee charged by the DOE in the standard contract. The major difference is that the DOE standard contract includes disposal of the used fuel in a geologic repository. The regional interim storage contract does not include disposal: if permanent disposal becomes possible, a separate contract with appropriate costs will be written.

The second fee is the annual storage fee, which is based on the total number of MTU in storage. This fee would be reviewed periodically to assure that the business can meet its financial obligations to the host country. The financial model data can be used to conduct sensitivity analyses on the fees for transportation and interim storage in the proposed contracts.

The financial analysis begins with the transportation services. Transportation of used fuel requires a dedicated ship approved for high-level radioactive waste. The analysis assumes that a five-thousand dead-weight-ton vessel can transport up to forty used-fuel packages. The operating cost for the transportation vessel is estimated at $1,832,000. This value assumes that the fuel is transported ten thousand miles from the point of origin to the destination port.

Transportation overpacks are estimated to cost $4 million per unit. The overpacks are reusable, and the maintenance cost is included in the total cost of the overpacks. Once the fuel arrives at the interim storage location it is transferred from the transportation overpacks to the storage overpacks. The canisters containing the fuel are sealed at the point of origin and do not require being reopened. The combined cost of one canister and one storage overpack is estimated at $1 million. The storage overpacks are made of concrete and will be manufactured at the interim storage location.

There is a series of one-time expenses accounted for in the budget. These expenses include the transfer system used to move the used-fuel canister from the transportation overpack to the storage overpack ($5 million), the associated equipment to operate the transfer system ($5 million), facility design ($1 million), administration and laboratory building design and construction ($10 million), and construction of the first storage pad ($10 million per acre). A one-acre storage pad can hold 193 storage modules or about 3,280 MTU. Reaching the goal of storing 10,000 MTU will require about three acres of storage-pad space. The significant one-time cost for twenty transportation overpacks is $80 million.

The estimated total cost of the operational storage facility is $111 million. The annual cost of supporting facility operations is estimated at $63,663,000. Based on a fee of $0.0006 per kilowatt hour electric—and using the fuel burnup and a thermal efficiency of 33 percent—the estimated income for the first year of operation of the interim facility is $130,560,000. (The fee calculation may be adjusted as more accurate information becomes available.)

Critical to those who will provide financial backing for the business, the cash flow is positive from the first year of operations. First year net cash flow is estimated to be $30 million, and net cash flow through the first fourteen years of operation is estimated at $754 million. While that amount appears quite large, the cash flow analysis does not address the cost of the negotiated incentives package for the host country.

There is ample opportunity to improve the business plan as the project evolves. Because different approaches may be needed in the future, it is most important now to create a flexible financial model that can be relied on or modified as needed to evaluate alternative approaches. The values in the current budget are based on relevant U.S. industry experience with used-fuel storage; we believe they are reliable.

SENSITIVITY ANALYSIS

As is the case with any large-scale project, the cost-estimating process is less than perfect. This uncertainty may be better understood by conducting a sensitivity analysis of the relevant parameters. The parameters that can have the most significant effect on the project's financial performance are predominantly those that require large financial investments at the project's onset.

The infrastructure improvements related to the harbor and rail lines are estimated to cost $230 million. If this estimate is within plus or minus 50 percent of the actual cost, the impact is a gain or loss of about $23 million in year one. Since the infrastructure improvement cost is amortized over the first ten years, the financial impact is concentrated in that time frame: the net cash flow of year five changes by plus or minus $69 million if the cost impact is plus or minus 50 percent.

Perhaps the most important sensitivity is the fee for the service. Iteration of the formula finds the fee value at which the revenue and expenses are approximately equal over time to be $0.000126 per megawatt hour thermal. Converting to megawatt hour electric yields a value of $0.000378. This value is about 40 percent of the DOE fee in the standard contract. The sensitivity shows that there is adequate margin in the proposed fee structure to support the program. The proposed fee for the service is $0.0006 per kilowatt hour electric provided by the fuel. This higher-than-break-even fee will fund a portion of the insurance pool.

There is an open question regarding the expenses associated with the return of the fuel to the country of origin after the storage contract has expired (anywhere from twenty to one hundred years after it is signed). Rather than attempting to predict the exact cost of transportation and handling for an indeterminate future, we propose that there be a separate fee for return of the fuel.

The preliminary balances for the model case show a large surplus after twenty years of operation. Some customers may view the projected surplus as excessive and thus feel that the fee should be reduced. However, the surplus should be considered not as profit but as an insurance pool to cover expenses in the unlikely case of an event resulting in damage where clear liability cannot be established.

Much work remains to be completed prior to actually moving fuel. The important conversations with potential host countries, funders, politicians, and nuclear agencies must take place; efforts to date have laid the groundwork to make this possible. Obtaining feedback from the stakeholders is the next step.

Summary of Costs Related to Establishing and Operating a Regional Spent-Fuel Storage Facility

Initial Expenses		
Infrastructure Improvements		
Harbor, including Docks	$20,000,000	
Cranes	$20,000,000	
Rail Head Facility	$20,000,000	
Road Improvements	$20,000,000	
Rails and Roadbed	$150,000,000	
Infrastructure Total		**$230,000,000**
Storage Facility Expenses		
Transport Overpacks	$80,000,000	
Facility Design	$1,000,000	
Building Construction	$10,000,000	
Transfer System	$5,000,000	
Equipment	$5,000,000	
Initial Storage Pad	$10,000,000	
Storage Facility Expense Total		**$111,000,000**
Operating Expenses		
Security, Administration, and Maintenance Personnel	$20,000,000	
Operating Expense Total		**$20,000,000**
Transportation from Utility to Storage Facility		
Transport Ship Cost per Trip	$1,850,000	
Fuel Container Cost per Trip	$20,000,000	
Total Cost per Trip	$21,850,000	
Two Trips per Year Total		**$43,700,000**

Annual Estimated Expense and Revenue Summary
(Thousands of U.S. Dollars)

Year	Expense		Revenue		Net
	Capital	Operations & Maintenance (O&M)	Acceptance	Storage	
0	94,000	6,670	130,560	0	29,890
1	63,000	63,664	130,560	0	3,896
2	23,000	63,664	130,560	0	43,896
3	23,000	63,664	130,560	0	43,896
4	33,000	63,664	130,560	0	33,896
5	23,000	63,664	130,560	1,000	44,896
6	23,000	63,664	130,560	2,000	45,896
7	23,000	63,664	130,560	3,000	46,896
8	23,000	63,664	130,560	4,000	47,896
9	33,000	63,664	130,560	5,000	38,896
10		63,664	130,560	6,000	72,896
11		63,664	130,560	7,000	73,896
12		63,664	130,560	8,000	74,896
13		63,664	130,560	9,000	75,896
14		63,664	130,560	10,000	76,896
15		20,000	130,560	11,000	121,560
16		20,000	130,560	12,000	122,560
17		20,000	130,560	13,000	123,560
18		20,000	130,560	14,000	124,560
19		20,000	130,560	15,000	125,560
20		20,000	130,560	16,000	126,560

NOTES ON EXPENSE AND REVENUE SUMMARY

1. Initial capital expense includes one pad, equipment, transfer system, building construction, facility design, ten transport overpacks, and 10 percent of the infrastructure cost.
2. Year 1 capital expense includes ten transport overpacks and 10 percent of the infrastructure cost.
3. Years 4 and 9 include the addition of one-acre storage pads to the facility.
4. Year 0 O&M costs include one-third of the annual personnel costs.
5. Years 1 through 14 O&M costs include the cost of two shipments and the full cost of one year of personnel.
6. Years 15 and later O&M costs include only the personnel costs because the facility will be full at that time.
7. Acceptance fees are based on $0.0006 per kilowatt hour electric of the fuel received at the facility.
8. The storage fee per canister is $25,000 per year or $1 million per year for forty canisters. This cost recurs each year.

Contributors

Lenka Kollar is an MBA Candidate at INSEAD and is the Owner and Editor of Nuclear Undone, a consulting company and blog that provides information on nuclear energy and nonproliferation issues. Formerly a researcher at Argonne National Laboratory and the National Nuclear Security Administration, she now works on nuclear issues by collaborating with organizations such as the Nuclear Literacy Project, American Nuclear Society, American Academy of Arts & Sciences, and Argonne National Laboratory. She received her Bachelor's and Master's in Nuclear Engineering from Purdue University. She is an active member of the American Nuclear Society, North American Young Generation in Nuclear, and Women in Nuclear. She is passionate about getting more women into the science, technology, engineering, and math (STEM) fields.

James P. Malone is Chief Nuclear Fuel Development Officer at Lightbridge. In 2009, he retired after a decade with Exelon Generation Company, where as Vice President, Nuclear Fuels he oversaw nuclear fuel reload design, safety analysis, and fuel procurement for seventeen operating nuclear reactors; and guided management of used fuel. Before joining Exelon, he served for ten years as Vice President and Senior Consultant at NAC International, advising on fuel reliability and the front- and back-ends of the nuclear fuel cycle. While at NAC, he worked on the international safeguards system for the Rokkasho Mura reprocessing plant in Japan. Previously, he worked at SWUCO, Inc., as a nuclear fuel broker, a manager of technical services, and finally as Vice President; he also served as manager of economic analysis at Yankee Atomic. He began his career in 1968 as an engineer in the utility reactor core analysis section of the Nuclear Engineering Department of United Nuclear Corporation. He is a member of the American Nuclear Society and past Chairman of its Fuel Cycle Waste Management Division.

Robert Rosner is a theoretical physicist who since 1987 has been on the faculty of the University of Chicago, where he serves as the William E. Wrather Distinguished Service Professor in the departments of Astronomy & Astrophysics and Physics, as well as in the Enrico Fermi Institute and the Harris School of Public Policy Studies. He served as Argonne National Laboratory's Chief Scientist and Associate Laboratory Director for Physical, Biological, and Computational Sciences from 2002 to 2005, and was Argonne's Laboratory Director from 2005 to 2009; he was the founding Chair of the U.S. Department of Energy's National Laboratory Directors' Council from 2007 to 2009. He is also the founding Codirector of the Energy Policy Institute at Chicago (EPIC), located at the Harris School of Public Policy Studies and Booth School of Business at the University of Chicago. He was elected to the Norwegian Academy of Science and Letters (as a Foreign Member) in 2004; he is also a Fellow of the American Physical Society. Most of his scientific work has been related to fluid dynamics and plasma physics problems, as well as in applied mathematics and computational physics, especially in the development of modern high-performance computer simulation tools, with a particular interest in complex systems (ranging from astrophysical systems to nuclear fission reactors). Within the past few years, he has been increasingly involved in energy technologies, and in the public policy issues that relate to the development and deployment of various energy production and consumption technologies, including especially nuclear energy, the electrification of transport, and energy use in urban environments. He was elected a Fellow of the American Academy of Arts & Sciences in 2001. He is a member of the Academy's Council and serves as Cochair of the Academy's Global Nuclear Future Initiative.

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