

Interim Storage of Spent Nuclear Fuel

A Safe, Flexible, and Cost-Effective Near-Term Approach to Spent Fuel Management

*A Joint Report from the
Harvard University Project on Managing the Atom and the
University of Tokyo Project on Sociotechnics of Nuclear Energy*



Harvard University



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Executive Summary

THE MANAGEMENT OF SPENT FUEL from nuclear power plants has become a major policy issue for virtually every nuclear power program in the world. For the nuclear industry, finding sufficient capacity for storage and processing or disposal of spent fuel is essential if nuclear power plants are to be allowed to continue to operate. At the same time, the options chosen for spent fuel management can have a substantial impact on the political controversies, proliferation risks, environmental hazards, and economic costs of the nuclear fuel cycle.

Interim storage of spent fuel offers a safe, flexible, and cost-effective near-term approach to spent fuel management that may be attractive regardless of a particular country's perspective on the continuing debate over whether spent fuel should ultimately be reprocessed or disposed of as waste. Today, in fact, there is less divergence among countries in what is actually done with spent fuel than official policy statements concerning reprocessing and direct disposal might suggest. With most of the spent fuel generated each year remaining in storage, a quiet consensus has developed that for the near term, simply storing spent fuel while continuing to develop more permanent solutions is an attractive approach.

Interim storage approaches are not without their problems, however. Political, legal, and regulatory obstacles have limited both expansion of at-reactor storage and establishment of away-from-reactor storage facilities in several countries, putting some reactors at risk of having to shut down if solutions cannot be found. Finding a genuinely democratic process for siting spent fuel storage facilities that builds acceptance of and support for such facilities in the communities and regions where they are located, while

meeting the continuing spent fuel storage needs of the nuclear industry, has posed an enormous challenge. Japan and the United States, in particular, each face complex political and institutional constraints on their ability to expand spent fuel storage capacity. Concepts for international sites that would accept spent fuel from several countries for storage or disposal pose even more complex political issues.

This report is intended to:

- Clarify the current economic and technological status of interim storage of spent fuel in the United States, Japan, and worldwide.
- Illuminate the institutional, legal and political issues with regard to spent fuel storage and its relationship with basic nuclear energy and nonproliferation policies.
- Explore possible policy options to overcome obstacles to interim storage of spent fuel, and assess the advantages and disadvantages of various approaches to both domestic and international spent fuel storage.

On the basis of the analysis in this report, we offer the conclusions and recommendations outlined below.

Conclusions

General

Technology is available to manage spent nuclear fuel safely and securely until permanent management options are implemented.

The diverse technologies now available for storing spent nuclear fuel—from wet pools to dry casks—offer safe,

secure, and cost-effective options for storing the spent fuel generated by the world's power reactors for decades, or for much shorter periods of time, as circumstances warrant. These interim storage possibilities will allow time for permanent options for management and disposal of spent fuel and nuclear wastes to be prepared and implemented with the care they require. Interim storage of spent fuel can also allow time for spent fuel management technology to improve, and for the economic, environmental, and security advantages of different approaches to permanent management of spent fuel and nuclear wastes to become clearer.

There is an urgent need to provide increased interim storage capacity in the United States, Japan, and around the world. Failure to meet this challenge could have serious economic, environmental, and energy-security consequences.

The spent fuel cooling ponds at nuclear reactors in many countries around the world are filling up. Delays in both reprocessing and geologic disposal programs have left reactor operators with far more spent fuel to manage than had been expected when the nuclear plants were built. If additional storage capacity does not become available—whether at the reactors or elsewhere—reactors could be forced to shut down well before the end of their licensed lifetimes. Such a failure to provide adequate capacity to store spent fuel could result in billions of dollars in economic losses, reduced diversity in electricity supply, and more consumption of fossil fuel, emitting additional pollutants and greenhouse gases. Moreover, if the addition of interim storage capacity is not managed appropriately, increasing quantities of spent fuel could end up being stored in less than optimal conditions, reducing safety. Thus, providing additional spent fuel storage is important not just to the interests of the nuclear industry, but to the interests of society as a whole.

Interim storage is a key element of the fuel cycle—regardless of whether the planned permanent option is reprocessing or direct disposal.

Interim storage of spent nuclear fuel is *not* simply a matter of postponing decisions. It is a central element of an optimized nuclear fuel cycle—whether that fuel cycle approach will ultimately involve direct disposal or reprocessing of the spent fuel. While there continue to be strong differences of

opinion over whether spent fuel should be regarded as a waste or a resource—and there is some merit in each view—a consensus is emerging that interim storage of spent fuel is an important strategic option for fuel management, which can be pursued by supporters of both open and closed fuel cycles.

Interim storage is a complement, not an alternative, to moving forward expeditiously with permanent approaches to managing spent fuel and nuclear waste.

Interim storage, by its nature, is a temporary solution, designed to be safe and secure during a defined period when humans and their institutions are monitoring it. It is not a substitute for a permanent approach to the nuclear waste problem designed to provide safety for hundreds of thousands of years. Interim storage approaches should be carefully designed to avoid undermining funding and political support for continued progress toward acceptable permanent solutions for spent fuel management and radioactive waste disposal. Regardless of how much interim storage is provided, facilities for permanent disposal of nuclear wastes will be needed, whether those facilities are intended to hold spent fuel, wastes from reprocessing spent fuel, or both, and interim storage approaches should not be allowed to undermine efforts to develop such facilities. Interim storage should not become a mechanism for this generation to simply leave problems to the next; hence, it is important to make continued progress toward permanent solutions (and a set-aside of sufficient funding to implement them) a part of any interim storage strategy. Indeed, continued visible progress toward the establishment of such permanent waste facilities—providing some confidence that “interim” facilities will not become “permanent”—is likely to be essential to gaining political acceptance for the establishment of adequate interim storage capacity.

Flexibility is crucial to safe, secure, and acceptable management of spent nuclear fuel—and interim storage is crucial to providing such flexibility.

The history of the nuclear age is filled with cases in which billions of dollars were wasted on projects that seemed to make sense when first started, and to which countries became “locked in,” but which were no longer what was needed years later. The economics of different energy

approaches (and projections of what the costs of those approaches will be in the future) change; government policies, political attitudes, and perceptions shift; rules and regulations that set the basic framework for decisions are modified; market structures are transformed; particular projects fail or are abandoned; and technology advances. Because nuclear energy involves very large capital investments that are paid off over decades, and because it is embedded within a web of regulation, political commitments, and government oversight that often adapts only slowly to new circumstances, the nuclear industry has had considerable difficulty maintaining the flexibility to adapt to these changing circumstances. Flexibility, where it can be achieved, is critical to the future of nuclear energy.

Interim storage of spent fuel, which keeps all options open, offers such flexibility in managing the nuclear fuel cycle, and is thus a key element of a fuel cycle optimized for cost, safety, and security. Providing adequate interim storage capacity makes it possible to adapt approaches to permanent management as circumstances change, and to choose the optimum rate at which such approaches should be implemented. Whatever one's view of the future of the nuclear fuel cycle, for example, it does not make sense to incur the costs and risks of reprocessing spent nuclear fuel before the plutonium recovered by reprocessing is needed or wanted, just because there is no room to store the spent fuel. Similarly, it does not make sense to rush spent fuel into a repository before all the necessary studies are completed just because there is no other place to put it. The approaches to interim storage itself should also emphasize flexibility, avoiding being entirely reliant on any single approach or facility where practicable.

A period of perhaps 30–50 years of storage is an appropriate initial figure for planning facilities, but in many cases it may be possible and desirable to implement permanent solutions sooner.

The period over which interim storage facilities are designed to operate should be long enough to offer maximum flexibility, but short enough not to be seen as making them effectively permanent. Thirty to fifty years—the planned operating lifetime of the most recent reactors—in our judgment, is a reasonable planning figure for the lifetime of such facilities. This would require extending the licenses of dry cask storage facilities, which, in the United

States, are licensed only for 20 years. It may often, however, be desirable to implement permanent solutions before the 30-50 year period is complete, for example if a suitable permanent repository becomes available, or a decision is taken that the plutonium in the spent fuel is now needed as fuel. In the future, it may in some circumstances be desirable to consider even longer periods of interim storage. In France, for example, storage periods of as much as 100 years are being examined.

Approaches to the back end of the nuclear fuel cycle should be chosen on their economic, environmental, security, and energy security merits, not on the basis of ideology, sunk costs, or inertia.

In the past, too many decisions have been dictated by momentum of past plans and contracts, or ideological judgments for or against reprocessing. Instead, decisions should be made based on in-depth consideration of which approaches offer the best combination of advantages and disadvantages, for each type of fuel at each particular time. The decisions that result from such analyses may change over time as circumstances change. Just as the United States continues to carry out various types of processing on some types of fuel to prepare them for disposal (from reprocessing to “melt and dilute” processing of aluminum-clad fuels), while placing its primary emphasis on direct disposal, Japan should consider adopting a flexible approach including direct disposal as a possibility for some types of fuel (including, for example, fuels with very low plutonium content that are not attractive to reprocess, such as those from the Japan Atomic Research Institute's reactors).

The most difficult and complex issues facing interim storage are not technological but political, legal, and institutional. Transparency is key in resolving them.

Interim storage of spent nuclear fuel is technically straightforward. The key problems that have made it difficult to provide adequate interim storage capacity for spent nuclear fuel arise from the difficulties of gaining political acceptance for such arrangements by the potentially affected publics, and from the complex web of legal and institutional constraints related to management of spent fuel and nuclear wastes. These constraints vary from one country to the next—but in every circumstance, ensuring a transparent process that allows a well-informed public to feel that

its concerns have been fully addressed will be essential to success.

Safety, Economics, Security, and Technology

If appropriately managed and regulated, interim storage of spent nuclear fuel is very safe.

By its nature, storage is a process with very little going on, and very little that could go wrong that could result in radiation being released. While storage (particularly wet pool storage) does require good design and management to ensure safety—as well as effective, independent regulation—where these are in place interim storage is perhaps the safest part of the entire nuclear fuel cycle. The U.S. Nuclear Regulatory Commission has concluded that dry cask storage of spent fuel would be safe for 100 years.

Interim storage of spent nuclear fuel is cost effective.

The cost of storing spent fuel for 40 years is substantially less than a tenth of a cent (or a tenth of a yen) per kilowatt-hour of electricity generated. In the case of dry cask storage, once the initial capital cost of the casks is paid, the costs of maintaining the fuel in storage are very low. Although interim storage does involve a cost, it allows the higher costs of permanent solutions to be paid at a later date and therefore discounted somewhat, so that the overall fuel cycle contribution to electricity costs need not increase.

If appropriately safeguarded, interim storage of spent nuclear fuel is secure and proliferation-resistant.

Although spent nuclear fuel contains weapons-usable plutonium, the plutonium is bound up in massive, highly radioactive spent fuel assemblies. As a result, it would be difficult to steal and recover the plutonium for use in weapons. Hence, spent fuel poses only modest proliferation risks. Stored spent fuel in either pools or dry casks can easily be secured, accounted for, and made subject to international safeguards, with relatively low costs, intrusiveness, and uncertainty.

Several technologies for interim storage are safe and acceptable—but for many applications, dry cask storage may best meet the needs.

There is a variety of technological options for storage of spent nuclear fuel, including pool storage and several types

of dry storage. Each of the available approaches has been shown through experience to be safe. Each of these approaches has its advantages and disadvantages, and each is likely to find market niches where it is most appropriate. Wet spent fuel pools pose somewhat greater operating complexities and costs than dry storage approaches, but pools have been the technology of choice for a wide range of spent fuel storage applications. Dry storage technologies, especially dry casks, have been increasingly widely used in recent years. The combination of simplicity, modularity, and low operational costs and risks offered by dry cask storage systems make them highly attractive for many storage applications.

Transportation of spent nuclear fuel involves additional costs and risks, but can be safe and secure if managed and regulated appropriately.

Spent fuel transportation around the world has an excellent safety record, and the approaches being used are continually improving. Whenever fuel has to be transported over long distances, there are additional expenses and greater safety and sabotage risks than there would if the fuel just remained stored at a secure location. Transportation is inherently simpler within Japan, where nuclear material is transported by sea to facilities on the coasts, than in the United States, where it sometimes has to cross thousands of kilometers by road or rail.

Political, Legal, and Institutional Factors

In both the United States and Japan, the politics and legal constraints surrounding interim storage of spent fuel are complex, and options for the future are substantially constrained by the legacies of past decisions.

The U.S. government and the U.S. nuclear industry have been attempting to find a site for a large centralized interim storage facility for spent nuclear fuel for decades without success (though two proposals are still in development). This effort has been substantially shaped and constrained by factors such as the initial decisions to provide only a modest amount of storage space at reactor pools; Congress' decision to limit studies of potential geologic repository sites only to Nevada's Yucca Mountain, and to require that any centralized storage facility be in another state; the gov-

ernment's commitment to accept the utilities' spent fuel by January 1998, and the delays in the repository program that made it impossible to meet that deadline; and the legacy of public distrust of both government nuclear agencies and the nuclear industry. At the same time, however, efforts to establish additional dry cask storage at reactor sites have been far more successful, with many facilities established, many more planned, and only a few having raised substantial controversy. Any future decisions on interim storage approaches will have to take these past decisions into account, as these experiences substantially shape political reactions to proposals for management of spent fuel.

In Japan, efforts to expand interim storage capacity for spent fuel are more recent, but have similarly been shaped and constrained by Japan's past decisions—including the commitment to a closed fuel cycle with reprocessing of all spent fuel; the related commitment to remove all spent fuel from reactor sites for reprocessing; delays in the reprocessing program; and the complex web of political, legal, and institutional commitments related to construction of the reprocessing facility at Rokkasho-mura. In Japan too, the increased distrust following recent accidents, particularly the criticality accident at Tokai-mura in 1999, is likely to make developing a process that will lead to public support for building a spent fuel storage facility more difficult. In Japan, the current focus is on developing a large centralized facility, not on the at-reactor storage approach that has so far been more successful in the U.S. political context.

In both the United States and Japan, there is significant local concern over hosting spent fuel storage facilities.

Many communities simply do not want to be host to a facility for storing spent nuclear fuel, for a wide range of reasons. In particular, many communities are concerned about spent fuel storage facilities becoming de facto permanent repository sites. Local opposition has prevented many past proposed interim storage facilities and other nuclear facilities from being successfully established. Such objections pose the largest obstacle to building adequate storage capacity for spent nuclear fuel.

An approach emphasizing transparency, democracy, and fairness can help overcome the obstacles to gain-

ing acceptance for siting interim storage facilities.

In the past, nuclear decisions have often been made in secret, announced, and then imposed on affected communities over their objections—the so-called “decide, announce, defend” approach. This approach has proved in most cases to generate local opposition rather than support, and has contributed to a number of the recent failures to gain approval for siting nuclear and other facilities. Secrecy surrounding key decisions, in particular, while often justified by the desire to avoid exposing proposals to criticism prematurely, tends to breed mistrust and opposition. Communities want transparent access to all the important information they need about the proposed facility and the process of decision; a democratic process that will allow them to ensure that their concerns are fully addressed; and a process for choosing a site that is fair in its allocation of the burdens and benefits from nuclear energy and storage of spent fuel, and does not single out any one particular community against its will.

The process for siting interim spent fuel storage facilities must give the host community high confidence that safety will be assured, that all potential negative impacts of the facility will be addressed, and that the host community will be better off, overall, once the facility is built.

Ensuring that stringent safety standards will be reliably met is absolutely essential to building public support for interim storage facilities for spent nuclear fuel. No community will accept a storage facility it does not believe is safe. Strong and fully independent safety regulation, and opportunities for experts from the community itself to confirm that safety is being maintained, are likely to be very important in building local confidence that safety commitments are being met. Other potential negative impacts of a facility, such as traffic and impacts on the value of local property and products, must also be effectively addressed.

Ultimately, communities are not likely to support the establishment of spent fuel storage facilities in their vicinities unless there is some benefit to them (and to the nation as a whole) in doing so. Thus, fair compensation to communities for the service to society of hosting interim storage facilities is very important. It should not be assumed, however, that simply offering compensation is enough to build support for such facilities—indeed, the evidence suggests

that unless handled with considerable care, such offers of compensation have modest benefit or can even backfire.

Building confidence that permanent management options are progressing, and that interim storage facilities will not become permanent “dumps,” is essential to building public support for establishing interim storage facilities.

In both the United States and Japan, communities near spent fuel management facilities have placed very high priority on ensuring that facilities built to be temporary will in fact be temporary—that ultimately, there will be some more permanent solution for managing the spent nuclear fuel. Building confidence that permanent solutions are progressing and will be available in a reasonable period of time is likely to be a central part of gaining public support for interim spent fuel storage facilities. A variety of approaches to legally, financially, and institutionally linking interim storage to continued progress toward permanent solutions can be envisioned, and may be useful in building public confidence. At the same time, however, it is important not to repeat past mistakes by setting deadlines that cannot be met or committing too firmly to implementing particular approaches decades in the future that may turn out not to be appropriate when the time comes; such mistakes would undermine the flexibility that is one of the key advantages of interim storage of spent nuclear fuel.

The “Facility Siting Credo” offers useful guidance for efforts to implement interim storage approaches that can gain public support.

The “Facility Siting Credo,” with the slight modifications described in this report, can provide a useful framework for building support for siting facilities for interim storage of spent nuclear fuel. The modified credo includes the following goals: achieve agreement that a facility is needed, that the status quo without it is unacceptable; institute a broad-based participatory process; seek consensus; work to develop trust; seek acceptable sites through a volunteer process; consider competitive siting processes; set realistic timetables (“go slowly in order to go fast”); keep multiple options open; choose the storage approaches and sites that best address the problem; guarantee that stringent safety standards will be met; build confidence that storage will be temporary and permanent solutions forthcoming; fully address all negative aspects of the facility; make the host community better off; use contingent agreements (specifying what

happens if something goes wrong); and work for geographic fairness. Not all of these goals can be achieved in every case, but the credo offers a constructive road-map for a transparent, democratic, and fair process to build support for siting interim storage facilities.

At-reactor, centralized, and multiple-site away-from-reactor approaches to interim storage are all acceptable, and each have advantages and disadvantages requiring a case-by-case approach to choosing the best option.

In the United States, there has been substantially greater success with establishing at-reactor dry cask storage facilities than with building a large centralized facility. There is no immediate need in the United States for a large, centralized facility. Nevertheless, there appear to be good arguments for providing at least some centralized storage capacity, for example to handle fuel from reactors that are being decommissioned. In Japan, on-site dry cask storage has been built at only one reactor site, and the government and utilities are working to establish a large centralized storage facility. Successful establishment of such a facility would be highly desirable.

Governments and industry share responsibility for ensuring that spent nuclear fuel is managed appropriately, and both have a role to play in interim storage.

In the United States, legislation has given the government a legal obligation to take responsibility for the spent nuclear fuel generated by nuclear utilities. But with no repository yet available, the spent fuel remains at the utility sites, inevitably creating a shared responsibility for its management. Exactly how this burden will be shared is still being negotiated. In Japan, the spent fuel remains the utilities’ legal responsibility, but the government has key roles to play in providing effective regulation, and defining national plans and policies. At least in the United States, the government may also have a useful role to play in the future in providing limited spent fuel storage capacity on government sites to deal with special needs, such as those of utilities whose spent fuel ponds might be filled before additional storage capacity becomes available.

The government could also play an important role in demonstrating the safety and effectiveness of various storage technologies, an approach that could help ease local concerns over the safety of spent fuel storage. These meas-

ures could be undertaken without interfering with ongoing efforts toward deregulation of the electricity market.

Transportation of spent nuclear fuel can be highly controversial, raising political, legal, and institutional issues that require intensive effort to resolve.

Managing transportation in a way that builds public support, particularly in countries like the United States, where spent fuel has to be transported long distances through many local and state jurisdictions, and where public distrust of nuclear institutions is very high, poses an enormous political and institutional challenge. Resolving it requires implementation of stringent safety procedures; intensive discussion and interaction with the public and with state and local officials to resolve concerns; and careful attention to designing optimal routes.

International Approaches

Proposals for international sites for storage or disposal of spent fuel and nuclear waste pose a complex mix of potential advantages and disadvantages, and face significant obstacles. On balance, it would be highly desirable to establish one or several such facilities over the next two decades.

Each country that has enjoyed the benefits of nuclear energy bears the responsibility for managing the resulting wastes. But this does not preclude the possibility that cooperation among countries could improve efficiency, reduce proliferation risks, and provide other benefits, if managed appropriately. Each proposal related to international storage or disposal of spent fuel and nuclear wastes is unique, poses different issues, and needs to be evaluated carefully on its merits. The obstacles to establishing such an international facility are substantial, and while there has been greatly increased interest in such ideas in recent years, it remains unclear whether these obstacles can be overcome in the near term. If appropriately managed, such sites could contribute both to stemming the spread of nuclear weapons and to the future of civilian nuclear energy.

Advanced countries with large and sophisticated nuclear programs, such as the United States and Japan, should continue to plan on storing and disposing of their spent fuel and nuclear wastes domestically.

Both the United States and Japan have the technical capaci-

ty and wealth to manage their own storage facilities and repositories. While we would not rule out the possibility that some limited amount of Japanese spent fuel might be sent to an international site, the primary focus in Japan, as in the United States, should remain on domestic options for managing spent fuel and nuclear wastes. Both countries have a responsibility to manage the wastes resulting from the large quantities of nuclear electricity they have produced, and the issue is too pressing in both countries to delay the search for domestic solutions until an international option may become available.

Establishing one or more international storage facilities could make it possible to remove spent fuel from countries of proliferation concern and enhance transparency and confidence-building in spent fuel management.

The 1990s witnessed a number of cases in which nuclear material was removed from particular countries to reduce proliferation risks, and more such cases can be expected. An international storage facility would provide a ready site for accepting material in such situations. Moreover, if an international system was established for spent fuel storage, including one or more international sites, the resulting increased international information about and control over spent fuel management could contribute to building confidence and reducing international concerns.

Over the long term, establishing one or more international disposal sites is essential, at least for material from countries with small nuclear programs and geologies poorly suited to permanent disposal.

It will simply not be practical to establish a geologic repository in every country that has a nuclear power reactor or a research reactor. Eventually, some form of international disposal site or sites will be needed. The ultimate trend should be toward consolidating spent fuel in a smaller number of locations worldwide.

Proposals for international sites in Russia pose especially complex issues. Such a facility could make a substantial contribution to international security and would deserve support if several criteria were met—but these will not be easy to meet.

Russia is in the process of debating possible changes to its laws that would allow it to become a host state for spent fuel from other countries. A variety of different specific

approaches have been proposed, each raising different issues. Russia's Ministry of Atomic Energy strongly supports entering this potential market, while Russian and international environmentalists are strongly opposed. Such a facility would deserve support *if*:

- Effective arrangements (including independent regulation) were in place to ensure that the entire operation achieved high standards of safety and security;
- A substantial portion of the revenues from the project were used to fund disarmament, non-proliferation, and cleanup projects that were agreed to be urgent, such as securing nuclear material and eliminating excess plutonium stockpiles;
- The project did not in any way contribute to separation of additional unneeded weapons-usable plutonium, or to Russia's nuclear weapons program; and
- The project had gained the support of those most likely to be affected by it, through a democratic process, including giving them ample opportunity to ensure that their concerns were effectively addressed.

Whether an arrangement that meets these criteria can be put in place in Russia—and what the reaction will be if a proposal advances which meets the first three criteria but not the fourth—remains to be seen.

Recommendations

We recommend that:

- **Interim storage, designed to last for perhaps 30-50 years (though with flexibility to shorten that time to match the progress of permanent solutions) should be pursued as the best near-term approach to managing a large fraction of the world's spent fuel, including much of the spent fuel in the United States and Japan.**
- **Capacity for interim storage of spent fuel should be substantially expanded—in Japan, in the United States, and in the rest of the world.**

- **Approaches to establishing interim spent fuel storage facilities should be based on the principles of flexibility, transparency, democracy, and fairness—making use of the approaches outlined in the modified Facility Siting Credo to the extent possible.**
- **In particular, the degree of secrecy and reliance on hidden negotiations in past siting efforts should be substantially reduced, with all key information about proposed facilities, including potential options for benefits to host communities, made available to those potentially affected.**
- **Approaches to establishing interim storage should be designed so as not to undermine progress toward acceptable solutions for spent fuel management and nuclear waste disposal.**
- **In particular, when spent fuel is placed in interim storage, sufficient funds should be set aside to implement permanent management approaches at a later time, so that a future generation will not be stuck with the bill.**
- **In both the United States and Japan, the respective responsibilities of government and private industry in managing spent nuclear fuel should be clarified, and the possibility of establishing some limited interim storage capacity at centralized sites to address particularly urgent storage needs should be considered.**
- **In both the United States and Japan, the policy-making process for management of spent nuclear fuel and nuclear wastes should be improved, making possible an in-depth consideration of all the relevant factors in deciding on the best approach to managing each type of nuclear material, with interim storage of spent nuclear fuel as one central element of a larger back-end strategy.**
- **In both the United States and Japan, additional steps should be taken to address the concerns of local communities hosting nuclear facilities—both existing facilities and**

proposed new ones—including efforts to address issues of geographic fairness, community control, and timelines for removing spent fuel and implementing permanent approaches.

- The international community should contin-

ue to seek to establish safe and secure international facilities for storage or disposal of spent nuclear fuel, but countries such as the United States and Japan should focus on domestic facilities for the spent nuclear fuel from their own nuclear power plants.

1. Introduction

Interim Storage: A Crucial Issue for the Future of Nuclear Energy

THE MANAGEMENT OF SPENT FUEL from nuclear power plants has become a major policy issue for virtually every nuclear power program in the world. For the nuclear industry, finding sufficient capacity for storage and processing or disposal of spent fuel is essential if nuclear power plants are to be allowed to continue to operate. At the same time, the options chosen for spent fuel management can have a substantial impact on the political controversies, proliferation risks, environmental hazards, and economic costs of the nuclear fuel cycle.

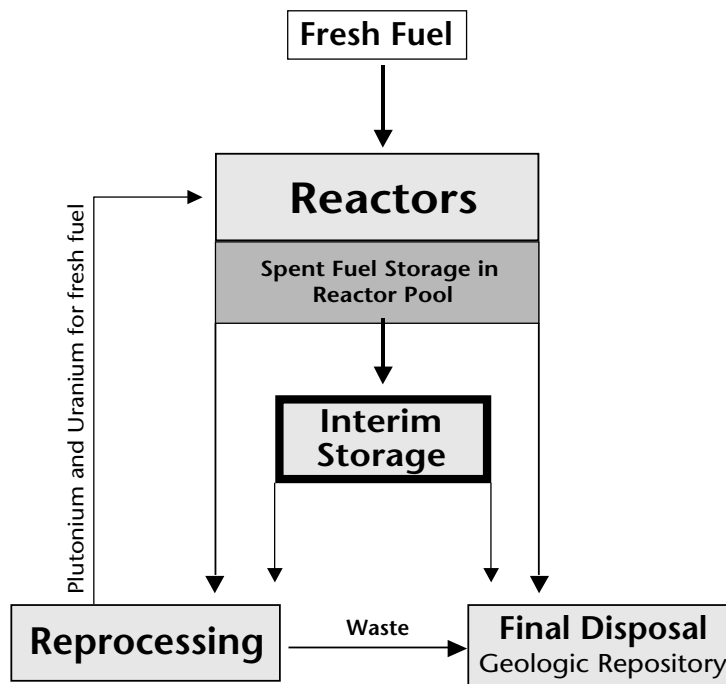
Today, some countries, including Japan, see spent nuclear fuel as a valuable energy resource, since most of its mass is uranium and plutonium that could be recovered and re-used for additional energy production. Other countries, including the United States, tend to view spent fuel as a waste, arguing that the cost of recovering its energy content is more than that energy is worth, and that reprocessing and recycling weapons-usable plutonium creates unnecessary proliferation hazards. There is some merit in both of these points of view: today, spent fuel is like oil shales, a potential energy resource whose exploitation cannot be economically justified at present, but may become important at some unknown point in the future. The critical difference between spent fuel and oil shales, of course, is that the contents of spent fuel pose both environmental and nonproliferation hazards, and hence generate political controversies, that oil shales buried in the ground do not. The countries that view spent fuel as an energy resource generally plan on reprocessing it—either in the near term or fur-

ther in the future—and recycling the plutonium and uranium. The countries that see spent fuel as a waste generally plan on disposing of it directly, without reprocessing, in geologic repositories. These differences of perspective have been debated for decades, and are not likely to be resolved soon.

Interim storage of spent fuel offers a safe, secure, flexible, and cost-effective near-term approach to spent fuel management that may be attractive regardless of a particular country's perspective on these debates over whether spent fuel is better seen as a resource or a waste. For those countries that favor reprocessing, interim storage keeps the fuel available for use whenever the material within it is needed, while making it possible to avoid prematurely building up stockpiles of separated plutonium, and offering the flexibility needed to modify the pace and scale of reprocessing as technical, economic, and policy factors change. For countries that favor direct disposal of spent nuclear fuel, interim storage allows more time to analyze and develop appropriate geologic repositories with the care required, and makes it possible to accommodate delays in repository development without imperiling the operation of existing reactors. In either case, a period of interim storage can allow time for improved technologies and policy approaches to nuclear fuel management to develop. Indeed, over the decades during which spent fuel may be stored, changes may occur in some countries' decisions as to whether to rely primarily on reprocessing or on direct disposal. Figure 1.1 outlines the place of interim storage in the nuclear fuel cycle.

In short, interim storage of spent nuclear fuel is crucial to a flexible fuel management strategy. Although inter-

Figure 1.1: Interim storage of spent nuclear fuel can be a central element of either the reprocessing and recycle or direct disposal fuel cycles.



Interim storage does involve a cost, it allows the higher costs of permanent solutions to be paid at a later date and therefore discounted somewhat, so that the overall fuel cycle contribution to electricity costs need not increase.

Interim storage of spent nuclear fuel is *not* simply a matter of buying time and postponing decisions. It is a central element of an optimized nuclear fuel cycle. Indeed, overcoming the obstacles to providing adequate interim storage capacity around the world is crucial to the future of nuclear energy.

Interim Storage: The Quiet Consensus

Today, in fact, there is less divergence among countries in what is actually done with spent fuel than official policy statements might suggest. As no geologic repository for spent fuel has yet been opened, and world reprocessing capacity is far less than world spent fuel generation, most of the spent fuel generated each year simply remains in stor-

age. As of the end of 1997, civilian nuclear power programs around the world had generated roughly 200,000 metric tonnes of spent fuel, of which only about 70,000 had been reprocessed; the other 130,000 tonnes remained in interim storage—a figure which had increased to roughly 150,000 tonnes by the end of 2000. Indeed, as the IAEA has pointed out, most countries with nuclear programs have explicitly decided to take a “wait and see” approach to spent fuel management, leaving their spent fuel in interim storage, which leaves both the reprocessing and direct disposal options open for the future.¹ In short, despite the continued debate over the future of the fuel cycle, a quiet consensus has developed that for the near term, simply storing spent fuel while continuing to develop more permanent solutions is an attractive approach.

Indeed, even once geologic repositories are opened, as long as they remain open and spent fuel placed in them remains readily retrievable (a period expected to last in many cases for decades or even centuries), they will offer

¹ *Survey of Wet and Dry Spent Fuel Storage*, IAEA-TECDOC-1100 (Vienna, Austria: International Atomic Energy Agency, July 1999). 2000 figure estimated based on data provided by the IAEA.

some of the same flexibility as interim storage, making it possible to remove the spent fuel at any time, should circumstances make that desirable. There is, however, a crucial technical difference between interim storage facilities and permanent underground repositories, even if the repositories remain retrievable: interim storage facilities are by their nature designed to be temporary, have no permanent disposal purpose, and are not intended to have the capacity to ensure safety for thousands of years, even after human monitoring may end—whereas deep underground repositories are designed to be permanent, and to ensure that human health and the environment will be protected for as long as the radioactive material in the repository poses a hazard (far longer than the likely lifetime of the human institutions that help ensure the safety of interim storage facilities). Thus, interim storage facilities are a complement, not a substitute, for permanent approaches to managing spent fuel and nuclear wastes. Both are needed.

Interim Storage: Political, Legal, and Institutional Constraints

Interim storage approaches are not without their problems. Political, legal, and institutional obstacles have limited both expansion of at-reactor storage and establishment of away-from-reactor storage facilities in several countries. Today, cooling ponds for storage of spent fuel at many reactor sites are nearing capacity, and some reactor operators have been unable to find a legally and politically acceptable means to establish additional capacity, putting them at risk of having to shut their reactors if a solution is not found. Some utilities are pursuing reprocessing of spent fuel not because they have any immediate desire to recycle the plutonium from the spent fuel, but simply because shipping the fuel to a reprocessing plant is the best (or the only) solution for getting it out of their reactor cooling ponds that they have been able to find. But that expedient forces them to deal with the resulting separated plutonium, recovered uranium, and high-level wastes, which in some cases has proven costly and controversial.

The situation in the United States offers an example of some of the difficulties and dilemmas of spent fuel storage. The 1982 Nuclear Waste Policy Act established dispos-

al in geologic repositories as the principal approach for spent fuel management, and laid out an institutional and legal framework for both permanent disposal and interim storage; the burden of nuclear waste disposal was to be balanced by having one repository in the West and one in the East, and it was specified that a centralized interim storage site should be built in a state other than the state where the first repository would be located, to further spread the burden. In 1987, however, the act was amended to prohibit the Department of Energy from studying any geologic repository site other than Yucca Mountain. Since the 1982 Act, both the government and coalitions of utilities in the United States have attempted to find an acceptable site for a centralized interim storage facility where fuel could be stored pending disposal in a geologic repository. So far these efforts have been wholly unsuccessful, despite a long history of different approaches and proposals.

Meanwhile, the U.S. program to establish a geologic repository has encountered serious delays, and as a result the Department of Energy failed to meet the 1998 deadline specified in the 1982 act (and in contracts with the utilities) for beginning to accept the spent fuel from the reactor sites. A substantial number of U.S. reactors are likely to fill their spent fuel cooling ponds to the point that they no longer have the capacity to unload an entire reactor core in an emergency long before a geologic repository is ready to accept their spent fuel. To resolve this problem, and avoid having to continue to pay for spent fuel storage they had expected the Department of Energy to take care of after 1998, the nuclear industry has pushed hard for legislation to establish a Federally funded centralized interim storage site near the planned repository, which could accept spent fuel long before a permanent repository actually opened. The utilities have also sued the Department over its failure to meet its contractual obligations to take the fuel.

But the proposal for a centralized site near Yucca Mountain has been strongly opposed as prejudging the outcome of the decision as to whether the Yucca Mountain repository site is suitable, and potentially risking transporting all the spent fuel to one place only to have to transport it somewhere else if the Yucca Mountain site never opens.² In the meantime, utilities have been investing in dry cask storage, but in a few cases there has been substantial con-

² See Allison Macfarlane, "Interim Storage of Spent Fuel in the United States," *Annual Review of Energy and the Environment*, forthcoming.

troverly over expanding on-site spent fuel storage in the absence of any guarantee that there will be somewhere else to ship it to soon, leaving a few utilities wondering if they will be able to find a solution before they have to close their reactors. Some utilities are now working to establish utility-sponsored centralized storage sites, but whether these proposals will be any more successful in overcoming the legal and political hurdles to establishing such sites than past ones remains to be seen.

Similarly, in Japan, the law until recently prohibited storage of spent fuel at sites other than reactor sites and reprocessing plants, but delays in building a reprocessing plant at Rokkasho-mura have left a number of utilities concerned that they will run out of storage space. The government has therefore changed the law to allow the establishment of away-from-reactor storage facilities that are not at reprocessing plants, and the utilities have begun quiet discussions with the governments of some prefectures concerning the possibility of establishing such facilities. The mayor of Mutsu in Aomori prefecture, in particular, has volunteered that community for preliminary investigations of whether it would be a suitable site for a storage facility. In the meantime, the utilities are negotiating additional reprocessing contracts with France (to provide training for eventual operation of the Rokkasho plant), which will allow a modest amount of spent fuel to be removed from existing storage pools.

But at the same time, the plutonium fuel and high-level wastes arising from reprocessing are becoming more and more controversial in Japan, particularly in the wake of the Tokai-mura accident and the revelations of falsification of safety data in the fabrication of plutonium fuel for Japanese reactors in Britain. As a result, immediate plans to begin burning plutonium fuel in Japanese commercial reactors have been postponed, at least temporarily. In recent years, local politics in the areas near nuclear facilities has had a growing influence on Japanese nuclear energy and nuclear safety policy. Siting of any new nuclear facilities requires the consent of the prefectural governor. In addition, for each nuclear facility, a “nuclear safety agreement” is negotiated between the local community and the utilities. While not official regulatory documents, these agreements often require “prior consent” from the governor before major actions—including even expanding spent fuel storage capacity at an existing site—are taken. With increasing local

concern and non-government activism over nuclear safety, the governors have begun wielding their consent power much more energetically, postponing a variety of projects or seeking concessions in return for their support. As spent fuel management decisions are often linked to each other, one governor’s decision about a particular facility can influence Japan’s entire nuclear energy program.

In Japan, the United States, and other countries, spent fuel storage facilities are inevitably controversial, as communities are concerned about nuclear safety and do not wish to become a permanent “dumping ground” for nuclear waste generated elsewhere. Finding a genuinely democratic process for siting spent fuel storage facilities that builds acceptance of and support for such facilities in the communities and regions where they are located, while meeting the continuing spent fuel storage needs of the nuclear industry, has posed an enormous challenge in countries around the world. No reliable answer to the problem has yet been found, though a number of general principles to increase the chances of success in building public support for siting such facilities have been developed from past experience, and are described in this report. The most critical and difficult issues facing interim storage of spent fuel around the world are political, legal, and institutional challenges, more than technical ones.

In recent years, there has also been increased attention to the possibility of international storage or disposal sites for spent fuel—that is, sites that would accept spent fuel from multiple countries, either in their region or around the world. This new focus on international concepts has been driven by the increasingly urgent need for additional spent fuel storage capacity around the world, the likelihood that some countries with nuclear power programs might be unable to find reasonable solutions (for reasons of geography, poverty, or politics), the economies of scale that might be achieved through cooperation, and the willingness of many reactor operators to pay substantial sums of money for a solution to their spent fuel storage problems. Such international approaches, if appropriately safeguarded and secured, could potentially offer some nonproliferation benefits, by allowing plutonium-bearing spent fuel to be removed from regions of acute proliferation risk, allowing utilities that do not wish to recycle plutonium immediately an alternative to near-term separation of weapons-usable plutonium. Some proposals might also provide large rev-

enue streams that could be used to finance other nonproliferation and disarmament objectives, such as security and disposition for Russia's excess weapons plutonium. Proposals for international spent fuel sites, however, also raise a number of troubling issues and face a range of difficult obstacles.

Objectives and Organization of This Report

This report is intended to:

1. Clarify the current economic and technological status of interim storage of spent fuel in the United States, Japan, and worldwide.
2. Illuminate the institutional, legal and political issues with regard to spent fuel storage and its relationship with basic nuclear energy and non-proliferation policies.
3. Explore possible policy options to overcoming the obstacles to interim storage of spent fuel, and assess the advantages and disadvantages of various approaches to both domestic and international spent fuel storage.

The remainder of this report consists of four major chapters, followed by conclusions and recommendations. *Chapter 2* examines current approaches to interim storage of spent nuclear fuel in Japan, the United States, and other countries, including safety, economics, flexibility, and non-proliferation aspects, as well as an assessment of current status and experience. The review shows that there are no substantial technical or economic obstacles to implementation of interim storage of spent fuel. Nevertheless, we note one important technical and economic (as well as political) issue—namely transportation of spent fuel to storage facilities. Transportation of spent fuel is not a technically complex operation, but it requires careful handling and special attention to safety.

Chapter 3 examines the institutional, legal and political factors affecting spent fuel storage in the United States

and Japan. This chapter reviews the history of the issue, exploring how institutional, legal and political commitments to the current approaches have built up over time, and created increasing rigidity in spent fuel management programs. The analysis highlights the importance of integrating the uncertainties in predicting the future into long-term planning, and the importance of maintaining flexibility to respond to changing circumstances. At the same time, however, the review focuses on the challenges to gaining support for siting of spent fuel storage facilities from local communities and regions.

Chapter 4 examines the possibilities for international storage of spent fuel, including the history of the issue, the advantages and disadvantages of an international approach to the issue, current proposals (including a review of the various concepts for a site in Russia and their status), and obstacles to establishing international facilities.

Chapter 5 assesses a number of the key choices to be made in pursuing interim storage of spent nuclear fuel, and then outlines steps toward a new approach to overcoming some of the obstacles to siting interim storage facilities. It emphasizes that to increase the chances of success in siting such facilities requires a trust-building process based on the principles of transparency, democracy, and fairness, involving all the parties who have major interests in the outcome, and ensuring that all negative aspects of a facility are addressed and benefits provided so that the affected communities are better off once the facility is built than they were before. It also emphasizes the substantial value of maintaining flexibility (and, in many cases, pursuing multiple approaches)—in the choice of interim storage sites and technologies, in the balance of emphasis on at-reactor vs. away-from-reactor storage, in the balance between national and international approaches, and on when permanent solutions such as geologic disposal should be implemented. Avoiding too great a dependence on any one solution can be crucial.

Finally, *Chapter 6* summarizes our conclusions and recommendations.

2. Current Technologies, Economics, and Status of Interim Spent Fuel Storage

Types of Spent Fuel Storage: Wet vs. Dry

ALL NUCLEAR POWER REACTORS generate spent nuclear fuel. A typical 1 gigawatt-electric (GWe) light water reactor generates roughly 20 to 30 metric tonnes of heavy metal (tHM) in spent fuel per year. Today, just over 10,000 tHM is generated annually (including from other reactor types such as CANDU reactors that generate much larger quantities of spent fuel per gigawatt-electric-year). As of the end of 1997, roughly 200,000 tHM of spent fuel had been generated by civilian power reactors since the dawn of the nuclear age, of which roughly 130,000 remained in some form of interim storage (the remaining 70,000 tonnes having been reprocessed).¹ By the end of 2000, the amount of spent fuel in storage had increased to over 150,000 tHM.²

All currently operating nuclear power reactors use water pools to store their spent fuel when it is first discharged from the reactor, to allow the fuel to cool. After the intense initial radioactivity has decayed, the reactor operator faces a choice: the fuel can be stored in the pool (or some other pool) for a longer period, it can be placed in one of several forms of dry storage, or it can be sent to a repro-

cessing plant to be reprocessed. (In principle, it can also be sent to a geologic repository for disposal, but as no such repositories for spent fuel have yet been opened, reactor operators do not yet have this option.)

Wet storage of spent fuel in water pools is well understood, and there is enormous worldwide experience with its safety.³ More than 90% of the spent fuel in storage in the world today is stored in pools, either at reactor sites or in away-from-reactor facilities.⁴ Figure 2.1 shows spent fuel in pool storage. Some spent fuel has been stored in pools for more than four decades with no substantial problems. Spent fuel assemblies are typically placed in racks in pools made of concrete, which are often lined with stainless steel or epoxy-based paints. The pool is enclosed within a building, and the chemistry of the pool is controlled. The pools are closely monitored for leakage, and radioactivity in the water is kept as low as reasonably achievable (ALARA). The key safety issues in wet pool storage are (a) to ensure that the pool water is not lost and continues to cover the spent fuel, and (b) to ensure that there is sufficient spacing and neutron absorption to prevent any accidental nuclear chain reaction in the pool. With appropriate management and

¹ *Survey of Wet and Dry Spent Fuel Storage*, IAEA-TECDOC-1100 (Vienna, Austria: International Atomic Energy Agency, July 1999). For another excellent summary of the various types of spent fuel storage available and their advantages and disadvantages, see Toshiara Saegusa, Chihiro Ito, and Atsuyuki Suzuki, *An Overview of the State of the Arts of Nuclear Spent Fuel Management* (Tokyo: Central Research Institute of Electric Power Industry, February 1999).

² Estimated based on spent fuel generation and reprocessing data provided by the IAEA.

³ See, for example, IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit.

⁴ As of the end of 1997, there were just over 5,000 tHM of spent fuel in dry storage (though this figure was increasing rapidly) out of some 130,000 tHM of spent fuel in storage at that time. Ibid.

Figure 2.1: Spent fuel assembly being lowered into a storage pool



regulation, these safety goals are not difficult to achieve, but there have been incidents in the United States, for example, which suggest that more careful attention to pool storage safety would be desirable.⁵

When a pool for a nuclear reactor is first being built, the additional cost of expanding the amount of fuel it can hold is not large. Nevertheless, because nearly all countries originally planned on reprocessing spent fuel shortly after it was discharged, many of the world's reactors were built with much less pool storage capacity than would be needed to hold all the spent fuel they would generate in their lifetimes. In the United States, for example, prior to the 1976

decision to forego reprocessing (the period during which nearly all U.S. reactors were built), cooling pools were designed to hold only one and one-third full-core loadings of spent fuel.⁶

In recent years, with some countries (such as the United States) foregoing reprocessing but experiencing delays in establishing geologic repositories, and other countries facing delays in reprocessing and recycle programs, many reactor operators have had to find ways to store much larger quantities of spent fuel for much longer periods than they had planned on when the reactors were first built. This poses a crucial issue for the future of nuclear energy,

⁵ For a critique of past approaches to managing pool storage safety in the United States, see David Lochbaum, *Nuclear Waste Disposal Crisis* (Tulsa, Oklahoma: PennWell Books, 1996), chapters 8 and 9. Lochbaum notes a number of incidents at U.S. power plants which included some of the key elements that could lead to a serious spent fuel storage accident (such as water leaking from pools without being detected, which in a severe case could lead to fuel becoming uncovered and melting down), and outlines concerns over whether, in certain U.S. reactor designs, a serious reactor accident such as the Three Mile Island accident could also lead to a spent fuel storage accident. (Lochbaum was a safety engineer at the Susquehanna nuclear power plant when he first raised these concerns, and now monitors nuclear power safety for the Union of Concerned Scientists, a U.S. non-government organization.) He argues for new monitoring and regulatory steps to ensure pool safety, and concludes that such "measures should provide reasonable assurance that spent fuel storage at nuclear power plants presents negligible risk to public health and safety." (p. 122).

⁶ *Ibid.*

because if there is not sufficient storage space to hold spent fuel, reactors could be forced to shut down—and lack of confidence that approaches will be available to manage the spent fuel could prevent new reactors from being built.

The first step in addressing this issue in most cases is “re-racking” of the spent fuel in the pool—re-arranging the pool storage so that the same amount of pool space can hold substantially more spent fuel. This has already been done—in some cases more than once—at most operating reactors in the United States, and at many reactors elsewhere in the world. Higher storage densities have been achieved without the risk of a nuclear chain reaction by adding neutron absorbing materials (typically boron) in storage racks and baskets, and dissolved in the water itself.⁷

Once the possibilities of re-racking have been exhausted, reactor operators have a number of choices: (a) build additional pool capacity; (b) transport the fuel to other sites which have additional pool capacity (such as more recently built reactors); (c) ship the fuel to a reprocessing plant to be reprocessed; or (d) establish dry storage capacity for the fuel, either at the reactor site or elsewhere. In general, reactor operators are seeking increased flexibility to manage their spent fuel in the ways that seem most appropriate at particular times, so that they will not be entirely reliant on any one particular approach.

Of these choices, reprocessing is expensive and not called for if the plutonium is not needed as fuel. Maintaining and operating a spent fuel storage pool involves significant operational costs, and some modest generation of radioactive wastes. Thus, for spent fuel that is to be stored for a substantial period, many reactor operators are beginning to turn to dry storage. As of the end of 1997, more than 5,000 tHM of spent fuel was in dry storage in 11 countries, and these figures are expanding rapidly.⁸ Dry storage, however, is by no means the only technology being purchased for expanded spent fuel storage capacity: both wet and dry technologies have found market niches where operators find them to be the most appropriate approach.⁹

Types of Dry Storage of Spent Fuel

As its name implies, dry storage of spent fuel differs from wet storage by making use of gas or air instead of water as the coolant (often an inert gas such as helium, or an only modestly reactive gas such as nitrogen, to limit oxidation of the fuel while in storage) and metal or concrete instead of water as the radiation barrier. Fuel must be stored in pools for several years before it becomes cool enough for dry storage to be possible. As discussed below, dry storage is both safe and cost-effective: once the fuel has been placed in storage, there are few continuing operational costs or risks. Reactor operators have a large range of choice of dry storage systems. For those seeking economies of scale in storing large quantities of spent fuel for a prolonged period, vaults and silos are attractive, while for those seeking the flexibility of a modular, piece-by-piece storage system, dry casks are preferred.

Dry Storage Vaults

In a vault, the spent fuel is stored in a large concrete building, whose exterior structure serves as the radiation barrier, and whose interior has large numbers of cavities suitable for spent fuel storage units. The fuel is typically stored in sealed metal storage tubes or storage cylinders, which may hold one or several fuel assemblies; these provide containment of the radioactive material in the spent fuel. Heat is removed in vault systems by either forced or natural air convection. In some vault systems, fuel is removed from the transport cask and moved without any container to its storage tube, while in others the fuel stays in the container in which it arrives, which is then placed in a transfer cask and moved by crane to its storage cylinder. Thus, vault systems typically also require cranes or fuel-handling machines.¹⁰

While the up-front cost of establishing a vault is substantial, the marginal cost of building a larger vault to expand its capacity is small. Given this economy of scale, for storage of very large quantities of spent fuel at a single

⁷ Considerable care is required to ensure that these arrangements for preventing accidental chain reactions are effective and will remain so. For example, there have been incidents in which panels of neutron-absorbing material placed between fuel assemblies have developed large holes, or in which additional water flowed into the cooling pool, diluting its boron content. See Lochbaum, *Nuclear Waste Disposal Crisis*, op. cit., pp. 115, 118–119.

⁸ IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit., p. 5.

⁹ See, for example, Koji Nagano, “Comments on Spent Fuel Storage: Technology and Economics,” presentation to the Harvard University and University of Tokyo Workshop on Interim Storage of Spent Nuclear Fuel, Tokyo, Japan, July 20, 2000.

¹⁰ IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit., pp. 5–6.

facility, the cost of vaults tends to be somewhat lower than the cost of other dry storage approaches. Vaults are used at the Paks facility in Hungary, the Magnox Dry Storage Facility at the Wylfa reactor in the United Kingdom, the Gentilly 2 power plant in Canada, the CASCAD facility in France, and at the former experimental high-temperature gas reactor Fort St. Vrain in the United States.

Dry Storage Silos

In a silo storage system, the fuel is stored in concrete cylinders, either vertical or horizontal, fitted with metal inner liners or separate metal canisters. The concrete provides the radiation shielding (as the building exterior does in the case of a vault) while the sealed inner metal liner or canister provides containment. Transfer casks are often used for loading of the fuel into the silos. Heat removal is by air convection. Silo systems are in use in the United States, Canada, the Republic of Korea, Argentina, and Armenia.¹¹

Dry Storage Casks

In a cask system, a flat concrete pad is provided (either outdoors or within a building), and large casks that contain the spent fuel can be added as needed to store the amount of fuel required. The casks provide both shielding and containment. The initial cost of establishing the facility is small, and the operating costs once the fuel is loaded are also small, but the capital cost of the casks themselves is significant; as each cask costs roughly the same amount as previous casks, there are few economies of scale in storing more fuel. For an at-reactor facility, the fuel can typically be moved from the pool to a dry cask using primarily fuel handling equipment already available at the reactor site. A wide variety of specific cask designs are available from several manufacturers, including both metal and concrete casks (the latter typically having metal inner liners).¹² Originally, like vaults and silos, casks were designed only for storage (so-called “single purpose” casks). More recently, some cask designs have been

Figure 2.2: Concrete storage casks at a U.S. nuclear power plant



¹¹ Ibid, pp. 7-8, 55.

¹² For information on current cask and silo designs from several manufacturers, see E.M. Johnson and P.M. Saverot, eds., *Monograph on Spent Nuclear Fuel Storage Technologies* (Northbrook, IL: Institute for Nuclear Materials Management, 1998). A description of Japanese cask designs is provided in Saegusa, Ito, and Suzuki, *An Overview of the State of the Arts of Nuclear Spent Fuel Management*, op. cit.

licensed for both storage and transport (“dual purpose”), and design work continues on casks intended to serve for storage, transport, and permanent disposal (“multi-purpose”). Figure 2.2 shows typical dry spent fuel storage casks at a nuclear power plant in the United States.

Because of their inherent flexibility, cask systems have proved popular with reactor operators. Most plans for long-term interim storage of spent nuclear fuel in both the United States and Japan, both at-reactor and away-from-reactor, focus on dry casks. Hence, the remainder of this chapter will focus primarily on dry casks.

Dry Storage Safety

Dry cask storage of spent fuel is among the safest of all the phases of the nuclear fuel cycle. The basic safety goals that must be met are to ensure that (a) sufficient shielding is provided so that workers at the facility are not exposed to hazardous levels of radiation, and (b) the fuel is contained so that any release of radioactive material from the casks to the surrounding environment is reliably prevented. These goals are not difficult to achieve. In dry cask storage there are very few scenarios that can be imagined that could provide the energy needed to break the cask and spread the radioactive material into the surrounding environment. This is quite different from the situation in a reactor core, where extreme care must be taken to contain the intense heat and pressure generated by the nuclear reaction, or a fuel processing plant, where a variety of strong chemical reactions are likely to be used that could potentially result in explosive energy releases, and there is the possibility of

an accidental chain reaction if too much material is gathered in one place during processing. With dry cask storage, a solid material (the spent fuel assemblies) is sitting completely still inside a strong, thick container. In such a system, there is very little that can go wrong badly enough to result in a significant release of radioactivity. Nevertheless, the entire process must be handled with care—especially during loading and unloading, when the fuel is not as fully protected by the casks, is in motion, and there may be sources of energy for a chemical reaction (such as welding torches for those casks that are welded).

To ensure that dry cask storage systems provide adequate shielding and containment, such systems are designed to meet the following requirements: (1) fuel cladding must maintain its integrity while in storage; (2) high temperatures that could cause fuel degradation must be avoided; (3) accidental chain reactions (“criticality”) must be prevented; (4) effective radiation shielding must be provided; (5) radiation releases must be avoided; and (6) fuel retrievability must be ensured in case any problem arises.¹³ The vast majority of pools and dry storage systems adequately fulfill these requirements for the types of spent fuel to be accommodated. For some fuel types, however, this is more difficult than for others. The fuel for Britain’s Magnox reactors, for example, being a metal, not an oxide, corrodes relatively rapidly in water (if the chemistry is not controlled extremely carefully) and therefore is usually reprocessed relatively quickly for safety reasons (though some has been in dry storage for many years).¹⁴

Both experience in countries around the world and a number of regulatory reviews reinforce the conclusion that

¹³ This summary is based on IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit. See also Nuclear Energy Agency, Organization for Economic Cooperation and Development, *The Safety of the Nuclear Fuel Cycle* (Paris, France: NEA/OECD, 1993), pp. 99-110. For a description of specific safety requirements and means to achieve them, see Saegusa, Ito, and Suzuki, *An Overview of the State of the Arts of Nuclear Spent Fuel Management*, op. cit. U.S. Nuclear Regulatory Commission safety requirements for independent storage facilities can be found in *10 Code of Federal Regulations Part 72: Licensing Requirements For the Independent Storage Of Spent Nuclear Fuel and High-Level Radioactive Waste* (Washington, DC: U.S. Government Printing Office, various years, available at <http://www.nrc.gov/NRC/CFR/PART072/>). For a recent NRC review of the safety of one particular proposed facility—the Private Fuel Storage facility proposed for Skull Valley, Utah, described in more detail in Chapter 3—see *Safety Evaluation Report Concerning the Private Fuel Storage Facility*, Docket No. 72-22 (Washington, DC: U.S. Nuclear Regulatory Commission, 2000, available at <http://www.nrc.gov/NRC/NMSS/SFPO/SER/PFS/index.html>).

¹⁴ There was one incident with dry storage of this fuel, when a leaky roof allowed rain to get in, which corroded the cladding of 45 fuel elements. The problem has since been fixed, and additional equipment added to monitor humidity and radioactivity. See IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit., pp. 36-37.

dry storage is safe. The 1990 U.S. Nuclear Regulatory Commission (NRC) Waste Confidence Decision Review, for example, concluded that spent fuel is safe at reactors, either in cooling pools or in dry storage systems, for at least 30 years beyond the reactor's licensed life of operation. Furthermore, the NRC went on to say that dry storage in particular is "safe and environmentally acceptable for a period of 100 years."¹⁵

Of course, this is not to say dry cask storage systems face no safety challenges. Effective regulation and safety monitoring is essential to ensure high-quality construction of the casks and supporting facilities, and appropriate procedures for loading the fuel and sealing the casks. The casks require regular monitoring after being loaded. The system must be designed to be safe not only during normal operations, but in the event of plausible accidents as well, including earthquakes, tornadoes, or plane crashes.

One important concern related to the long-term behavior of the fuel is degradation of the fuel cladding as it is exposed to the high temperatures generated by the spent fuel in a dry storage environment. If too much degradation were allowed to occur, the cladding might rupture and allow pieces of fuel to fall out into the canister; if that were to happen, when the fuel was eventually unloaded there would be a potential contamination risk. For this reason, both U.S. and Japanese regulatory agencies place strict limits on the maximum temperature for dry storage (effectively a limit of 380 degrees C in the U.S. case).¹⁶

A few situations have highlighted the need for effective regulatory oversight. In 1996, for example, after the fuel had been loaded into a cask at the U.S. nuclear plant at Point Beach, Wisconsin, and the cask lid was being welded

into place, hydrogen inside the cask ignited, lifting the three-tonne lid approximately 3 inches and tilting it at a slight angle. (This was actually the second hydrogen ignition that month at that site.) The spent fuel was not damaged, and a NRC review concluded that no measurable radioactivity was released. Nor were there any unanticipated exposures of workers from this incident. Nevertheless, had circumstances been different, some modest radioactivity might have been released into the environment from such an incident. It appears that the hydrogen resulted from an electrochemical reaction between the zinc coating used in the storage canister and the borated water in the spent fuel pool. NRC recommended reconsidering the use of such zinc coatings when there is a potential that the coating will be exposed to boric acid. Nevertheless, years later occasional hydrogen ignition incidents in loading similar spent fuel storage casks were continuing to occur.¹⁷ Ideally, cask materials should be designed to avoid generation of potentially reactive gases such as hydrogen.

Similarly, the U.S. Nuclear Regulatory Commission took action a number of times in the mid-1990s to address defective welds that led to cracked seals in some vendors' storage casks, and cask quality assurance problems at other vendors. Cracks were found in the welds of the inner lids of some casks, and if there had been cracks in both the inner and outer lids, helium could have leaked out and moist air could have leaked in, increasing temperatures and causing additional fuel corrosion. Quality assurance issues at another vendor led to the manufacture of casks that did not meet licensed design specifications. After the NRC blocked loading of certain cask types for a period, these issues appear to have been resolved, and use of these casks is again permitted.¹⁸

¹⁵ U.S. Nuclear Regulatory Commission, *Waste Confidence Decision Review*, published in the *Federal Register*, Vol. 55, No. 181 (Washington, DC: U.S. Government Printing Office, 1990) p. 38482.

¹⁶ See, for example, the discussion in Mujid S. Kazimi and Neil E. Todreas, "Nuclear Power Economic Performance: Challenges and Opportunities," *Annual Review of Energy and the Environment*, 1999.

¹⁷ For an account of the Point Beach incident, see, for example, U.S. Nuclear Regulatory Commission, Point Beach Augmented Inspection Team Report, July 1, 1996; Lee Bergquist, "Utility Criticized In Fire: Wisconsin Electric Misread Flames," *Milwaukee Journal Sentinel*, June 8, 1996, p. 1; and Dave Airozo, "Point Beach Cask Incident Prompts Possible NRC Enforcement Action," *Nuclear Fuel*, September 9, 1996, p. 4. For a discussion of an inspection at the Palisades reactor in 1999 during which a hydrogen ignition occurred during loading of storage casks, see U.S. Nuclear Regulatory Commission, Palisades Nuclear Power Plant: Inspection Report 72-00007/99002(DNMS), August 26, 1999. Both of these NRC documents and many others are available at the NRC site on dry cask storage, <http://www.nrc.gov/OPA/drycask/>.

¹⁸ See, for example, Jenny Weil, "Dry Spent Fuel Storage Problems Affect Vendors, Licensees," *Nuclear Fuel*, June 30, 1997, and documents on the NRC site cited above.

In general, effective regulation should ensure that casks are designed and manufactured to high standards that will pose few safety issues.¹⁹

Research is still under way to confirm some aspects of dry storage safety. Currently, for example, the licenses for dry cask storage in the United States last only 20 years. Research is underway to examine exactly how the fuel in the cask will behave over much longer periods, to confirm the NRC's judgment that storing fuel in dry casks would be safe for 100 years. Research is also being pursued to examine whether higher-burnup spent fuels would raise any significantly different safety issues.²⁰

Dry Storage Flexibility

Dry storage of spent fuel is an extremely flexible approach, providing the opportunity to implement the most convenient and cost-effective management for the storage of spent fuel, and to adapt to changing circumstances over time. For countries pursuing an open fuel cycle, such as the United States, dry storage offers an option to store the fuel safely for a prolonged period as a repository is developed. For countries pursuing a closed fuel cycle, such as Japan, dry storage offers more flexible options for controlling the timing and pace of reprocessing to better achieve national economic and energy goals; dry storage can be used, for example, to postpone reprocessing if a country does not wish to build up a stockpile of separated plutonium (as in Japan's case), or to maintain fuel until improved technologies for long-term management are developed. For countries employing a mix of both strategies, dry storage offers additional flexibility on either route. Dry storage systems allow

for storage at each reactor site, at a centralized facility (as in the case of Germany), or at multiple sites, including both at-reactor and away-from-reactor facilities. Additional dry storage capacity can be added at any facility as needed, in a modular fashion. In short, dry storage potentially provides the flexibility needed for a country to resist being forced into snap policy decisions on spent fuel management, by essentially "buying time" to allow careful planning for, perhaps, a permanent repository or a reprocessing facility.

Dry Storage Economics

Dry cask storage is a highly cost-effective approach to spent fuel management. Specific costs for dry storage will vary by the type of system used, the modifications required at the facility that will receive the dry storage, the licensing requirements of the country, and the capacity of the dry storage unit to be acquired.

Capital costs for dry storage at reactors involve (1) upfront costs, which include costs for design, engineering, NRC licensing, equipment, construction of initial storage pads, security systems, and startup testing, and (2) storage system and loading costs, which include the price of the casks themselves, additional pads, labor, decommissioning, and consumables. In the United States, total upfront costs to establish a new dry storage facility at a reactor site (which are largely fixed, regardless of the amount of spent fuel to be stored) are estimated by different sources at \$9 million or \$8-\$12 million, regardless of the specific amount of fuel to be stored.²¹ Costs to purchase and load the dry casks, including labor, consumables, and decommissioning, are estimated to be in the range of \$60-80 per kilogram of heavy

¹⁹ Lochbaum, *Nuclear Waste Disposal Crisis*, op. cit.

²⁰ See O. Ozer and J. Machiels, *Data Needs for Long-Term Dry Storage of LWR Fuel*, EPRI Technical Report EPRI TR-108757 (Palo Alto, CA: Electric Power Research Institute, 1998); M. Peehs, F. Garzarolli, and W. Goll, "Assessment of Dry Storage Performance of LWR Fuel Assemblies With Increasing Burnup," in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999; R.E. Einsiger, M.A. McKinnon, and A.J. Machiels, "Extending Dry Storage of Spent LWR Fuel for Up to 100 Years," in the same volume; and Maureen Conley, "NRC Embarks on Spent Fuel Test Programs to Fulfill Data Needs," *Inside N.R.C.*, January 29, 2001.

²¹ The first estimate is an official one, from TRW Environmental Safety Systems Inc, *CRWMS Modular Design/Construction and Operation Options Report* (Washington, DC: Department of Energy, December 1998, available at http://www.rw.doe.gov/techrep/modular_toc/modular_toc.htm), table E-7; the second is from Eileen M. Supko, "Minimizing Risks Associated with Post-Shutdown Spent Fuel Storage and LLW Disposal," paper presented at the Infocast "Nuclear Power in the Competitive Era" post-conference workshop, "Developing Risk Strategies for Successful Decommissioning," January 30, 1998.

metal (kgHM) in the spent fuel.²² Operating costs are very modest, since virtually nothing needs to be done to the casks each year once they are loaded; the principal operating costs relate to providing the security and safety monitoring needed to maintain the NRC license for the facility. For storage sites co-located with operating reactors, many of these costs can be charged to the reactor operation, and the net additional operating costs are estimated to be only \$750,000 per year (largely independent of the amount of spent fuel to be stored).²³ For independent storage sites or storage sites at reactors which have been shut down, these costs must be attributed to the storage site itself, and so the net additional operational cost is substantially higher. For shutdown reactors with all their spent fuel in dry storage, operating costs are estimated to be \$3-4 million per year.²⁴ (By contrast, if the utility chooses to keep the fuel in its storage pool after the reactor has been shut down, with no changes from previous pool operations, annual costs are estimated at \$9 million per year.²⁵) Total undiscounted life-cycle costs for 40 years of dry cask storage for the roughly 1000 tonnes of spent fuel generated in a typical reactor lifetime, if incurred while the reactor is still operating, would be roughly \$120 million, or \$120/kgHM; for 40 years of storage after the reactor was shut down, total undiscounted costs would be \$250 million, or \$250/kgHM. The discounted present value of this 40-year life cycle cost is only modestly less, since nearly all the cost is up-front expendi-

ture. At a 5% rate, the net present cost would be \$100/kgHM for the case in which the reactor was operating during the storage period, and \$160/kgHM for 40 years of post-shut-down storage. Per-kilogram estimates for a large centralized facility are similar to these at-reactor costs.²⁶

In Japan, all fuel cycle costs are higher than they tend to be in the United States, as many other costs are, and spent fuel storage is no exception. In 1998, an advisory committee to the Ministry of Trade and Industry prepared an estimate of future spent fuel storage costs for both pool and dry cask storage.²⁷ The base case examined involved storage of 5,000 tHM of spent fuel in a centralized facility for 40 years. The undiscounted total of capital cost, operations and decommissioning costs, and costs of transporting the spent fuel to the facility was:

- pool storage: 299.7 billion yen (\$2.29 billion²⁸)
- cask storage: 160.8 billion yen (\$1.23 billion)

Table 2.1 provides a breakdown of these estimated costs. Applying a 5% discount rate over the 54 years considered from start of construction to completion of decommissioning and disposal, these total costs resulted in the following costs per unit of spent fuel, or per kilowatt-hour produced:

- pool storage: 51,830 yen/kgHM (0.150 yen/kWh); \$396/kgHM (1.15 mills/kWh)
- cask storage: 31,190 yen/kgHM (0.091 yen/kWh); \$238/kgHM (0.70 mills/kWh)

²² TRW, *CRWMS Modular Design*, op. cit., estimates \$80/kgHM for the total of all these costs (table E-7); Supko, "Minimizing Risks," op. cit, estimates \$60-\$70/kgHM for casks and loading, with another \$1/kgHM for eventual unloading, and a total of \$2-\$4 million for decommissioning of a 1000-tonne facility (adding another \$2-\$4/kgHM).

²³ TRW, *CRWMS Modular Design*, op. cit. (table E-7).

²⁴ Supko, "Minimizing Risks," op. cit.; the estimate in TRW, *CRWMS Modular Design*, op. cit. (table E-7) is \$4 million/yr.

²⁵ TRW, *CRWMS Modular Design*, op. cit. (table E-7). On the other hand, one analysis from Holtec International estimates that the total of all annual costs for operating and maintaining a dry cask storage facility at a decommissioned reactor would be only \$1.1 million per year, and that by modifying the pool for passive rather than active operations (given the age of fuel from a decommissioned plant), operations cost for leaving the material in the pool could be reduced to \$1.4 million per year. See K.P. Singh, "In-Pool Storage of Spent Nuclear Fuel," in E.R. Johnson and P.M. Saverot, eds., *Monograph on Spent Nuclear Fuel Storage Technologies* (Northbrook, IL: Institute for Nuclear Materials Management, 1997).

²⁶ See Allison Macfarlane, "The Problem of Used Nuclear Fuel: Lessons for Interim Solutions From a Comparative Cost Analysis," *Energy Policy*, forthcoming.

²⁷ *Toward Implementation of Interim Storage for Recycled Fuel Resources*, Interim Report of the Nuclear Energy Working Group, Advisory Committee for Energy, Agency of Natural Resources and Energy, Ministry of Trade and Industry (Tokyo, Japan: June 11, 1998).

²⁸ 1998 yen converted to 1998 dollars at a 1998 exchange rate of 130.91 yen to the dollar. The figure would be significantly lower, \$1.83 billion, at a purchasing power parity adjusted rate of 163 yen/dollar, from National Science Board, *Science and Engineering Indicators 2000* (Washington, DC: National Science Foundation, 2000). Currency exchange rates are more commonly used in nuclear economic calculations, and more appropriately reflect the prices of goods and services traded internationally; purchasing power parity rates are intended to better reflect the actual local buying power of a given amount of currency in different economies, and are less subject to year-to-year fluctuations.

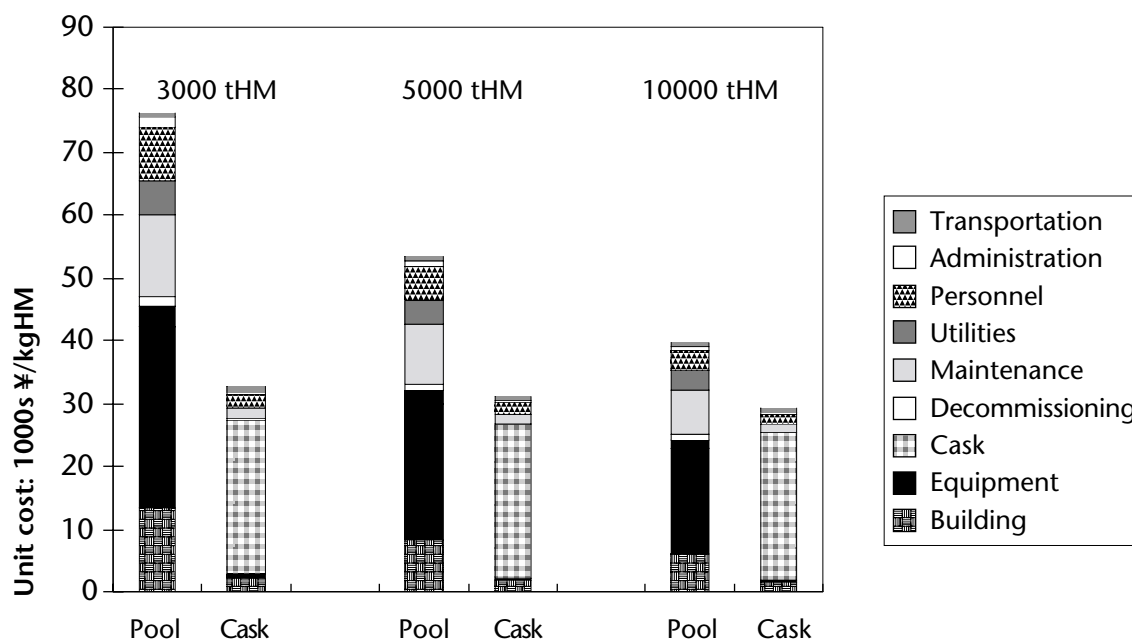
It should be noted, however, that all of these assessments were for the purpose of study and comparison, not for the purpose of actually purchasing these goods and services. Japanese utilities are working to reduce these estimated costs (as are U.S. utilities and cask providers).

The report also analyzed the costs for storage at different scales (3,000 tonnes and 10,000 tonnes), and concluded that cask storage is more economical than pool storage for all cases, though at the 10,000 tonne level, the difference is very small, as the economies of scale of pool

Table 2.1: Breakdown of Estimated Storage Costs for 5,000-tonne Facility in Japan²⁹

Cost (100s of million 1998 yen)	Pool storage	Cask storage
Capital cost	1,561	1,310
Construction cost	1,328	105
Cask cost	100	1,195
Decommissioning and disposal cost	133	10
Operations cost	1,395	238
Transportation cost	41	60
Total	2,997	1,608

Figure 2.3 Breakdown of discounted costs of pool and cask storage



²⁹ MITI, *Toward Implementation of Interim Storage for Recycled Fuel Resources*, op. cit. The costs shown are the undiscounted sum of all costs over 54 years from initiation of construction to decommissioning and disposal of the storage facilities. The unit cost of the casks was assumed to be 240 million yen.

storage allow it to begin to catch up with cask storage. Figure 2.3 shows the breakdown of estimated discounted costs of pool and cask storage at several sizes.³⁰

For both the United States and Japan, it should be noted that costs of the variety of benefits that may be paid to the local community to build public acceptance and gain government approvals are not included in these totals. These costs will vary from zero to significant additions to the total, depending on the circumstances of the individual case.

The costs of interim storage of spent fuel are quite modest when compared to either reprocessing costs (more than \$900/kgHM in current European facilities, even after their initial capital costs have been paid, and more for Japan's Rokkasho-mura facility) or the costs of direct disposal. This is to be expected, since interim storage offers only a temporary solution, and in virtually all industries, permanent solutions are more expensive than temporary ones. From a strictly economic point of view, interim storage pays for itself by allowing the reactor operator to discount the costs of either reprocessing or direct disposal of the spent fuel into the future. For example, at a discount rate of 5%, a reprocessing cost of \$1000/kgHM need only be postponed for 5 years to save over \$200/kgHM—somewhat more than the lifetime dry cask storage cost estimated in Japan. Much the same could be said, of course, with respect to using interim storage to postpone and thus discount the costs of direct disposal. The point is not that permanent solutions should be postponed, but that at low

cost, interim storage provides the flexibility to implement permanent solutions at an optimized timing and pace.

Nonproliferation and Safeguards Aspects of Dry Storage

Spent nuclear fuel contains a small percentage of plutonium, and therefore must be appropriately secured and safeguarded. Indeed, more than two-thirds of all the plutonium that now exists, over 1,100 tonnes, is in spent nuclear fuel, in dozens of countries around the world.³¹ The reactor-grade plutonium in typical spent fuel would not be the preferred material for making nuclear weapons, but once separated from the spent fuel, it is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states.³² Fortunately, providing appropriate safeguards and security for spent fuel in storage is a straightforward task.

In spent fuel, plutonium is embedded in massive, intensely radioactive fuel assemblies which would be rather difficult to steal and recover plutonium from—and which are easy to count and monitor. To get enough plutonium for a bomb would require removing 1-2 roughly 670 kilogram fuel assemblies for a pressurized water reactor (PWR), or 3-4 roughly 250 kilogram assemblies from a boiling water reactor (BWR)—and such removal would be quite easy to detect. Thus, the security hazard posed by plutonium in spent fuel is much less than the hazard posed by separated plutonium that is directly usable in nuclear weapons.³³

³⁰ MITI, *Toward Implementation of Interim Storage for Recycled Fuel Resources*, op. cit.

³¹ See David Albright and Mark Gorwitz, "Plutonium Watch: Tracking Civil Plutonium Inventories: End of 1999" (Washington, DC: Institute for Science and International Security, October 2000). Albright and Gorwitz provide an estimate of 1,065 tonnes in spent fuel as of the end of 1999, but this amount increases by some 60 tonnes per year, so the total at the end of 2000 was over 1,100 tonnes.

³² At the low end of the spectrum of sophistication (capabilities that might be available to a less developed state or, conceivably, a particularly well-organized terrorist group), reactor-grade plutonium can be used to make an explosive with a reliable, assured yield in the kiloton range (meaning a radius of destruction one-third that of the Hiroshima bomb) using technologies no more sophisticated than those used in the first nuclear weapons. At the high end of the spectrum of sophistication, advanced weapon states such as the United States and Russia could make weapons from reactor-grade plutonium having yield, reliability, weight, and other characteristics generally comparable to those of weapons made from weapon-grade plutonium. For an official declassified statement making this point, see *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, DOE/NN-0007 (Washington, DC: U.S. Department of Energy, January 1997), pp. 37-39.

³³ For a discussion of how difficult it would be for states and non-state actors to recover plutonium from spent fuel, see Committee on International Security and Arms Control, Panel to Review the Spent-Fuel Standard for Disposition of Excess Weapon Plutonium, U.S. National Academy of Sciences, *The Spent-Fuel Standard for Disposition of Excess Weapon Plutonium: Applications to Current DOE Options* (Washington, DC: National Academy Press, 2001), and *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, op. cit., pp. 52-60.

Indeed, programs to reduce stockpiles of excess weapons plutonium are typically focused on putting that material in a form in which it would be no more accessible and attractive for use in nuclear weapons than plutonium in spent fuel—the so-called “spent fuel standard.”³⁴

Typical spent fuel from a light-water reactor contains roughly 1% by weight plutonium, 3-4% intensely radioactive fission products, and the remainder uranium. For some decades after the spent fuel is discharged, the gamma radiation from a typical LWR spent fuel assembly is enough to cause a lethal dose of radiation in a relatively short time to anyone attempting to handle the fuel without shielding. Under both U.S. domestic and IAEA standards, material that generates radiation of more than 100 rem/hour at one meter is considered “self-protecting” against theft and recovery of the fissile material within it, and subject to a substantially lower level of safeguards and security than material which is not self-protecting. A PWR fuel assembly irradiated to 40 megawatt-days per kilogram of heavy metal (MWd/kgHM) would generate over 2,000 rem/hour at one meter ten years after discharge, nearly 1,000 rem/hr 30 years after discharge, and nearly 200 rem/hour 100 years after discharge.³⁵ This radiation barrier does not last forever, however. The radioactivity from the fission products decays rapidly for the first few years after the fuel is discharged from a reactor, and then continues to decay with a half-life of about 30 years, corresponding to the decay of Cesium-137 and Strontium-90, for more than a century. Since the radiation barrier to theft or diversion of the spent fuel and recovery of the plutonium from it thus decays with time, it is important that other barriers – such as the geologic barrier that would be created by disposing of the fuel

in a geologic repository – eventually be put in place to ensure that the spent fuel continues to pose a low proliferation risk.³⁶

Safeguards for spent fuel storage are straightforward. The purposes and implementation of safeguards are different in the United States (which is a nuclear-weapon state) and Japan (which is a non-nuclear-weapon state). In the United States, while civilian reactor facilities are eligible for IAEA safeguards under the U.S. voluntary offer agreement, in practice the IAEA does not choose to expend its limited resources safeguarding U.S. civilian reactors. The safeguards that are applied are U.S. domestic safeguards, designed to ensure against possible theft or sabotage of the material, not international verification of peaceful use. In Japan, the Nonproliferation Treaty requires safeguards on all peaceful nuclear activities, and so both domestic and IAEA safeguards measures are applied to all spent nuclear fuel.

To safeguard a spent fuel pool, the spent fuel assemblies are counted as individual items – there is no measurement uncertainty as there is when nuclear material is handled in powders or solutions. Radiation monitoring techniques or instruments to check the Cherenkov glow from highly radioactive spent fuel can be used to ensure that the spent fuel assemblies are genuine, and not substituted with dummies. Surveillance cameras are used to monitor any movement of the spent fuel. For IAEA safeguards, the timeliness goal for detecting any diversion of material in spent nuclear fuel is three months, so routine inspections are performed at Japanese spent fuel storage pools every three months, and an inventory inspection once a year.³⁷ Non-destructive assay is performed on any

³⁴ This standard was first outlined in Committee on International Security and Arms Control, U.S. National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium* (Washington, DC: National Academy Press, 1994); for a more detailed discussion of what the spent fuel standard implies, see *The Spent-Fuel Standard for Disposition of Excess Weapon Plutonium*, op. cit.

³⁵ See Committee on International Security and Arms Control, Panel on Reactor-Related Options, U.S. National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium: Reactor-Related Options* (Washington, DC: National Academy Press, 1995) pp. 270-273.

³⁶ For this reason, the 1994 National Academy of Sciences study of plutonium disposition (*Management and Disposition of Excess Weapons Plutonium*, op. cit.) concluded, in a section entitled “Beyond the Spent Fuel Standard,” that “long-term steps will be needed to reduce the proliferation risks posed by the entire global stock of plutonium, particularly as the radioactivity of spent fuel decays.” The report identified geologic disposal and fission options to burn plutonium stocks much more completely as among the possibilities to be considered, and recommended that “research on fission options for near-total elimination of plutonium should continue at the conceptual level.” (p. 17)

³⁷ See, for example, discussion in Saegusa, Ito, and Suzuki, *An Overview of the State of the Arts of Nuclear Spent Fuel Management*, op. cit.

spent fuel assemblies received at or shipped from the spent fuel pool.

Safeguarding spent fuel in dry cask storage is both simpler and more complex than safeguarding spent fuel in wet pools. It is simpler in that once the spent fuel is loaded into the cask and the cask sealed, the fuel is inaccessible, welded or bolted into the cask until the cask is opened again (which may not happen for decades), and there are no ongoing movements of fuel that need to be verified. It is more complex, since the fuel is also inaccessible for regular inspection, making it necessary to rely on containment and surveillance—primarily tamper-resistant seals applied to the outside of the cask—to ensure that once the fuel has been verified on loading into the cask, it remains in the cask and has not been removed. Since it would not be easy to open the cask and carry out an inspection if one of the seals were to fail, the IAEA uses a dual-seal approach with dry casks in Japan. In this approach, if one seal is accidentally broken or fails, one more is always in place to ensure continuous verification that the cask has not been opened. Initial loading of the fuel into the casks and subsequent sealing of the casks is closely monitored and repeatedly checked. Inspections every 2–3 months confirm that the seals are intact.³⁸

The requirements for physical security for interim spent fuel storage facilities are comparatively modest, since the spent fuel poses a much less accessible and attractive target for theft than does separated plutonium in forms that could be used directly in nuclear weapons. For storage facilities at reactor sites, the spent fuel storage simply relies on the overall security for the reactor itself, designed to prevent sabotage. For away-from-reactor stores, appropriate fencing, intrusion detection, guards, and arrangements for rapid arrival of a response force if necessary are needed, as they are for any nuclear facility.³⁹ In Japan, unlike the United States, nuclear facilities do not have armed guards: if an armed response is required, a response force is available some minutes away.

It is sometimes argued that there would be a substantial nonproliferation advantage in consolidating spent fuel in a small number of locations.⁴⁰ Certainly from the point of view of both the amount of inspector travel-time for safeguards and the expenses for security, fewer locations are better than more, and as discussed in Chapter 4, there could be significant nonproliferation advantages in consolidating spent fuel at a few international sites. But as long as current reactors continue to operate, they will continue to generate spent fuel and will continue to require safeguards and security of their own, so removing a portion of the older spent fuel from those reactors to one or more centralized locations within a particular country would not make a substantial difference in either the proliferation hazard or the safeguards and security burden.

Transportation

Transportation of spent nuclear fuel is a complex topic, a full treatment of which is beyond the scope of this paper. Nevertheless, if interim storage is to be carried out at away-from-reactor sites, transportation of the spent nuclear fuel will be required; for the international storage and disposal concepts described in Chapter 4, overseas transportation would generally be needed. Hence, at least a brief discussion of transportation is necessary. During transportation, there are inevitably somewhat greater complexities, costs, and risks than there are when the fuel is simply sitting in a storage facility—and in recent years, transportation of spent fuel and other nuclear material, particularly across national boundaries, has been the subject of substantial political controversies.

The issues posed by nuclear waste transportation are quite different in the United States and Japan. Transportation of spent fuel within Japan is less difficult, costly, and controversial than it is in the United States, because Japan's nuclear facilities are located on the coasts, so that transport

³⁸ Ibid.

³⁹ The U.S. Nuclear Regulatory Commission requirements for security for spent fuel storage facilities can be found at *10 Code of Federal Regulations Part 73.51: Requirements For the Physical Protection of Stored Spent Nuclear Fuel and High-Level Radioactive Waste* (Washington, DC: Government Printing Office, various years, available at <http://www.nrc.gov/NRC/CFR/PART073/>). A recent NRC description of the approach to security planned for one particular proposed spent fuel storage facility can be found in *Security Evaluation Report Concerning the Private Fuel Storage Facility*, op. cit.

⁴⁰ See, for example, Luther J. Carter and Thomas H. Pigford, "The World's Growing Inventory of Spent Nuclear Fuel," *Arms Control Today*, January/February 1999 (available at <http://www.armscontrol.org/ACT/janfeb99/carjf99.htm>).

of spent fuel is mostly done by sea, in ships specially designed to carry spent fuel transport casks. (Transport of spent fuel, plutonium, and nuclear wastes from Japan to Europe and back, however, has been both costly and politically controversial.) Regulation of radioactive material transport is the responsibility of the Ministry of Transportation. The size of the transport ship depends on the local conditions of the ports. The “Rokuei-Maru”-class ship has a capacity of 15-20 casks (about 300 fuel assemblies). In the United States, spent fuel has to be shipped overland by road and rail, passing through many jurisdictions and communities—creating both different technical issues and more complex political issues.

Transport Safety

With careful attention to safety, including extensive pre-planning and effective and independent regulation, transportation of spent nuclear fuel can be accomplished with

very little risk to the public. Indeed, as the U.S. Nuclear Regulatory Commission has pointed out:⁴¹

The safety record for spent fuel shipments in the U.S. and in other industrialized nations is enviable. Of the thousands of shipments completed over the last 30 years, none has resulted in an identifiable injury through release of radioactive material.

Recently, the NRC has published detailed new analyses suggesting that the risk is even lower than their previous studies had concluded.⁴² In the United States, for example, in roughly 1300 commercial spent fuel shipments between 1979 and 1995 (1045 by highway and 261 by rail), there were 8 accidents, none of which damaged the fuel casks, compromised the shielding, or caused any release of radioactive material.⁴³ Worldwide, over 88,000 tonnes of spent fuel had been shipped by 1995 by sea, road, and rail, with an excellent safety record.⁴⁴ It seems clear that the

Figure 2.4: A spent fuel cask loaded on a truck for transport



⁴¹ U.S. Nuclear Regulatory Commission, *Public Information Circular for Shipments of Irradiated Reactor Fuel* NUREG-0725, Rev. 11 (Washington, DC: July 1996), quoted in Mark Holt, *Transportation of Spent Nuclear Fuel* (Washington, DC: Congressional Research Service, May 29, 1998, available at <http://www.cnie.org/nle/eng-34.html>).

⁴² Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, *Discussion Draft: An Updated View of Spent Fuel Transportation Risk: A Summary Paper for Public Meetings* (Washington, DC: U.S. Nuclear Regulatory Commission, 2000, available at <http://ttd.sandia.gov/nrc/docs/draft.pdf>), based on a study prepared for NRC by Sandia National Laboratories: J.L. Sprung et. al., *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672 Vols. 1-2, SAND2000-0234 (Washington, DC: U.S. Nuclear Regulatory Commission, 2000, available at <http://ttd.sandia.gov/nrc/docs.htm>).

⁴³ NRC, *An Updated View of Spent Fuel Transportation Risk*, op. cit.

⁴⁴ IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit., p. 64.

dramatically larger-scale fuel shipments required for fossil energy sources, which regularly cause fatalities and large-scale environmental damage, represent a greater external cost to society for those energy sources than do the risks posed by transport of spent nuclear fuel.

Both the United States and Japan have detailed regulations on spent fuel transport cask safety, based in substantial part on IAEA transport regulations, which require a series of tests of the casks' ability to survive being dropped from a specified height, rammed by a specified object, immersed to a specified depth, or exposed to a fire of specified temperature and duration without releasing radioactivity.⁴⁵ Nevertheless, critics have expressed concern that the regulatory requirements may not be fully representative of some types of transportation accidents, and that the tests conducted to meet regulatory requirements may not be fully adequate to demonstrate compliance.⁴⁶

Both the International Atomic Energy Agency and the International Maritime Organization regulate international transportation of spent nuclear fuel. Here, too, extensive tests of casks are required to ensure that they would survive most types of accidents without releasing radioactivity. Critics, however, have argued that these regulations should be more stringent.⁴⁷

In April 1988, it was revealed that casks used for transporting spent fuel between Germany, Switzerland, France, and the United Kingdom had levels of radioactive

contamination on the exterior of the casks far exceeding the legal limits.⁴⁸ The German Environment Minister announced that the industry had been aware of the excessive radiation since the 1980s, but had failed to inform the government. While the levels of radiation were too low to pose any health hazard to those handling the casks, the revelations were nonetheless a severe blow to the public credibility of the safety assurances provided by the firms and regulatory agencies involved. The head of the German police union announced that his union would refuse to protect further shipments until the issue was resolved, and the German Environment Minister called a halt to all shipments. Nuclear regulators of the four countries involved formed a working group to address the issues raised by the episode, which concluded that while contaminated shipments had been occurring for at least a decade without the public or the workers handling the shipments being informed, "as far as health is concerned, the non-compliance with the . . . standard did not have any radiological consequence." Moreover, the group concluded that the contamination did not result from leaking from the interior of the casks, but from radioactivity present in the spent fuel pools where the casks were loaded and unloaded, and that with modest improvements in procedures and regulations, it was safe to resume transports.⁴⁹ The French and German governments did not reach agreement on resuming transports until early 2001, however, nearly three years after the contamination

⁴⁵ For the IAEA regulations, see *Regulations for the Safe Transport of Radioactive Material*, 1996 Edition, Requirements, Safety Standards Series No. ST-1 (Vienna, Austria: IAEA, 1996). The U.S. regulations are *10 Code of Federal Regulations Part 71: Packaging and Transportation of Radioactive Material* (Washington, DC: Government Printing Office, various years, available at <http://www.nrc.gov/NRC/CFR/PART073/>). Japan incorporated the 1985 edition of these IAEA transport regulations into its domestic regulations in 1991, and is now studying incorporation of the 1996 edition. See Saegusa, Ito, and Suzuki, *An Overview of the State of the Arts of Spent Nuclear Fuel Management*, op. cit.

⁴⁶ See, for example, discussion in Holt, *Transportation of Spent Nuclear Fuel*, op. cit. The views on transportation safety and security of the Nevada Nuclear Waste Project Office, which has raised some of the most detailed concerns and criticisms regarding current U.S. approaches, can be found at <http://www.state.nv.us/nucwaste/trans.htm>.

⁴⁷ See, for example, Edwin Lyman, *The Sea Transport of Vitrified High-Level Radioactive Wastes: Unresolved Safety Issues* (Washington, DC: Nuclear Control Institute, 1996).

⁴⁸ For a detailed account of the revelation from the perspective of an industry critic, see Mycle Schneider, "The Contaminated Transport Saga: A Personal Account," *Plutonium Investigation* (Paris), May-June 1998. See also the summary of this and related episodes in Kate O'Neill, "International Nuclear Waste Transportation: Flashpoints, Controversies, and Lessons," *Environment*, Vol. 41, No. 4 (May 1999).

⁴⁹ *Surface Contamination of Nuclear Spent Fuel Transports: Common Report of the Competent Authorities of France, Germany, Switzerland, and the United Kingdom* (Paris, France: Ministry of the Environment, October 24, 1998).

was revealed.⁵⁰ Also in 1998, it was revealed that similar contamination had been observed on spent fuel transport casks used to ship fuel from Japan to Europe in the early 1990s.⁵¹ Later that year, the Japanese firm that manufactures spent fuel transport casks acknowledged that data on the radiation protection provided by a particular set of the casks had been falsified.⁵² Issues concerning data on transport cask safety have continued to arise since then. This episode highlights the need for strong and effective regulation of transport, including independent measurements to confirm that safety requirements are being met—and its political reverberations are likely to be lasting.

Transport Security

Another issue that has been the subject of some concern is the security of nuclear waste shipments. Spent fuel shipments, like spent fuel storage, must be guarded against both theft and sabotage intended to spread radioactive contamination (a more likely threat). The United States and Japan both have regulations in place specifying the security measures required for spent fuel transports.⁵³ A variety of studies have concluded that even an attack on a spent fuel transport using shaped-charge explosives on the casks

would spread only a minor amount of radioactivity. These regulations and studies too, however, have been criticized as inadequate.⁵⁴ Critics have attacked security arrangements for overseas transport of nuclear material with particular vigor—indeed three Greenpeace members successfully boarded one recent shipment to demonstrate their security concerns.⁵⁵ Security for nuclear material transports clearly needs to be carefully tailored to the circumstances of the particular transport and an assessment of the threats that transport is likely to face.

Transport Cost

The cost of transporting spent nuclear fuel is dependent on the circumstances of the particular transport—the distances involved, the quantities of material, the modes of transport, the levels of security required, and the like. A 1994 study of the costs of the nuclear fuel cycle by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development provided an estimate of \$50/kgHM for transportation within Europe.⁵⁶ Similarly, the U.S. Department of Energy estimates a total cost for transporting civilian spent nuclear fuel to the Yucca Mountain repository and accepting it there of \$4.76 billion, for

⁵⁰ “Resumption of Transport of Nuclear Waste Between France and Germany” (Paris, France: Office of the Prime Minister, January 31, 2001, available at <http://www.pu-investigation.org/ournews/news5.html>).

⁵¹ Japanese utilities reported the contamination to nuclear regulators on May 28, 1998; the utilities argued that there had been no legal requirement to report it to regulators or the public when it occurred. Fifteen casks shipped during 1990-1994 had been contaminated, at levels in one case up to 148 becquerels per square centimeter. “Spent Fuel Transport Casks From Japan Also Contaminated,” *Nuke Info Tokyo*, Citizens’ Nuclear Information Center, July/August 1998.

⁵² See, for example, “Data Falsified on 37 of 43 Nuclear-Fuel Receptacles,” *The Daily Yomiuri*, October 14, 1998. On October 9, 1998, responding to the falsified data, the Science and Technology Agency (STA) prohibited any further shipments using these casks until the safety of the casks was demonstrated (*Nihon Keizai Shimbun*, October 10, 1998). Although the STA expert committee judged a month later that the casks satisfied the safety requirements (*Asahi Shimbun*, November 12, 1998), the utility companies decided to take voluntary actions to regain public confidence, first replacing the president of Japan Atomic Power Engineering, the firm responsible for the data falsification (*Asahi Shimbun*, December 3, 1998), and ultimately forcing the firm to shut down (“The Cost of Data Altering Escalates,” *Nuclear Engineering International*, January 31, 1999).

⁵³ The U.S. regulations are *10 Code of Federal Regulations Part 73.37: Requirements For Physical Protection of Irradiated Reactor Fuel in Transit* (Washington, DC: Government Printing Office, various years, available at <http://www.nrc.gov/NRC/CFR/PART073/>).

⁵⁴ See, for example, Ed Lyman, “A Critique of Physical Protection Standards for Transport of Nuclear Materials,” in *Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management*, July 1999 (available at <http://www.nci.org/el-inmm99.htm>). This is another area where the Nevada Nuclear Waste Project Office has been particularly detailed in its criticism. See, for example, Robert J. Halstead and James David Ballard, *Nuclear Waste Transportation and Security Issues: The Risk of Terrorism and Sabotage Against Repository Shipments* (Carson City, NV: Nuclear Waste Project Office, 1997).

⁵⁵ This incident is described in O’Neill, “International Nuclear Waste Transportation,” *op. cit.*

⁵⁶ Nuclear Energy Agency, *The Economics of the Nuclear Fuel Cycle* (Paris, France: OECD/NEA, 1994).

some 86,300 tonnes of spent fuel, or about \$55/kgHM.⁵⁷ Overseas transportation would in general be somewhat more expensive, while transportation within Japan, which is carried out using ships that have already been paid for and casks that are re-used, would be expected to be cheaper. Indeed, the projected transportation cost for a centralized dry cask storage facility in Japan presented in Table 2.1 above, is extraordinarily low, amounting to roughly \$7/kgHM—presumably because the transport ships, vehicles, and casks already exist, so only the additional operations costs need to be included.

Of course, unique circumstances—including political circumstances—can affect the cost of transportation dramatically. In Germany, for example, 30,000 riot police were required to protect the first shipment of nuclear waste to the Gorleben site, at a cost of some \$57 million for a modest amount of spent fuel.⁵⁸

Political and Institutional Constraints on Transport

As with interim storage, the most difficult and complex aspects of transportation of spent fuel are building public confidence and overcoming the political and institutional constraints. In the United States, for example, legislation to establish a centralized interim storage site, was met with considerable skepticism over the safety of the required shipments, and was quickly dubbed the “mobile Chernobyl” bill by critics—a technically nonsensical but politically effective bit of sloganeering.⁵⁹ There has also been substantial public concern and political opposition to international transports of various nuclear materials, such as the shipments between Japan and Europe.⁶⁰

The political and institutional constraints on transportation are much more difficult and complex in the United

States than in Japan, because of the long overland transport routes that are likely to be required in the United States. These routes pass through nearly every state, hundreds of local communities, and the lands of numerous sovereign Native American tribes. Each of these jurisdictions must be involved in preparation for a transport, emergency planning, and the like, and each may have its own reasons for opposing the transport. A huge complex of Federal agencies—the Department of Energy, the Department of Transportation, the Nuclear Regulatory Commission, the Environmental Protection Agency, the Federal Emergency Management Agency, and more—share parts of the responsibility for ensuring the safety of transports of nuclear material, and must be involved. The planning process for any particular shipment can take years, and the opportunities for opponents to intervene to stop a shipment from taking place are legion.

In general, there has been greater success in addressing these concerns and building public support where there was an open and transparent process designed to build general agreement that the transport was necessary, and the alternative of the status quo without transportation was not acceptable.⁶¹ Approaches to such processes are discussed in detail in Chapter 5.

Current Storage Status: United States

As of the end of 1998, just over 38,400 tHM of commercial spent fuel was in storage in the United States. Of that total, all but 755 tHM was stored at reactor sites, and all but 1,511 tHM was in pool storage.⁶²

The spent fuel cooling pools at over half of U.S. power reactors are currently over 50% full. Had the reactor operators relied only on their storage pools, several would

⁵⁷ See *Report to Update Total System Life Cycle Cost Estimate for Site Recommendation/ License Application* (Washington, DC: DOE, December 1999), p. 35.

⁵⁸ See O’Neill, “International Nuclear Waste Transportation,” *op. cit.*

⁵⁹ See, for example, Nuclear Information and Resource Service, “Why We Call It ‘Mobile Chernobyl,’” fact sheet, available at <http://www.nirs.org/factsheets/whywecallitmobilechernobyl.htm>

⁶⁰ O’Neill, “International Nuclear Waste Transportation,” *op. cit.*

⁶¹ *Ibid.* The case of the U.S. Waste Isolation Pilot Plant (WIPP), where transportation was ultimately accepted after prolonged delays in opening the facility—and an extensive process of public discussion and of making provision for transparency in the shipments—is another example of this type of approach.

⁶² “Detailed United States Spent Nuclear Fuel Data as of December 31, 1998,” available at http://www.eia.doe.gov/neaf/nuclear/spent_fuel/ussnfdta.html.

already have filled their pools to capacity, losing the ability to offload a full reactor core into the pool. Many other reactors will lose this capacity over the next few years, unless additional storage is provided.⁶³ An appendix at the end of this chapter shows, for each U.S. reactor, the pool capacity, the amount of spent fuel currently stored, the date at which the ability to off-load a full core will be lost if no additional storage is provided, and whether the plant is using dry cask storage to complement its pool or not, as of late 1998.

As described in Chapter 3, a number of efforts to establish large centralized interim storage facilities in the United States have so far failed, though some are still being pursued. Hence, reactor operators have established dry storage facilities (primarily dry cask storage facilities) at their reactor sites. Spent fuel dry storage designs are well-established technologies that have been licensed in the United States since 1985. As of the end of 1998, 19 reactors at 11 sites employed dry storage to enhance their ability to meet their spent fuel storage needs.⁶⁴ Another 11 sites have identified a vendor for dry storage, and some of these are under construction.⁶⁵ The NRC has licensed twelve dry storage models of a variety of different designs.⁶⁶ Utility companies that own reactors can either add dry storage under their existing general site operating license using a pre-approved storage system design, or they can get a site-specific license for their dry storage system.⁶⁷

The amount of fuel in dry storage in the United States is more than in any other country except Canada (whose

CANDU reactors generate much larger tonnages of spent fuel per unit of electricity produced than light-water reactors do).⁶⁸ Overall, the safety record of dry storage in the United States has been very good. There have been no incidents that released any radioactivity to the environment, or that over-exposed any facility workers. There have, however, been a number of problems in the U.S. program reflecting the need to maintain constant vigilance over the quality of design, manufacture, loading, and sealing of all aspects of the dry cask storage system, as discussed above.

Current Storage Status: Japan

Although Japan's current policy is to reprocess all spent nuclear fuel, a substantial fraction of Japan's spent fuel has not yet been reprocessed. According to a recent estimate from the Ministry of International Trade and Industry (MITI), as of September, 1999, the cumulative amount of spent nuclear fuel generated in Japan was 14,620 tHM. About one-third of this (5,630 tHM) has been shipped to European reprocessing companies in UK and France, and 940 tonnes has been shipped to the pilot-scale Japanese reprocessing plant at Tokai. Only 20 tonnes had been shipped to the Rokkasho reprocessing plant now under construction. Therefore, about half of the spent fuel generated in Japan (8,030 tHM) was being stored at reactor sites. See Table 2.2 on the next page.

⁶³ For a detailed analysis of spent fuel storage capacity and the dates at which the capacity to off-load a full core will be lost, see Allison Macfarlane, "Interim Storage of Spent Fuel in the United States," *Annual Review of Energy and the Environment*, forthcoming. A chart showing projected year at which the capability to offload a full core will be lost for each reactor is available at <http://www.nrc.gov/OPA/drycask/sfdata.htm>.

⁶⁴ These reactors are: Surry 1 & 2, North Anna 1 & 2 (both Virginia Power), Robinson 2 (Carolina Light & Power), Oconee 1, 2 & 3 (Duke Power), Fort St. Vrain (Public Service Company of Colorado), Calvert Cliffs 1 & 2 (Baltimore Gas & Electric), Palisades (Consumers Energy), Prairie Island 1 & 2 (Northern States Power Company), Point Beach 1&2 (Wisconsin Electric Power), Arkansas Nuclear 1&2 (Entergy Arkansas Inc.), and Davis-Besse (First Energy Nuclear Operating). For an updated list of sites with NRC licenses for dry storage, see <http://www.nrc.gov/OPA/reports/cask.htm#licenses>.

⁶⁵ Nigel Mote, "Worldwide Experience of Dry Storage of Spent Nuclear Fuel," presentation to the Harvard Project on Managing the Atom and Tokyo University Project on Socio-Technics of Nuclear Energy Workshop on Interim Storage of Spent Fuel, February 18-19, 1999.

⁶⁶ See discussion in U.S. Nuclear Regulatory Commission, "Onsite Storage of Spent Nuclear Fuel," available at <http://www.nrc.gov/OPA/drycask/>.

⁶⁷ *Ibid.*

⁶⁸ IAEA, *Survey of Wet and Dry Spent Fuel Storage*, op. cit., p. 5.

Table 2.2: Current Status of Spent Fuel Storage in Japan (as of September 1999)⁶⁹

Location	Facility	SF in Store (MT)	Storage Capacity (MT)
Hokkaido	Tomari	220	420
Tohoku	Onagawa	170	370
Tokyo	Fukushima 1	990	2100
	Fukushima 2	1150	1360
	Kashi-Kari	1200	1890
Chubu	Hamaoka	620	860
Hokuriku	Shika	30	100
Kansai	Mihama	230	300
	Takahama	740	1100
	Ohi	620	840
Chugoku	Shimane	270	390
Shikoku	Ikata	290	530
Kyushu	Genkai 2	330	1060
	Sendai	540	700
JAPCo	Tsuruga	400	650
	Tokai 2	200	260
Total		8,030	12,930

At the current generation rate of roughly 900 tHM per year, the total available storage capacity at existing reactor sites (12,930 tHM) is only enough to hold 4-5 years of continued spent fuel accumulation. Some specific reactor sites have even less time remaining before their storage capacity is exhausted. Storage capacity is being increased at many reactors by re-racking existing storage pools, but there are clear limits to how much additional capacity can be gained by this means. Utilities are now permitted to move fuel from older reactors with limited storage capacity to the larger-capacity pools of newer reactors, but this

requires relicensing,⁷⁰ and does not address the problem of limited *total* storage capacity.

Unit 2 at Tokyo Electric Power Company's Fukushima site is the only reactor in Japan where new storage facilities have been built in addition to the reactor storage pool, including a new common storage pool and a dry cask storage building. The common storage pool was completed in 1997 and its capacity is 1,200 tHM (6,840 fuel assemblies). The dry cask storage facility—the only such facility operational in Japan—was completed in September 1995, and has a capacity of 20 casks, i.e. 860 fuel assemblies or about 150 tonnes.⁷¹

⁶⁹ Based on *Current Status of Spent Fuel Storage in Japan* (Tokyo: Ministry of International Trade and Industry, Nuclear Industry Division, February 2000). The capacity figures represent the capacity while keeping enough pool space empty for one full core load and one annual reload.

⁷⁰ For example, Tokyo Electric Power applied for a license for such a "reactor-to-reactor" transfer of spent fuel at the Fukushima plants in 1999. On April 13, 2000, 31 fuel assemblies were shipped from the #4 reactor to the #2 reactor, with its additional spent fuel storage facilities.

⁷¹ For an overview of the casks used in this facility and their specifications, see Saegusa, Ito and Suzuki, *An Overview of the State of the Arts of Nuclear Spent Fuel Management*, op. cit.

Two other spent fuel storage facilities exist in Japan in addition to those available at reactor sites—the spent fuel ponds at the Tokai and Rokkasho reprocessing plants, intended to store spent fuel temporarily in preparation for reprocessing. The Tokai plant has only a very limited storage capacity (140 tHM). While the Tokai plant resumed reprocessing in late 2000 after a shut-down of more than three years following an accident, fire, and cover-up at the plant, the amount of fuel that will be accepted for reprocessing at this plant in the future is likely to be relatively modest. The large spent fuel storage pool at the Rokkasho plant, designed to hold 3000 tHM of spent fuel, is complete, but only a limited amount of fuel has been shipped there to date (56 tHM as of the end of 2000).⁷² The politics of gaining approval for shipments has been tightly linked to continued progress toward construction and operation of the plant, as described in Chapter 3.

MITI's report also estimated future spent fuel generation in Japan. As of 1997, the quantity of spent fuel discharged annually was roughly 900 tHM. This is projected to increase to 1,400 tHM in 2010 (assuming 70 GWe of nuclear capacity) and perhaps to as much as 1,900 tHM annually in 2030 (assuming 100 GWe of nuclear capacity). Cumulative spent fuel generation in fiscal 1997-2010 is projected to be in the range of 15,200 tHM, while domestic storage and reprocessing capacity (assuming the Rokkasho reprocessing plant operates on schedule and at full capacity) is about 13,000 tHM. Therefore over 2000 tHM of additional storage capacity will be needed by 2010. This amount is projected to increase to 6,000 tonnes by 2020 and nearly 15,000 tonnes by 2030.⁷³ These should be considered minimum figures for the amount of new storage capacity required, as they assume there will be no constraints on the full use of any existing facilities, and no delays or constraints on the full operation of the Rokkasho reprocessing plant. In all likelihood, still more storage capacity will be needed. Currently, the utilities and the government are

working to find a suitable site for a centralized storage facility with a capacity of 15,000 tHM, to be opened by 2010.⁷⁴ This effort is described in more detail in Chapter 3.

Current Storage Status: Other Countries

Worldwide, some 150,000 tHM of spent fuel is in storage, as noted earlier. As of the end of 1997, worldwide spent fuel storage capacity was roughly 100,000 tHM greater than worldwide spent fuel storage inventory, and both inventory and capacity were increasing in parallel, so that this comfortable margin was expected to continue to exist for many years to come.⁷⁵ This comforting global picture, however, hides substantial differences in the situations in individual countries.

There are a number of countries that have not faced substantial problems with spent fuel storage. A few examples will show the range of factors that have contributed to such outcomes. Canada, for example, has one of the world's largest inventories of stored spent fuel, but because long-term storage of this fuel was envisioned from very early on in Canada's program, Canada has been able to provide dry storage for this fuel without facing undue obstacles. Sweden sited and built the CLAB away-from-reactor interim storage facility before siting of centralized interim storage sites became as controversial as it is in some countries today, and in a context in which there was agreement that there would be no more nuclear power plants in Sweden—reducing nuclear opponents' incentive to oppose the storage facility. France has had few spent fuel storage problems because its policy has been to reprocess all of its spent fuel—though now additional studies of long-term storage issues are underway, as the French utility does not plan to reprocess some types of spent fuel, such as MOX spent fuel.

Other countries, like the United States and Japan, have faced a range of political and institutional difficulties in expanding spent fuel storage capacity to meet the rising

⁷² 24 tonnes was shipped to the plant in December 2000, after the nuclear safety agreement for the facility had been agreed to. There had been three earlier "experimental" shipments, of 8, 11, and 13 tonnes. See "Full-Scale Shipment to Rokkasho Begins," Citizens Nuclear Information Center (Tokyo), January 12, 2001.

⁷³ *Current Status of Spent Fuel Storage in Japan*, op. cit.

⁷⁴ Subcommittee on Nuclear Energy, MITI Advisory Council on Energy, op. cit., 1998.

⁷⁵ See A. Bonne, M.J. Crijns, P.H. Dyck, K. Fukuda, V.M. Mourogov, "Spent Fuel Management Overview: A Global Perspective," in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999.

needs of their reactors, and the uncertainties surrounding spent fuel management have clouded the future of nuclear energy in many of these countries. Each country faces its own unique set of issues and problems. Below, we provide brief discussions of the spent fuel storage situations in a few selected countries.

Taiwan. Management of spent fuel and other nuclear wastes has become the subject of enormous political controversy in Taiwan, and an important factor in the heated national debate over whether to complete a new nuclear power plant.⁷⁶ Taiwan, which has six nuclear power reactors at three sites, is a small, densely populated, and seismically active country with highly contentious politics—not an ideal combination for nuclear waste management. All of Taiwan's spent fuel is U.S.-obligated, and the United States has not given its consent to reprocessing, judging Taiwan to be in a region of proliferation concern. As of early 1998, Taiwan had some 1,950 tHM of spent fuel in storage, with 115 tHM of additional spent fuel being discharged each year, and adequate storage capacity remaining for only a few years.⁷⁷ Taipower, the national utility, has re-racked the fuel in its storage pools, but nonetheless projects that the reactors at Chinshan might run out of space by 2007 if additional storage capacity is not provided, and hence hopes to build a dry cask storage facility by 2005.⁷⁸ This has been politically contentious, however, and Taipower's plans have been delayed both by the expected high cost of benefits to potential host communities to get them to accept spent fuel,⁷⁹ and by the fact that the particular cask design Taipower initially chose has been under intense regulatory scrutiny from the U.S. NRC (whose judgments are influen-

tial with Taiwan's regulators) after serious quality control problems in cask manufacture were revealed in the late 1990s. The cask manufacturer has now withdrawn the cask from NRC licensing review.⁸⁰ Taiwan has also pursued discussions with a variety of parties about shipping spent fuel or low-level nuclear wastes to sites in other countries, as described in Chapter 4, but none of these options have yet come to fruition. The ultimate outcome of Taiwan's nuclear waste dilemmas remains very much in doubt.

Republic of Korea. Korea has also had substantial political controversies over spent fuel and nuclear waste management. Korea has 14 nuclear power reactors, both LWRs and CANDUs, and plans to build more. Like Taiwan, much of the fuel in Korea is under U.S. obligations, and the United States has not given its consent to reprocessing, so the fuel remains in storage. By mid-1998, some 3,400 tHM of spent fuel had been discharged from these reactors, and some 500 tHM of additional fuel was being discharged each year.⁸¹ An initial plan for an away-from-reactor dry storage facility was put off after intense public opposition in the early 1990s, so fuel is currently stored at the reactor sites.⁸² The fuel pools at these sites have been re-racked to increase their capacity, fuel has been moved between neighboring reactor units, and at-reactor dry storage for both CANDU and LWR fuel has been added in recent years.⁸³ Unless additional storage capacity is provided, it is expected that storage capacity at some of the reactor sites would be filled by 2006.⁸⁴ Transshipment of fuel between reactor sites is being considered, and could extend the available storage capacity for a considerable period, particularly if fuel burnup were also increased.⁸⁵ Additional at-reactor dry cask storage is

⁷⁶ Mark Hibbs, "Battle Over Lungmen Forces Taiwan Waste Debate Into Open," *Nucleonics Week*, October 5, 2000.

⁷⁷ Estimates provided by the IAEA.

⁷⁸ Mark Hibbs, "Taiwan Planning on Dry Storage for Its Spent Fuel Inventory," *Nuclear Fuel*, November 1, 1999.

⁷⁹ *Ibid.*

⁸⁰ Mark Hibbs, "KEPCO, Taipower Will Not Rush Decisions on Spent Fuel Storage," *Nuclear Fuel*, May 15, 2000.

⁸¹ D.K. Min, G.S. You, S.G. Ro, and H.S. Park, "Current Status of Spent Fuel Management in the Republic of Korea," in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999.

⁸² Jungmin Kang, *Evaluation of Additional Spent Fuel Storage Requirements in Korea Through the Year 2030*, PU/CEES Report No. 312 (Princeton, NJ: Center for Energy and Environmental Studies, Princeton University, January 1999).

⁸³ Min, You, Ro, and Park, "Current Status of Spent Fuel Management in the Republic of Korea," *op. cit.*

⁸⁴ Min, You, Ro, and Park, "Current Status of Spent Fuel Management in the Republic of Korea," *op. cit.*, and Kang, *Evaluation of Additional Spent Fuel Storage Requirements in Korea Through the Year 2030*, *op. cit.*

⁸⁵ Kang, *Evaluation of Additional Spent Fuel Storage Requirements in Korea Through the Year 2030*, *op. cit.* See also Hibbs, "KEPCO, Taipower Will Not Rush Decisions on Spent Fuel Storage," *op. cit.*

also being considered, and a centralized dry storage facility is still planned late in this decade, if the political obstacles to building such a facility can be overcome.⁸⁶

China. China is still in the early stages of its nuclear power program, with only three reactors in operation (a Chinese-designed 300 MWe PWR at Qinshan, and 2 French-designed PWRs at Daya Bay). Several more are under construction, however, and additional reactors may be built in the future. As of 2000, China had approximately 400 tHM of spent fuel in storage, three quarters of which was from Daya Bay. As is the case in many other countries, the reactors now in operation were built with limited pool storage capacity, with the idea that fuel would be reprocessed. Indeed, the pool at Qinshan is expected to be full in 2001-2, while those for the two French-built units at Daya Bay are expected to be full in 2003- 2004—some ten years after those plants began operation.⁸⁷ The operators of the Daya Bay plant have so far been denied permission to re-rack the storage pools to increase capacity.⁸⁸ The plan is to transport the fuel to the 550 tHM away-from-reactor wet storage facility that has been built at Lanzhou (where the reprocessing would also take place), but it is not yet clear whether adequate transportation infrastructure is in place.⁸⁹ If, as is planned, the capacity of this away-from-reactor pool is doubled, and transportation is successful, there should be sufficient storage space to manage China's spent fuel discharges until at least 2020.⁹⁰ While a pilot-scale reprocessing plant has been built at Lanzhou, previous plans for a large commercial reprocessing plant may be reconsidered.⁹¹ China has the opportunity to avoid future spent fuel storage problems by incorporating provision for sufficient storage for life-time fuel arisings in the design of its new reactors as they are built (or providing away-from-reactor facilities with such capacity).

Germany. German utilities have been facing increasing difficulties with management of their spent fuel, as part

of the broader political opposition to nuclear energy in Germany. Originally, German law required the utilities to reprocess their fuel, and after the cancellation of the domestic reprocessing plant, the utilities entered into reprocessing contracts with BNFL and COGEMA to reprocess their fuel. When the law was changed in 1994 to allow either direct disposal or reprocessing, a substantial fraction of the utilities began to plan on direct disposal of their spent fuel, requiring additional interim storage capacity. Dry cask interim storage facilities are in operation at Gorleben and Ahaus, but the transports of spent fuel to these facilities have been intensely controversial, requiring the deployment of tens of thousands of riot police for each shipment, at a cost of tens of millions of dollars per shipment—an approach that would be very difficult to sustain. Moreover, the nearly three-year moratorium on shipments that resulted from the revelations of transport cask contamination in 1998 (described above) left utilities with additional fuel on-site requiring storage. The 1998 transport suspension created a critical situation for some German reactors, as their pools were expected to be full as soon as 2001⁹² (a situation that will presumably be resolved given the decision to resume transports in early 2001). In addition, the nuclear phase-out agreement reached in 2000 calls for the utilities to begin immediately to establish additional at-reactor storage facilities, with the objective of bringing them into operation by 2005, so that shipments to reprocessing facilities can end by that time—but the establishment of these at-reactor facilities is already proving controversial, with some state regulators threatening to block their licenses.⁹³

Eastern Europe and the Newly Independent States. The reactors in the states of eastern Europe are of Soviet design (with the exception of the CANDU plant in Romania and the Westinghouse plant in Slovenia) and originally were designed with pool storage for only three years of discharges, as the fuel was to be sent back to the Soviet Union

⁸⁶ Min, You, Ro, and Park, "Current Status of Spent Fuel Management in the Republic of Korea," op. cit.

⁸⁷ Hui Zhang, "China's Future Reprocessing Policy," presentation to the Managing the Atom Research Seminar, Harvard University, December 12, 2000. For the Daya Bay plants, see also Mark Hibbs, "China Barred Guangdong Joint Venture From Re-Racking Spent Fuel Pond," *Nuclear Fuel*, April 3, 2000.

⁸⁸ Hibbs, "China Barred Guangdong Joint Venture From Re-Racking Spent Fuel Pond," op. cit.

⁸⁹ Ibid.

⁹⁰ Hui Zhang, "China's Future Reprocessing Policy," op. cit.

⁹¹ Mark Hibbs, "Chinese Pu Lab to Operate in 2002, But Interim Storage Now Foreseen," *Nuclear Fuel*, October 30, 2000.

⁹² Mark Hibbs, "State Regulator Declares War on German Phase-Out Waste Strategy," *Inside N.R.C.*, July 31, 2000.

⁹³ Ibid.

for reprocessing.⁹⁴ In recent years, Russia has begun charging nearly world prices for reprocessing, and has changed its law to require that reprocessing wastes be sent back to the customer (though that law is in the process of being modified, as discussed in Chapter 4). Only a few remaining countries, such as Ukraine, Bulgaria, and Hungary, are still sending some of their fuel to Russia. As a result, many of the countries of the region have had to establish away-from-reactor storage facilities: some earlier facilities were wet pools, while more recent ones have been dry storage facilities. Delays resulting from lack of resources have posed significant storage problems in some cases. Armenia is the most extreme case. There, the spent fuel pond of the one remaining operating reactor is full, and the full core reserve has been used as well; the pool of the shut-down reactor is also full. A dry storage facility based on the NUMHOMS silo storage technology has been built to resolve this problem, and is expected to begin loading soon.⁹⁵

Russia. Russia faces substantial storage problems for some types of spent fuel. Naval fuel is the most pressing issue: fuel from more than 180 retired submarines requires safe storage, and despite financial support from several countries, progress in building adequate dry cask storage facilities for this material has been painfully slow. As a result, fuel has been left in the reactors of aging submarines tied up

at piers, creating serious safety hazards.⁹⁶ In the civilian sector, 29 power reactors are in operation generating some 790 tHM of fuel each year,⁹⁷ with over 11,000 tHM in storage as of 1999.⁹⁸ Because fuel from RBMK channel-type reactors is not reprocessed, the pools at RBMK plants are filling up, creating a “critical” situation that could force some of these plants to shut by 2005 if additional storage is not provided.⁹⁹ To resolve this issue, dry cask storage is being built for RBMK fuel, and shipment of some RBMK fuel to the RT-2 pool, designed for VVER-1000 fuel, is being considered.¹⁰⁰ A large (6,000 tHM) storage pool for VVER-1000 fuel was built at Zheleznogorsk (formerly Krasnoyarsk-26) as part of the construction of the planned RT-2 reprocessing plant, but that construction has been on hold for many years, and there is now little prospect that the funds to complete RT-2 will be found in the near term. VVER-440 fuel is reprocessed at Mayak, where there is a smaller (560 tHM) pool for this fuel.¹⁰¹ But with the decline in foreign contracts for Mayak’s reprocessing services, it may no longer be economical to operate the plant, and the United States and Russia have been discussing the possibility of a 20-year moratorium on separating plutonium by reprocessing, which would require additional storage for this type of fuel.¹⁰² As discussed in Chapter 4, Russia is now considering offering to import foreign spent fuel for storage or processing in Russia.

⁹⁴ F. Takats and H.P. Dyck, “Spent Fuel Storage Developments in Eastern Europe and Former Soviet Union,” *Journal of Nuclear Materials Management*, Summer 2000. Takats and Dyck also provide data on how much spent fuel is stored in at-reactor and away-from-reactor facilities for each country in the region.

⁹⁵ *Ibid.*

⁹⁶ See James Clay Moltz, “Russian Nuclear Submarine Dismantlement and the Naval Fuel Cycle,” *Nonproliferation Review*, Spring 2000. This spent fuel storage bottleneck has affected the rate at which Russia can dismantle submarines to meet its arms reduction commitments. Recently, however, two developments have improved the situation. Under the Cooperative Threat Reduction program, the U.S. Department of Defense has agreed to pay for some naval spent fuel to be reprocessed pending the construction of adequate dry cask storage for the remainder, and the Ministry of Atomic Energy has begun providing funding for submarine dismantlement from revenues generated by the sale of blended-down bomb uranium to the United States. As a result, the pace of dismantlement has increased from 4 subs dismantled in 1998 to 18 in 2000. See Valeriy Lebedev (Deputy Minister of Atomic Energy) “We Have To Find Some Optimal Way to Dismantle Nuclear-Powered Submarines (Interview),” *Yaderny Kontrol (Nuclear Control) Digest*, Winter 2001.

⁹⁷ V.A. Kournosov et. al., “Current State and Perspectives of Spent Fuel Storage in Russia,” in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999.

⁹⁸ Takats and Dyck, “Spent Fuel Storage Developments in Eastern Europe and Former Soviet Union,” *op. cit.*

⁹⁹ V.A. Kournosov et. al., “Current State and Perspectives of Spent Fuel Storage in Russia,” *op. cit.*

¹⁰⁰ Takats and Dyck, “Spent Fuel Storage Developments in Eastern Europe and Former Soviet Union,” *op. cit.*

¹⁰¹ *Ibid.*

¹⁰² See, for example, discussion in Matthew Bunn, *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Washington, DC: Harvard Project on Managing the Atom and Carnegie Endowment for International Peace, April 2000) pp. 53-57.

Appendix: Data on Spent Fuel Storage at Reactors in the United States¹⁰³

Plant Name	Core Size	Spent Fuel Pool			Current License Expires	Lose Full Core Offload Capability	Dry Cask Storage?
		Capacity	Assemblies Stored	Remaining Capacity			
Arkansas 1	177	968	818	150	2014	LOST	YES
Arkansas 2	177	988	701	287	2018	1999	YES
Beaver Valley 1	157	1627	756	871	2016	2018	NO
Beaver Valley 2	157	1088	392	696	2027	2012	NO
Braidwood 1	193	2870	1054	1816	2026	2010	NO
Braidwood 2	193				2027	2010	NO
Browns Ferry 1	764	3471	1864	1607	2013		NO
Browns Ferry 2	764	3133	2116	1355	2014	2013	NO
Browns Ferry 3	764	2353	1588	1879	2016	2006	NO
Brunswick 1	560	1767	984	783	2016	2000	NO
Brunswick 2	560	1767	1020	747	2014	1999	NO
Byron 1	193	2781	1278	1503	2024	2010	NO
Byron 2	193				2026		NO
Callaway	193	1340	829	511	2024	2004	NO
Calvert Cliffs 1	217	1830	1362	468	2014		YES
Calvert Cliffs 2	217				2016		YES
Catawba 1	193	1418	705	622	2024	2006	NO
Catawba 2	193	1418	686	695	2026	2006	NO
Clinton	624	2515	1124	1381	2026	2006	NO
Comanche Peak 1	193	556	765	526	2030	2002	NO
Comanche Peak 2	193	735			2033		NO
Cooper	548	2366	1340	1026	2014	2004	NO
Crystal River 3	177	1357	680	677	2016	2011	NO
Davis-Besse	177	718	601	117	2017	Lost in 1998	YES
D.C. Cook 1	193	3613	2015	1598	2014	2011	NO
D.C. Cook 2	193				2017	2011	NO
Diablo Canyon 1	193	1324	640	684	2021	2006	NO
Diablo Canyon 2	193	1317	660	657	2025	2007	NO
Dresden 2	724	3537	2562	975	2006	2002	NO
Dresden 3	724	3536	2380	1156	2011	2003	NO
Duane Arnold	368	2411	1648	763	2014	2003	NO
Farley 1	157	1407	662	527	2017	2006	NO
Farley 2	157	1407	593	641	2021	2010	NO
Fermi 2	764	2383	1296	1087	2025	2001	NO
FitzPatrick	560	2797	2080	717	2014		NO
Fort Calhoun	133	1083	706	377	2013	2007	NO
Ginna	121	1879	879	435	2009	NA	NO
Grand Gulf 1	800	4348	2488	1860	2022	2005	NO
Hatch 1	560	5946	4884	1062	2014	2000	NO
Hatch 2	560				2018	2000	NO

(Continued on next page)

¹⁰³ Data is from unevaluated utility information provided to the U.S. Nuclear Regulatory Commission, as of November 4, 1998, available at <http://www.nrc.gov/OPA/drycask/sfdata.htm>.

Plant Name	Core Size	Spent Fuel Pool			Current License Expires	Lose Full Core Offload Capability	Dry Cask Storage?
		Capacity	Assemblies Stored	Remaining Capacity			
Hope Creek	764	4006	1708	2298	2026	2008	NO
Indian Point 2	193	1374	917	457	2013	2006	NO
Indian Point 3	193	1345	672	655	2015	2011	NO
Kewaunee	121	990	780	210	2013	2009	NO
LaSalle 1	764	7932	3076	4852	2022	2013	NO
LaSalle 2	764				2023	2013	NO
Limerick 1	764	2832	1701	1131	2024	2006	NO
Limerick 2	764	3921	1893	2028	2029	2006	NO
McGuire 1	193	1351	871	480	2021	2002	NO
McGuire 2	193	1425	1039	386	2023	2001	NO
Millstone 2	217	1263	868	423	2015	2002	NO
Millstone 3	193	756	416	340	2025	2001	NO
Monticello	484	2209	1094	1115	2010	2006	NO
Nine Mile Point 1	532	2776	2200	576	2009	1999	NO
Nine Mile Point 2	764	4049	1400	2649	2026	2010	NO
North Anna 1	157	1737	1505	169	2018		YES
North Anna 2	157				2020		YES
Oconee 1	177	1312	1094	218	2013	2013	YES
Oconee 2	177	1312	1094	218	2013	2013	YES
Oconee 3	177	825	552	273	2014	2014	YES
Oyster Creek	560	2645	2420	180	2009	LOST	YES
Palisades	204	771	657	101	2007	LOST	YES
Palo Verde 1	241	1205	648	557	2024	2004	NO
Palo Verde 2	241	1205	644	561	2025	2003	NO
Palo Verde 3	241	1205	664	541	2027	2003	NO
Peach Bottom 2	764	3819	2720	1099	2013	2000	NO
Peach Bottom 3	764	3819	2777	1042	2014	2001	NO
Perry 1	748	4020	1504	2516	2026	2011	NO
Pilgrim	580	3859	1974	1885	2012	NA	NO
Point Beach 1	121	1502	1347	155	2010		YES
Point Beach 2	121				2013		YES
Prairie Island 1	121	1386	1237	125	2013	2007	YES
Prairie Island 2	121				2014	2007	YES
Quad Cities 1	724	3657	1933	1724	2012	2002	NO
Quad Cities 2	724	3897	2943	954	2012	2003	NO
River Bend	624	2680	1400	1280	2025	2006	NO
Robinson	157	544	302	242	2010	NO	YES
Salem 1	193	1632	772	850	2016	2012	NO
Salem 2	193	1632	584	1038	2020	2016	NO
San Onofre 2	217	1542	870	672	2013	2006	NO
San Onofre 3	217	1542	918	624	2013	2006	NO
Seabrook	193	1236	376	860	2026	2010	NO
Sequoyah 1	193	2091	1295	796	2020	2004	NO
Sequoyah 2	193				2021	2004	NO
Shearon Harris 1	157	4184	720 PWR and 1841 BWR	336 PWR and 557 BWR	2026		NO
South Texas 1	193	1969	428	1529	2027	2024	NO
South Texas 2	193	1969	400	1556	2028	2025	NO
St. Lucie 1	217	1706	1128	578	2016	2006	NO
St. Lucie 2	217	1076	692	384	2023	2001	NO

Plant Name	Core Size	Spent Fuel Pool			Current License Expires	Lose Full Core Offload Capability	Dry Cask Storage?
		Capacity	Assemblies Stored	Remaining Capacity			
Summer	157	1276	637	567	2022	2006	NO
Surry 1	157	1044	854	190	2012	NA	YES
Surry 2	157				2013	NA	YES
Susquehanna 1	764	2840	2655	None	2022	2000	YES
Susquehanna 2	764	2840	1762	823	2024	2000	YES
Three Mile Island	177	1338	755	583	2014	NA	NO
Turkey Point 3	157	1395	808	587	2012	2009	NO
Turkey Point 4	157	1389	770	619	2013	2009	NO
Vermont Yankee	368	2863	2331	532	2012	2001	NO
Vogtle 1	193	1475	1081	2392	2027	2015	NO
Vogtle 2	193	1998			2029	2015	NO
WNP 2	764	2654	1703	951	2023	1999	NO
Waterford 3	217	2398	700	1698	2024	2018	NO
Watts Bar 1	193	1612	80	1530	2035	2018	NO
Wolf Creek	193	1327	664	663	2025	2008	NO

3. Legal, Institutional, and Political Constraints on Interim Storage

IN THE UNITED STATES AND JAPAN, as in many other countries, there are substantial legal, institutional, and political obstacles to expanded reliance on interim storage as a major element of the nuclear fuel cycle. These factors, far more than technical or economic issues, are the main constraints on interim storage as an approach to nuclear fuel management. In this chapter, we explore these issues in the U.S. and Japanese contexts. Some key factors are similar in the two countries (and are likely to apply in a variety of other countries as well), while others are unique to specific political, cultural, institutional, and historical circumstances in each nation. In both the United States and Japan, the legacies of past decisions and events significantly limit current and future options.

A brief overview may provide a useful introduction to the U.S. and Japanese cases. In the United States, interim storage policy has been shaped by decisions in 1976-1977 not to reprocess (which eliminated the previously planned management approach for spent fuel); by failure to establish a geologic repository for spent fuel by the legislatively mandated January 31, 1998 deadline; and by the Department of Energy's consequent failure to meet its legal obligation to take title to the fuel and begin shipping it away from reactor sites on that date (which means that larger quantities of spent fuel will have to be stored for a longer period than previously planned). For decades, the U.S. government and nuclear utilities have sought through various means to establish a centralized interim storage facility for spent nuclear fuel—so far without success, though two private facilities are under development. The key obstacle has been community and state opposition to serving as host for

such a facility—particularly when the slow pace of progress on development of a geologic repository, and continuing controversies surrounding that facility, raise fears that an interim facility will become permanent.

At the same time, however, reactor operators have expanded on-site storage dramatically by re-racking fuel in their spent fuel storage ponds, and many have successfully added dry at-reactor storage capacity. This route has met some political opposition, and in a few cases states or communities have limited the amount of fuel that can be stored pending the availability of a permanent repository and imposed other costly conditions. Generally, however, this approach has proved workable for utilities (although it has generated prolonged litigation over allocation of incremental costs for interim storage), and it has recently become the official policy of the U.S. government.

In Japan, interim storage choices have been influenced by delays in reprocessing plans, which have led to larger-than-anticipated spent fuel buildups in at-reactor storage pools. Japan's initial contracts with European firms to reprocess spent fuel have run for their negotiated terms and are now completed (though a limited new contract is under negotiation with COGEMA to provide training for operation of Japan's Rokkasho-mura reprocessing plant). Japan's commercial-scale domestic reprocessing plant at Rokkasho-mura is not scheduled to begin commercial operation until 2005, a decade later than previously planned. Its maximum reprocessing capacity is 800 tonnes of heavy metal (tHM) per year, while Japanese reactors discharge 900 tHM each year—a figure that will rise if more reactors are built. A spent fuel storage pond has been built at

Rokkasho-mura, but it can hold only three to four years' worth of spent fuel from Japanese reactors (3000 tonnes of heavy metal). Moreover, the governor of Aomori prefecture, where Rokkasho-mura is located, has only recently begun to allow full-scale shipments of spent fuel to the facility, after receiving what he saw as sufficient guarantees that the reprocessing plant would be built and operated, providing both a permanent approach to managing the spent fuel and a substantial number of high-paying jobs for the region. In short, Japan will need either additional at-reactor storage or a large centralized facility to avoid having expensive reactors shut down for lack of spent fuel storage space.

Japanese utilities have made firm commitments to remove all spent fuel from reactor sites, due to both licensing regulations and to the nation's policy commitment to closing the nuclear fuel cycle. Nuclear safety agreements between utilities and local communities, which often include this commitment, make it all the more difficult for utilities to change course and pursue interim storage at reactors. Recent regulatory changes allow Japanese utilities to seek independent away-from-reactor storage sites, and the mayor of the town of Mutsu in Aomori prefecture has volunteered that community as a potential interim storage site, but it is not yet clear whether these efforts will bear fruit. Only one Japanese facility, the Tokyo Electric Power (TEPCO) plant at Fukushima, has built additional on-site storage (including both a pool and dry casks). While Japanese citizens traditionally have placed more trust in the government and the nuclear industry, than has the U.S. public, recent accidents and cover-ups have shaken public confidence and are likely to make establishing new interim storage facilities (whether centralized or at-reactor) significantly more difficult.

In both the United States and Japan, potential host communities and states (prefectures) have been concerned over the potential negative impacts of a spent fuel storage facility, from possible safety risks to impacts on factors such as property values and the fishing and tourism industries if a location comes to be publicly associated with "nuclear waste." Key issues in both countries have been the difficult task of building confidence that interim facilities will not become permanent, and the problem of finding a site selection process that is perceived as fair and clearly leaves the host community no worse off than before. These are likely to be key factors in other countries pursuing large-scale interim storage of spent nuclear fuel as well.

Important differences between the two countries include their current approaches to permanent management of spent fuel (direct disposal in the United States, reprocessing and disposal of high-level wastes in Japan); much greater public distrust of nuclear technology in the United States; a longer history of efforts to establish large-scale dry storage in the United States; promises in Japan to remove nuclear fuel from reactor sites; and divergent institutional, legal, and administrative arrangements in each country. Additionally, there is strong public concern over spent fuel transportation in the United States, where a large centralized facility would require hundreds of trips by trucks or trains, over thousands of kilometers. Japanese nuclear facilities are located on the sea coasts, so fuel is transported by ship and does not typically pass through a large number of potentially affected communities.

The Japanese Experience

Introduction

Management of spent nuclear fuel in Japan involves much more than finding an interim storage site. The controversy surrounding this issue runs throughout the history of Japan's nuclear fuel cycle policy and power plant siting debates. For Japan in particular, as for France, closing the nuclear fuel cycle is viewed as a key part of the national nuclear program, which will help achieve energy independence. This commitment to closing the nuclear fuel cycle has created a legal, social and political infrastructure that has effectively forced utilities to plan on early removal of spent fuel from power plant sites to reprocessing sites. Interim storage is also inherently connected to other parts of Japan's national nuclear program, such as plutonium recycling, as well as to future siting of new nuclear power plants.

Delays in Japan's reprocessing programs have made the accumulation of spent fuel on-site at reactors unavoidable. However, a series of nuclear accidents since 1995 has undercut public trust in Japan's nuclear system, making it difficult for utilities and local communities to discuss any new nuclear initiatives—even expanding spent fuel storage capacity at reactor sites. Interim storage of spent fuel—which, as discussed in Chapter 2, is technically and economically a sound option—is becoming a major bottleneck in Japan's nuclear fuel cycle programs, and if left unresolved may affect the continued operation of existing nuclear power plants, as well as future siting decisions.

This section addresses the following questions:

- What historic factors affect Japan's current spent fuel management policies?
- What specific legal and political conditions significantly influence spent fuel management options?
- What specific changes and initiatives would be required to deal with these issues? What are the current issues to be overcome?

History of Spent Fuel Management in Japan

The Original Nuclear Fuel Cycle Plan: Once There Was a Consensus

Closing the nuclear fuel cycle by reprocessing spent fuel and recycling plutonium and uranium in power reactors, particularly Fast Breeder Reactors (FBRs), was originally a common vision of all advanced national nuclear energy programs. Japan introduced its closed nuclear fuel cycle policy in 1956, and launched a national project to develop FBRs and nuclear fuel cycle technologies in 1967, by establishing a Power Reactor and Nuclear Fuel Development Corporation (PNC), now the Japan Nuclear Cycle Development Institute (JNC). The goal of closing the nuclear fuel cycle with the FBR, to achieve "energy independence," is framed in the "Long Term Program for Development and Utilization of Atomic Energy" (Long Term Program, or LTP), published by the Japan Atomic Energy Commission (JAEC).¹

Japan imported light water reactors (LWRs) from the United States for practical commercial reasons, based on the expectation that it would quickly commercialize reprocessing and a plutonium fuel cycle. Moreover, it then was

U.S. policy to encourage recipient countries to recycle plutonium in order to conserve uranium resources. Therefore, Japanese utilities made commitments to their stakeholders that they would remove spent fuel from power plant sites after a short cooling period. At that time, reprocessing was the national government's responsibility, so utilities expected that the Japanese government would develop a domestic reprocessing capacity.² Reactors were designed with small capacities for spent fuel storage, and additional storage options were not considered necessary. Legal and political conditions reinforced the expectations in commercial contracts that all spent fuel would be soon reprocessed and thus would never stay at the original site.³

Adjusting to New Realities: The Growing Need for Additional Storage Capacity

By the mid-1970s, early commercialization of FBR technology already appeared doubtful, and Japan's domestic reprocessing capacity was far short of the growing national stock of spent fuel. As the United States cancelled its commercial reprocessing projects in the course of its reevaluation of the nuclear fuel cycle, Japanese utilities turned to European companies to accept their spent fuel. Japanese utilities signed long-term reprocessing contracts with British and French companies that allowed them to ship a substantial portion of their spent fuel to Europe during the 1970s and 1980s. However, these agreements required Japan to accept the resulting plutonium and vitrified high level waste (HLW) back from Europe.⁴

Anticipating a need for domestic reprocessing capacity, in 1979 Japan changed its law to allow private industries to conduct reprocessing. In 1980, Japanese utilities estab-

¹ Japan Atomic Energy Commission (JAEC), *Basic Long Term Program for Development and Utilization of Atomic Energy*, (Tokyo, Japan: JAEC, September 1956). The latest plan was published in November 2000 (see http://sta-atm.jst.go.jp/jicst/NC/tyoki/siryo/tyoki_e/pdfc.htm for an unofficial English translation). The commitment to closing the nuclear fuel cycle so far remains unchanged throughout the programs.

² The Japan Nuclear Fuel Public Corporation was established to take charge of the nuclear fuel business in Japan. Japan considered at one point having the government purchase spent fuel from private utilities for reprocessing. See MITI Advisory Council on Energy Report, 1963, cited in Japan Atomic Industrial Forum, *Genshiryoku Wa Ima (Nuclear Power Now: 30 Year History of Japan's Atomic Energy)* (Tokyo, Japan: Japan Atomic Industrial Forum, 1986), pp. 152-153.

³ The first reprocessing requirement involved spent fuel from the Tokai-1 Gas Cooled Reactor (GCR). In 1967, Japan Atomic Power Co., the owner of Tokai-1, concluded a three-year reprocessing contract (about 160 tonnes) with the United Kingdom Atomic Energy Authority (UKAEA).

⁴ For the history of European connections with Japanese fuel cycle programs, see Frans Berkhout, Tatsujiro Suzuki, and William Walker, *Surplus Plutonium in Japan and Europe: An Avoidable Predicament*, MITJP 90-10 (Cambridge, MA: Massachusetts Institute of Technology, 1990).

lished a commercial reprocessing company, Japan Nuclear Fuel Service, now known as Japan Nuclear Fuel Limited (JNFL), with additional capital from other private companies such as banks, trading companies and manufacturers. Japanese utilities committed to build a large reprocessing plant, an HLW storage facility, an enrichment plant, and a low-level radioactive waste disposal facility at Rokkasho village in Aomori Prefecture. This reprocessing plant, with an annual capacity of 800 metric tonnes of heavy metal, was expected to handle most spent fuel generated at Japanese reactors in the 1990s. Plans were also made to construct a second reprocessing plant early in the next decade. Utilities made further commitments to the local community at Rokkasho that spent fuel and HLW from reprocessing would be removed from the site (see below).

By this time, however, it was clear that early reprocessing of all spent fuel was unrealistic, as both the plutonium recycling programs and the Rokkasho reprocessing project met delays. JAEC's 1987 long-term program officially introduced a "partial reprocessing" policy under which not all spent fuel would be reprocessed immediately, although it would be reprocessed eventually, and stated that "spent fuels that will not be immediately reprocessed can and should be adequately stored."⁵ This was effectively the first official focus on the idea of a period of interim storage for spent fuel beyond initial cooling in reactor spent fuel pools. Meanwhile, prospects for commercializing fast-breeder technology were fading, and demand for plutonium was falling. Since Japanese utilities had committed to long-term reprocessing contracts with European companies, it was predictable that the country would build up a large stockpile of separated plutonium. Japan thus shifted the focus of its plutonium use policy from near-term use of plutonium as fuel in breeder reactors to use as uranium-plutonium mixed-oxide (MOX) fuel in Japan's existing light-water reactors. Nevertheless, international critics called this plutonium "glut" a threat to regional stability because neighboring countries feared that it might serve as a basis for a nuclear arsenal, and a threat to global security because plutonium shipments from Europe might

be vulnerable to theft or terrorist attacks. In 1991, responding to controversy over shipments of separated plutonium reprocessed in France from Japanese fuel, JAEC introduced a "no plutonium surplus" policy⁶ under which it pledged that Japan would not accumulate excess domestic plutonium stocks. This commitment was to be achieved through the program to burn MOX in LWRs, and by storing any plutonium that had not yet been used with the reprocessors in Europe.

By the mid-1990s, the spent fuel storage pool at the Rokkasho reprocessing plant had been completed, although construction of the main part of the reprocessing plant was significantly delayed. Since reprocessing at Rokkasho was Japan's main long-term option for handling spent fuel, this situation created a potential shortage of spent fuel storage space. The utilities knew that even if the storage pool started operation without delays, its capacity was only 3000 tonnes—the amount of spent fuel Japanese reactors generate in less than four years. The 1994 long-term program postponed Japan's second commercial reprocessing plant by delaying a decision on its construction until 2010, which was originally the plant's expected start-up date. In these circumstances, the need for additional spent fuel storage capacity was obvious. In 1998, the Advisory Council of the Ministry of International Trade and Industry (MITI, now the Ministry of Economy, Trade, and Industry, or METI) officially introduced a policy of interim storage of spent fuel, referring to it as a "recyclable fuel resource."⁷ This step is expected to give Japan's fuel cycle policy the flexibility it needs to allow long-term, large-scale storage of spent fuel without an early commitment to reprocessing.

Interim Storage as a Strategic Choice

As this record illustrates, past decisions have significantly influenced Japan's current spent fuel management programs. In particular, the commitment to closing the fuel cycle, along with delays in plutonium programs, have reduced Japan's options for dealing with spent fuel. While the basic policy of a closed nuclear fuel cycle has not

⁵ JAEC, *Long Term Program for Development and Utilization of Atomic Energy* (Tokyo, Japan: JAEC, June 22, 1987).

⁶ JAEC, *Report of the Advisory Committee on Nuclear Fuel Recycling in Japan* (Tokyo, Japan: JAEC, August 1991).

⁷ MITI Advisory Council on Energy, Subcommittee on Nuclear Energy, *Toward the Realization of Interim Storage of Recyclable Fuel Resources* (Tokyo, Japan: MITI, June 1998).

changed, interim storage of spent fuel is becoming an important option for keeping the entire nuclear power program going. Although interim storage is often viewed as only a temporary “escape” from “overflowing” spent fuel storage pools, it can and should be viewed as a key strategic element of Japan’s nuclear fuel cycle program, offering the flexibility needed to optimize the fuel cycle to meet changing circumstances. First, it allows Japan to choose the optional timing for reprocessing while it stores potential energy resources for the future. Second, interim storage can provide time for plutonium recycling technology to advance. Finally, interim storage will make it easier to maintain Japan’s “no plutonium surplus” policy commitment, by reducing pressure to reprocess spent fuel. The question then becomes what obstacles may impede greater reliance on interim storage.

Major Constraints: Laws and Local Politics

Laws and Regulations

The most important law affecting spent fuel management in Japan is the *Law Concerning Nuclear Materials and Reactor Regulations*.⁸ Under this law, detailed rules and ordinances are issued for specific regulations. These legal requirements are both explicitly and implicitly linked with the political relationship between utilities and local governments. It is therefore critically important to understand the relationship between those social, political, and institutional factors that may need to be changed to facilitate interim storage of spent fuel.

Under the law, utilities are required to specify what they will do with spent fuel when they apply for reactor licenses (Article 23, item 1, no. 8). The more detailed rules of reactor licensing (*Rules Concerning Siting and Operating of Commercial Reactors*) also require utilities to specify “spent fuel storage capacity” (Article 2, item 2) and “the methods and the other (contracted) party for the sales, loans, returns etc. of spent fuels as well as the methods of disposition” (Article 2, item 5). Since the final disposal method cannot be specified until Japan adopts a formal HLW disposition policy, reprocessing and storage of vitrified waste has traditionally been accepted as a “disposition method.” Utilities must specify the reprocessing company with which they

have contracted to accept spent fuel. The law also directs that “[licensing activities] will not cause any troubles for smooth implementation of the long term plan for development and usage of nuclear energy” (Article 24, item 2), and that the “Prime Minister and relevant Ministers must listen to JAEC’s opinion and respect the JAEC’s opinion” (Article 24). JAEC’s long-term program specifies that closing the nuclear fuel cycle is an “essential” part of Japan’s nuclear program. In other words, reprocessing is the only option for dealing with spent fuel under this licensing law, which allows spent fuel to be stored only at reactor sites (in specified amounts) and at specified reprocessing companies’ sites.

The law requires utilities to apply for new licenses in order to expand their fuel storage capacity at power plants (including re-racking spent fuel in cooling ponds). Site-to-site transfers also require relicensing, as do transfers of spent fuel on a single site from an old reactor’s storage pool to a new reactor’s storage pool. Therefore, securing storage capacity to keep up with accumulating spent fuel from reactors poses legal headaches for utility companies.

Local Politics(1): The Importance of “Nuclear Safety Agreements”

Relationships between local communities and utilities are formed long before the official licensing process begins for building a new nuclear power plant. The siting process often begins with a decision by the community (for example, a city council resolution) to invite utilities to investigate a site as a candidate for new power plants. Utilities may informally propose to a local community to start such investigations. Extensive private negotiations between utilities and the community take place during this period. Local fishing or agricultural industry associations often participate, as well as individual landowners. Utility companies also must approach the prefecture’s governor, whose consent is required for the official licensing process. Once private negotiations are settled, the utility company can start the official licensing process. At this point, key stakeholders have already consented, so licensing typically moves smoothly.

During these pre-licensing negotiations, nuclear safety is the main subject, since prefectural governors will not

⁸ This is the basic law concerning regulations on nuclear materials, nuclear fuels, and nuclear reactors.

consent to siting new plants if they cannot assure public safety. In the early days of nuclear power there apparently were no official agreements between local governors and the utilities: Fukui prefecture first introduced a “Memorandum of Understanding” in 1971, which specified important safety arrangements between the utility and the local government. The pact became a more comprehensive and formal “Nuclear Safety Agreement” in 1972.⁹ Since that time, especially after the experimental nuclear ship *Mutsu* suffered an accident in 1974,¹⁰ Nuclear Safety Agreements (NSAs) on the siting and operation of nuclear facilities have become key documents for both utilities and prefecture governments, even though they are not part of official Japanese nuclear safety regulations.

NSAs are typically signed by prefecture governors (and possibly by local mayors) and by utility company presidents. They are important tools for communities to assure public safety, since local governments have no legal authority once the license is issued to the nuclear facility. On the other hand, NSAs can provide *de facto* veto power to prefecture governors, without any explicit conditions on the exercise of this power being attached. Therefore, they can create uncertainty for utilities as the companies proceed with new plants.

NSAs are not typically disclosed, as they are private agreements between local governments and utilities. According to published sources, such as Niigata Prefecture’s home page, agreements consist of the following items:

- Strict compliance with nuclear safety regulations and performance that is even better than these standards;
- Prior consent from the local community;
- Reporting requirements and methods for

informing the public;

- Safety and radiation monitoring;
- Inspections by the local community; and
- Compensation rules.¹¹

The key item is the requirement for prior consent, which typically is needed for building new or additional facilities, or for major modifications of existing facilities. Expanding spent fuel storage capacity can fall in either category, depending on the plan. Introducing MOX fuel into a reactor is also subject to prior consent. As discussed above, most of those changes involve relicensing the reactor. Prior consent is typically needed before utilities submit this official licensing application. It is often more difficult to obtain prior consent: whereas legal licensing conditions are technical and explicit, conditions for prior consent include implicit factors as well, and therefore the utilities face substantial uncertainties over whether they will be able to get the consent they need, and what it will take to do so.

Recent events in Aomori prefecture illustrate how NSAs can make spent fuel management decisions politically controversial issues. In the mid-1990s, Morio Kimura, the prefecture governor, and JNFL were negotiating an NSA for spent fuel shipments to the Rokkasho reprocessing plant (which were supposed to start in 1996 when the storage pool was completed). However, the accident at the Tokai reprocessing facility in March 1996 stalled negotiation of the Aomori safety agreement. In March 1998, returned vitrified waste from Europe arrived at the port of Mutsu-Ogawara, but Kimura refused permission to unload the waste for several days, despite requests from the national government to sign the Safety Agreement as soon as possible.¹² The governor finally allowed a first shipment of spent fuel as a “test case” in October 1998, but stated that

⁹ Home page of Mr. Yoshihide Ide, a member of Ibaraki Prefecture Diet, http://www.jsdi.or.jp/^y_ide/gen_fukuankyoun.htm.http://www.jsdi.or.jp/^y_ide/gen_fukuankyoun.htm.

¹⁰ In September 1974, during its first experimental cruise, a small radiation leak was detected from the reactor of the first (and only) Japanese nuclear-powered ship, the *Mutsu*. Because of the incident, the ship could not return to port and was transferred to Sasebo port in Kyushu for repair. It took 4 years to move the *Mutsu* back to its mother port (Ohminato). Eventually, the mother port was also changed and the government decided to phase out the nuclear ship project.

¹¹ “Agreement Regarding Safety Assurance of Tokyo Electric Power Company’s Kashiwazaki-Kariha Nuclear Power Station and Relevant Local Community,” available at <http://www.pref.niigata.jp/atom/text/kyoutei.htm>.

¹² “Aomori Governor Allowed Unloading HLW,” *Asahi Shimbun*, March 13, 1998.

one key condition for accepting spent fuel storage was assurance that Aomori would never become a final repository site.¹³ Two further “test” shipments followed.

To ensure that the spent fuel would not stay in the pool indefinitely, and the high-paying jobs for the region associated with the reprocessing plant would be forthcoming, Aomori prefecture also requested the completion and early start-up of the Rokkasho reprocessing plant. Plant construction had been repeatedly delayed, leading to suspicions in the local community that the project might not be completed as planned. JNFL and the Aomori governor exchanged a Memorandum of Understanding (MOU) in July 1998, which stated that “if Rokkasho project faced serious difficulties, all spent fuel and HLW would be removed from the site.”¹⁴ The Aomori prefectural government finally signed the safety accord in October 2000, followed by six towns and villages.¹⁵ The first regular shipment of spent fuel to the Rokkasho storage pool took place in December 2000, and was quickly followed by additional shipments.¹⁶

So far, safety agreements have not yet become major obstacles to expanding spent fuel storage capacity at existing nuclear power plant sites. However, spent fuel issues can be linked to other issues where nuclear safety agreements have posed obstacles, such as Japan’s MOX recycling plan or construction of new nuclear power plants. For example, during negotiation of a safety agreement for MOX recycling in Fukushima prefecture, the governor expressed

greater concern over the future of spent fuel storage at the site than over MOX recycling itself.¹⁷

Local Politics (2): Local Development, Financial Incentives, and Equity Issues

The impacts of nuclear projects on local development are also important factors in local politics.¹⁸ In Japan, local development and economic compensation are closely linked to siting of nuclear and other large power plant projects. Compensation packages were first introduced in 1974 by Japan’s three laws to promote electric power development.¹⁹ In addition, private compensation packages are paid to local communities (mostly to fishermen or farmers whose jobs would be affected by the projects). Under the three basic laws, an “electric power development tax” was introduced in the electricity tariff (0.445 yen/kWh, including 0.160 yen/kWh for a siting promotion subsidy, or Kofu-kin).²⁰ Funds from the siting promotion account are distributed to communities to promote siting of electric power plants. The total annual budget for Kofu-kin, coming from the tax on the electricity tariff, was roughly \$1.4 billion in FY 1998. Kofu-kin is applied to new construction projects, and payments end when the facility enters commercial operation. Regular local taxes, such as cooperation taxes and real estate taxes, typically succeed Kofu-kin payments. Kofu-kin was originally applied only to power production facilities, but the law was amended in 1987 to include

¹³ “First Spent Fuel Shipment Came To Aomori,” *Yomiuri Shimbun*, October 4, 1998. In 1995, when the previous HLW shipment took place, the Science and Technology Agency and the Aomori Governor signed the agreement in which the STA assured that Aomori would not become a final disposal site without the Governor’s consent.

¹⁴ “First Step Toward Closing Nuclear Fuel Cycle, While Issues Remain,” *Asahi Shimbun*, October 3, 1998.

¹⁵ *Japan Times*, October 13, 2000; *Mainichi Shimbun*, November 29, 2000.

¹⁶ “Third Full-Fledged Delivery of Spent Fuel Arrives in Rokkasho,” *Kyodo News International*, February 7, 2001. The site expects to accept regular shipments totaling 97 tHM by March, 2001, and 1960 tHM by July 2005, when the reprocessing plant is scheduled to start full commercial operation. See *Kyodo Tsushin*, February 6, 2001.

¹⁷ He was quoted as saying, “The cost of MOX recycling is not an issue for us. As long as spent fuel is shipped away from the site, we are satisfied.” *Mainichi Shimbun*, October 3, 1998.

¹⁸ For the relationship between local development and nuclear power siting, see Toru Ohkawara and Kenshi Baba, *Nuclear Power Plant Siting Issues in Japan: Relationships between Utilities and Host Communities*, CRIEPI Report EY 97003 (Tokyo, Japan: Central Research Institute of the Electric Power Industry, April 1998).

¹⁹ Law Concerning Regional Development Around Facilities For Power Production; Law Concerning Tax To Promote Electric Power Development; Law Concerning Special Account For Measures To Promote Electric Power Development.

²⁰ The Siting Promotion Account (0.16 yen/kWh) is used for Kofu-kin for power plant sites (its annual budget is about 70 billion yen) and Kofu-kin for surrounding towns (the annual budget is about 26 billion yen). The Power Source Diversification Account (0.285 yen/kWh) is primarily used for alternative energy R&D programs, about 75% of which is now used for nuclear energy R&D.

nuclear fuel cycle facilities. As a result, local communities have an incentive in principle to host more facilities, including nuclear fuel cycle facilities.²¹

As the number of new projects decreases, so do financial benefits to the local community. The number of projects and programs to receive Kofu-kin reached its peak in FY 1981 (with 614 projects receiving such benefits), and declined to 191 projects by FY 1998.²² In order to compensate for the decreasing amounts of Kofu-kin in the future, MITI further amended the law in 1998 and created a “long term development subsidy” which will be paid to local communities during commercial operation of nuclear facilities.²³ In addition, in December 2000, the Diet passed a special law to provide additional financial benefits to local communities where nuclear facilities are located. Under this new law, the Government will increase subsidies to local public investment projects and will allow Kofu-kin to be used to pay back bonds issued by local communities.²⁴

However, Kofu-kin is only applied to facilities, not materials, so there are no clear economic incentives for communities to accept expansion of spent fuel storage on site—except the economic advantages of keeping the reactors running. One possible tool is the “nuclear fuel tax,” which is already applied as a regular tax by local governments. For example, in Niigata prefecture, 7% of the total value of nuclear fuel is charged as a nuclear fuel tax, provid-

ing an annual income estimated at about 2.0 billion yen in fiscal year (FY) 2000.²⁵ This amount can be significant: for comparison, the total annual Kofu-kin to Niigata prefecture was about 5.5 billion yen in FY 1999.²⁶ The government of Fukui prefecture has announced that it plans to raise its nuclear fuel tax from 7% to 10%.²⁷ If this nuclear fuel tax were applied to interim storage facilities, it could provide communities with an additional revenue source. In the case of Aomori prefecture, a “nuclear material handling tax” is to be charged against spent fuel storage at the Rokkasho reprocessing plant. The tax rate is 24,800 yen per kg (~\$220/kgHM) and thus Aomori prefecture will receive as much as 2.4 billion yen during FY 2000 as a total of 97 tonnes of spent fuel will be shipped to Rokkasho.²⁸

But economic benefits are only part of the story. Trust and equity issues also shape the local politics of spent fuel management. For example, the Rokkasho nuclear complex is an essential part of the large scale Mutsu-Ogawara regional development project, which is supported by both the Japanese government and industry, not only by the utilities. However, the original promise of the Mutsu-Ogawara project has not been fulfilled, and thus Aomori prefecture believes that it has a right to demand more from the government and industry.²⁹ Changes and delays in fulfilling initial commitments have generated mistrust between the public, utilities, and the central government. Early promis-

²¹ The economic impact of Kofu-kin on the local area can be quite significant, but it may not be as central to prefectural income. For example, the total amount of Kofu-kin to Rokkasho village is about 20 billion yen, but Aomori Prefecture receives less than 4 billion yen. See Eugene Skolnikoff, Tatsujiro Suzuki, and Kenneth Oye, *International Responses to Japanese Plutonium Programs*, CIS Working Paper #2614 (Cambridge, MA: Center for International Studies, MIT, August 1995).

²² Ministry of International Trade and Industry, Agency of Natural Resources and Energy, *Yutakana Kurashi ni Mukete (Toward an Affordable Life)* (Tokyo, Japan: MITI, 1999).

²³ “Partial Amendment to Special Account Under the Electric Power Development Law,” MITI press release, August 28, 1998.

²⁴ The Law on Special Measures Regarding the Development of Local Communities Where Nuclear Facilities Are Located. The law became effective as of April 1, 2001, and the details of the rules are just being established (*Nihon Keizai Shimbun*, December 4, 2000).

²⁵ “FY 2000 Budget Outline,” Niigata Prefecture, February 16, 2000.

²⁶ Home page of Niigata prefecture, <http://www.pref.niigata.jp/atom/niigata/syukoku.htm>.

²⁷ The tax was introduced at 5% in 1976 and raised to 7% in 1981. See *Denki Shimbun*, February 2, 2001.

²⁸ *Nihon Keizai Shimbun*, Tohoku edition, December 20, 2000, p. 24.

²⁹ The Mutsu-Ogawara area, of which Rokkasho is the main village, was once called the “Siberia of Japan.” In 1969, the government and Aomori prefecture developed a national project to invite heavy and chemical industries to the area. However, due to the economic slowdown caused by the dollar shock in 1971 and the oil shock in 1973, the project was cut back in 1977. In 1978, the government decided to build a national petroleum reserve, which was the only major facility completed for the project before the Rokkasho nuclear fuel cycle project. What to do with the large debt of the

es that spent fuel would be removed from Rokkasho were required to reassure local citizens that it would not remain permanently in their communities.

Questions of environmental equity also are coming into play in the game of spent fuel management. The perception that benefits are unequally distributed between communities that host nuclear plants and those that consume the resulting power is influencing negotiations over construction of future nuclear-related facilities. During the Roundtable Discussion initiated by the JAEC in 1998 to obtain national consensus on nuclear energy policy, this issue of “equity” was raised by governors from prefectures with a significant number of siting communities, but there has been little response or recognition from the consumer side, i.e., large cities.³⁰ This lack of response has created a feeling of unfairness among local communities which makes it difficult for utilities to look for spaces for spent fuel storage.

Recently, local communities have taken a number of steps to oppose nuclear waste disposal and spent fuel storage facilities, which highlight the difficulties in siting such facilities. For example, Gifu prefecture, where JNC plans to establish the Deep Underground Geological Research Laboratory, along with the cities of Mizunami and Toki, signed an agreement with JNC in 1995, in which JNC promised that the site will never become a repository site. The city of Toki also passed a city law prohibiting any radioactive waste (including spent fuel) from entering the city.³¹ A similar law was passed by Hokkaido Prefecture in October 2000.³² The small island of Toshima in Kyushu, where there was a rumor that an interim storage site will be built,

adopted a resolution prohibiting such facilities in December 2000.³³

Accidents and Mistrust of National Nuclear Energy Policy

Finally, a series of accidents, each followed either by misleading statements or active cover-ups of key information, have increased both concern over nuclear energy and mistrust of the nuclear policy-making process.³⁴

Despite serious nuclear accidents elsewhere, such as Three Mile Island in 1978 and Chernobyl in 1986, public support for nuclear power in Japan has historically been relatively stable. However, public confidence in nuclear power has seriously eroded since the sodium leak accident at the Monju prototype fast-breeder in 1995, particularly in response to the cover-ups and slow dissemination of information that characterized the nuclear authorities’ response. This was followed by the accident at the Tokai reprocessing plant in 1996, which led to a similar cover-up of key safety-related information. The JCO criticality accident in 1999, which killed two workers (the first such fatalities in Japan), was the worst nuclear accident in Japanese history. The immediate impact on local opinion was dramatic. According to polls taken at Tokai village, 64 % of the inhabitants polled felt “safe” or “fairly safe” about nuclear power before the accident. This view dropped to 15% after the accident. Only 22% of the village people polled felt “in some danger” or “in danger” before the accident. This went up abruptly to 78% after the accident. As to the future of nuclear power, 52% before the accident answered that it “should be promoted positively” or “should be promoted cautiously,”

Mutsu-Ogawara Corporation, jointly owned by private industries and Aomori prefecture, is still a subject of political negotiation. For the complex relationship between local community development and the Rokkasho project, see H. Funahashi, K. Hasegawa, and N. Iijima, *Kyodai Chiiki Kaihatsu-no Koso to Kiketsu—Mutsu Ogawara Kaihatu no Kaku Nenryo Saikuru Shisetsu (Origin and Results of Large Regional Development Project—Nuclear Fuel Cycle Facilities in Mutsu-Ogawara Project)* (Tokyo, Japan: University of Tokyo, January, 1999).

³⁰ For example, both the mayor of Tsuruga and the Governor of Fukui stated at the 3rd Roundtable discussion in 1998 that inequality between “consumer” (large cities) and “power supplier” (local community) is becoming too large. See <http://sta-atm.jst.go.jp/entaku/H10/3kokai/sokuhou3.html>.

³¹ “Where Will Nuclear Waste Go? Increasing Amount of HLW,” *Chunichi Shimbun*, December 14, 2000.

³² “Hokkaido Prefecture Congress Passed a Law Rejecting Nuclear Waste,” *Yomiuri Shimbun*, October 16, 2000.

³³ “Toshima Island Village Adopted a Resolution to Oppose Spent Fuel Storage,” *Minami Nihon Shimbun*, December 21, 2000.

³⁴ For a detailed assessment of the consensus-building process in Japanese nuclear energy policy, see Susan Pickett, *Integrating Technology and Democracy: Nuclear Energy Decision-Making in Japan*, Ph.D. thesis, University of Tokyo, September 2000.

falling to 32% after the accident. Those who believed nuclear power “should remain as it now stands” dropped to 18% from 30% while those who thought it “should be phased out over time” or “should be abolished immediately” increased sharply to 40% from 12%.³⁵ This opinion shift at Tokai, which formerly was quite receptive to nuclear power, shows how difficult it will be to find future locations for nuclear power facilities. Local conditions may differ, however, and thus specific attitudes toward inviting nuclear power projects may vary.³⁶

A recent series of mishaps on fuel cycle projects has also undercut public confidence in nuclear programs. The MOX recycling program was postponed for a year after the JCO accident, and has been further postponed by a scandal involving illegal handling of data on the fabrication of MOX fuel for Japan by British Nuclear Fuels, Limited (BNFL).³⁷ This delay could have serious implications for spent fuel management. Unless the MOX recycling program makes smooth progress, local communities will remain concerned that spent fuel will not leave reactor sites. The question is not only the technical safety issues associated with spent fuel or MOX fuel, but also the mistrust created by recent accidents and mismanagement.

Recent Changes and Initiatives: Issues Remain

Amendment to the Reactor Regulations: Toward a Centralized Interim Storage Site?

The 1999 Amendment to Japan’s nuclear regulations is critically important to provide flexibility in spent fuel storage. The amendment allows private entities to store spent fuel

beyond reactors’ specified storage capacities, subject to a requirement for a license from METI. As conditions for receiving a license, the utility must pledge that the spent fuel will be used only for peaceful purposes; that storage will not impede the smooth progress of Japan’s Long Term Program; that it has appropriate technical and financial capabilities; and that the storage facility will not cause any contamination.³⁸

Under this Amendment, once storage facilities are established, utilities can ship spent fuel to sites other than reprocessing companies. However, this route still requires a relicensing application, since it changes the “contracted party” that is designated to accept the spent fuel. Nevertheless, this amendment is an essential condition to proceed with interim spent fuel storage outside of existing sites. It will certainly increase the options and flexibility for utilities’ spent fuel management plans. On November 29, 2000, the mayor of the city of Mutsu invited Tokyo Electric Power Company (TEPCO) to investigate the feasibility of siting an interim spent fuel storage site in Mutsu, and the city council has invited such a study as well.³⁹ The process of discussion of a possible site at Mutsu is moving forward: in January, 2001, TEPCO opened a feasibility investigation office in Mutsu, and plans to finish an initial feasibility study in one year. METI has estimated that if a 5,000-tonne storage facility is built there, Mutsu would be eligible for up to 2 billion yen in Kofu-kin.⁴⁰ If the process is successful and leads to the establishment of a substantial storage facility there, that would be a dramatic step toward breaking the long log-jam over spent fuel storage in Japan. The utilities are exploring siting possibilities with a range of other potential locations

³⁵ “The Prevention of Disasters and Town Building,” Tokai-mura polls, Public Relations Department, Tokai-mura, *Tokai* No. 659, February 16, 2000.

³⁶ On February 23, 2000, Chubu Electric Power announced its decision to cancel the Ashihama nuclear power plant project, following the Mie Governor’s decision to suspend the project. This is the first nuclear project ever by a private utility company. On the other hand, on July 13, 2000, the Hokkaido governor endorsed the Tomari #3 nuclear power plant. This is the first new nuclear project authorized by a local government since the accident at Tokai-mura. Other prefectures such as Shimane and Fukui may follow (*Asahi Shimbun*, July 14, 2000). Ten utility companies have already announced delays in nuclear power plant projects, primarily due to slower growth in electricity demand (*Asahi Shimbun*, April 1, 2000)

³⁷ In September 1999, illegal handling of data on MOX fabrication at a BNFL facility was revealed. Later it was found that MOX fuel assemblies for the Takahama 3 and 4 reactors were affected by this incident. Kansai Electric Power immediately postponed the MOX recycling program. Although the British safety authority (NII) assured the safety of MOX fuel, it is not clear when the MOX program will restart.

³⁸ Atomic Energy Commission, <http://staatm.jst.go.jp/jicst/NC/teirei/siryo99/siryo06/siryoyou22.htm>.

³⁹ *Mainichi Shimbun*, November 29, 2000; *Kawakita Shimpō*, November 29, 2000.

⁴⁰ *Nihon Keizai Shimbun*, Tohoku regional page, February 2, 2001, p. 24.

as well.⁴¹ It is not yet clear, however, how local citizens at Mutsu or at other candidate sites will react to this proposal.

High Level Radioactive Waste Law

Another important legislative development is the *Law concerning Final Disposal of Specified Radioactive Waste*, passed on June 7, 2000. Among its major features, the law:

- Defines “Specified Radioactive Waste,” i.e. “solid waste after recovering useful materials from spent fuel (reprocessing),” as the only type of material subject to geologic disposal (effectively ruling out direct disposal of spent fuel);
- Defines the “Nuclear Waste Management Organization” (NUMO), established in October 2000, as a non-profit, private organization solely responsible for final disposal; and
- Assigns financial responsibility for HLW disposition to utility companies who own and operate nuclear power plants. The utilities will have to submit annual contributions (to be determined) to NUMO to cover disposal costs.

Although the law does not specifically deal with spent fuel, it demonstrates that Japan is making progress toward final disposal of HLW. The two are linked: communities concerned over when spent fuel will be removed from reactor sites know that progress on reprocessing that spent fuel may be constrained if there is no progress toward disposal of the resulting HLW.

Consensus Building and Long-Term Nuclear Energy Policy

Since the Monju accident in 1995, the Japanese government and nuclear industry have taken several major initiatives in order to achieve national consensus on nuclear energy pol-

icy.⁴² The new JAEC long-term program, issued in November 2000, highlights the importance of public trust in order to make progress in nuclear technology development.⁴³ In particular, it emphasizes:

- safety and emergency planning;
- information disclosure and public education; and
- the co-prosperity of nuclear energy and local communities.

One of the unique aspects of this new long term program is the process by which it was put together. In the past, JAEC has typically set up an ad-hoc LTP Council consisting of nuclear experts, designed to incorporate most stakeholders among the nuclear community. This time, however, the JAEC set up six subcommittees, chaired by both nuclear experts and non-experts, and each sub-committee consisted of members with a variety of backgrounds intended to be broadly representative of the Japanese public.⁴⁴ The LTP Council itself had 33 members, with a variety of backgrounds, including consumer advocates, nuclear opponents, local governors, lawyers, labor union representatives, journalists, and writers. All of the discussions were disclosed through the internet, and some of the discussions were very lively, identifying key policy issues such as the role of the government in a deregulated market. Based on the reports published by each subcommittee, the LTP Council also had a heated discussion, and published a draft for public comments. About 1,190 comments were received and 31 commentators participated in the public hearing. This whole process was much more transparent than ever before.

The second big change is the flexible nature of the report. Most notably, it abandons completely the past practice of setting numerical targets for overall nuclear energy development, although some program targets are men-

⁴¹ See “Latest Developments in Aomori Prefecture,” *Nuke Info Tokyo*, March/April 2001.

⁴² See Pickett, *Integrating Democracy and Technology*, op. cit.

⁴³ JAEC, *Long Term Program For Research, Development, and Utilization of Nuclear Energy* (Tokyo, Japan: JAEC, November, 2000), unofficial translation available at http://sta-atm.jst.go.jp/jicst/NC/tyoki/siryotyoki_e/pdf.htm.

⁴⁴ The six subcommittees were: (1) People, Society and Nuclear Energy; (2) Nuclear Energy as an Energy Source; (3) Future Prospects of Fast Breeder Reactor and its Associated Technologies; (4) Advanced Research and Development Frontiers; (5) Utilization of Radiation Contributing to People’s Lives; and (6) New Perspectives on International Cooperation of Nuclear Energy. There were a total of 115 subcommittee members, and a total of 57 meetings were held.

tioned in other specific activities. There has been some criticism of this “ambiguity,” with critics arguing that the lack of targets will make the report useless as a planning document. However, the committee members believed that it made sense not to provide specific figures for the number of nuclear plants to be built or the amount of nuclear electricity to be generated, as the electricity market is being liberalized and important investment decisions are to be made by the private sector. In fact, the LTP put much more emphasis on the role of the private sector in implementing the program, and limited its description of the role of the government to setting basic policy, giving guidance, and other supplementary roles, with particular emphasis on the government’s role in setting long-term direction.⁴⁵ This emphasis on market orientation is new, and its “flexible” attitude toward specific programs is worth noting.

While the new plan maintains the basic policy of recycling, it addresses the importance of “intermediate spent fuel storage” as follows:

Intermediate storage of spent fuel provides an adjustable time period until the fuel is reprocessed and thus lends an element of flexibility to the nuclear fuel cycle as a whole...For this purpose, it is important for the government and electric utilities to explain to the general public the necessity and safety of these facilities in a proper, easy-to-understand manner.⁴⁶

In addition, METI’s Advisory Council on Energy has started a comprehensive review of energy policy. A subcommittee on Comprehensive Energy Policy has been established for the first time in 10 years, and the new energy policy is expected to be released in some time in 2001. These governmental efforts are expected to help improve public confidence in nuclear power. However, it is not clear how specific policy choices will affect prospects for spent fuel management.

Observations

Because every Japanese regulatory decision is dependent on past decisions (whether they are negatively or positively correlated), it is important to recognize the path dependence of regulatory decisions in order to create a policy framework that is adaptable to changing circumstances. The history of commitments to an absolute path has brought current Japanese nuclear fuel cycle policy to a point where little flexibility is available and commitments to past decisions threaten to prevent leaders from adapting to changing circumstances.

Two related problems are central. The first is the specific issue of siting interim storage facilities (or expanding existing storage capacity). This task is closely connected with local politics and can be viewed as fundamentally an issue of negotiation with local communities. However, this local issue is closely connected to the second problem, that of overall nuclear fuel cycle policy. Spent fuel management choices are closely linked to Japan’s reprocessing/recycling policy, as well as its policy for final disposal of HLW. Unless public concerns over these issues are adequately addressed, siting interim storage facilities will be very difficult.

Current regulatory changes that will allow private industry to establish an entity specifically designed to deal with interim storage of spent fuel are welcome. These changes will provide flexibility for utilities to deal with spent fuel, as well as to optimize the timing and scale of reprocessing. The renaming of spent fuel as a “recyclable fuel resource” may also help to mitigate perceptions of spent fuel as a dangerous waste and thereby improve prospects for gaining local support for siting spent fuel storage facilities. More needs to be done, however, to assure the success of interim spent fuel storage, as some basic issues have not been addressed by these regulatory changes. Several unique social and political conditions in Japan must be overcome:

⁴⁵ For example, the LTP says, “It is strongly hoped that highly-motivated private business operators will take positive measures for investment and technological development activities...In the energy sector, the role of government should be to seek public understanding of its actions by clearly setting forth its policy on necessary measures to secure a stable supply of energy from a long-term point of view....the government should provide private nuclear operators with proper guidance...to ensure that...the voluntary activities are sufficient to attain the target set on the basis of the role nuclear power is to play...” (pp. 28, 29).

⁴⁶ JAEC, *Long Term Program*, 2000, op. cit., p. 38 (unofficial translation).

- *Difficulties in expanding on-site storage:* Political and legal commitments by utilities to remove spent fuel from sites make it difficult for them to expand on-site storage capacity. Legal constraints have been relaxed, but the political hurdles remain very high. So far, Fukushima is the only site that has allowed utilities to build additional spent fuel storage capacity.
- *Strong Nuclear Safety Agreements:* The agreements between local communities and utilities have given great political power to communities. In some cases, they may provide *de facto* veto power over any decisions. Moreover, because the agreements often are confidential, negotiations typically are not open, so it is not easy to determine acceptable public solutions.
- *Shared (but vague) responsibility for nuclear fuel cycle policy:* In Japan, the government is responsible for overall nuclear fuel cycle policy and private utilities are responsible for management of commercial projects. However, nuclear energy projects are considered as “national projects” and thus the division of responsibility becomes vague. Local communities often request government commitments to private nuclear energy projects, but final responsibility for the project still rests with private industry. This shared but vague division of responsibility makes political negotiation more complex.

The U.S. Experience

Introduction

Since the early 1970s, when U.S. policymakers first focused on the back end of the nuclear fuel cycle, difficulties in implementing a long-term disposition program for spent

nuclear fuel have generated a number of proposals for interim spent fuel storage, both at and away from reactors and for varying periods of time. These debates have failed to achieve consensus on two key questions:

- Is interim storage really needed, and if so, how much and where?
- What degree of linkage should exist between interim storage and long-term disposal?

Absent agreement on these issues, no state has been willing to assume the perceived safety risks and stigma of hosting a centralized interim storage facility—including the possibility that such a site might become permanent if DOE fails to open a geologic repository.⁴⁷ Since the mid-1980s, however, a number of U.S. utilities have used re-racking and onsite dry cask storage to manage spent fuel until a repository becomes available. In mid-2000, DOE reached its first agreement to compensate a utility for the incremental costs of onsite storage due to delays in the repository program; assuming that other nuclear plant owners accept similar agreements, this *de facto* reliance on expanded onsite storage will become formal U.S. policy.⁴⁸ Since DOE has missed the original target date of 1998 for accepting spent fuel for permanent disposal in a repository, and currently is not expected to start fulfilling this obligation until at least 2010, the United States is likely to develop a substantial onsite interim storage program over the next several decades.

The chief driving factor behind U.S. proposals for interim spent fuel storage has been concern on the part of the nuclear industry, state regulators and some policy experts that lack of sufficient onsite storage space might force reactors to shut down, leading to power shortages and rate increases. Industry representatives and regulators also argue that since nuclear operators have been paying legally mandated fees into the Nuclear Waste Fund since 1983 to support work on a repository, requiring them to pay as well for expanded onsite storage amounts to double-billing util-

⁴⁷ As discussed below, several communities and Native American tribes have offered to host centralized interim storage facilities, but states have vetoed these offers in instances in which they had the authority (i.e., when communities were the potential hosts) or strenuously opposed them when the potential hosts were sovereign Native American tribes and the state could not exercise formal legal control.

⁴⁸ For a cross-section of views on interim storage and other U.S. nuclear policy issues, see *The Nuclear Top Ten, 1999* (Washington, DC: Numark Associates, April 1999, available at <http://www.numarkassoc.com>).

ities (who pass the charge on to ratepayers).⁴⁹ In addition, nuclear power advocates fear that long-term storage at reactors may contribute to a perception that no final solution exists for managing spent nuclear fuel—which in turn could spur opposition to constructing new nuclear reactors or extending the operating lives of existing reactors.⁵⁰ Nuclear industry representatives and some policy experts have argued in addition that centralized interim storage would be safer, more economical, and easier to safeguard than on-site storage facilities spread across the country.⁵¹ In 1996, the Nuclear Waste Technical Review Board recommended creating a centralized interim storage site by approximately 2010 to add flexibility to repository operations and to enable reactors that will begin shutting down at that time to move spent fuel offsite.⁵² Some critics of the process for characterizing a permanent repository at Yucca Mountain, Nevada have called for developing interim storage (at Yucca Mountain in some cases, at reactors in others) in order to allow more extended research on the site and on ways to isolate radioactive waste from the environment.⁵³

Environmental and consumer advocacy groups and some policy experts have strongly opposed creating a centralized interim storage site, arguing instead for expanded onsite storage until a permanent repository is ready. These groups generally maintain that there is no compelling near-term safety or technical reason to move spent fuel from reactors, especially given what some view as major risks

from transportation of spent fuel. They argue that creating a centralized interim storage site would undercut work on a long-term repository, and that onsite storage is more equitable since the communities that benefit from nuclear power generation bear the risks of spent fuel storage.⁵⁴

Some past proposals for interim spent fuel storage in the United States envisioned storing fuel for relatively short periods of time—typically no more than several decades—until it could be placed in a geologic repository. Others framed the concept in a more open-ended fashion, with storage lasting for fifty years or more. In some cases these plans sought to buy time for major research efforts on long-term disposal options (including mined geologic repositories and alternatives such as sub-seabed disposal), but other advocates argued that interim storage could substitute altogether for permanent disposal. Proposals for effectively substituting interim storage for long-term disposal have been especially controversial, since both nuclear power proponents and opponents seek a long-term “solution” to managing spent fuel, albeit for different reasons: nuclear advocates see such a policy as essential to maintaining a role for nuclear power in the United States, while critics contend that the United States has neglected for too long what they view as unacceptable risks posed by accumulated spent nuclear fuel.

This section summarizes past debates over interim storage in the United States, and outlines the legal, political,

⁴⁹ See, for example, Nuclear Energy Institute, *National Used Nuclear Fuel Management Program* (Washington, DC: NEI, 2000), and National Association of Regulatory Utility Commissioners (NARUC), *Resolution Regarding Guiding Principles for Legislative Changes to the Nuclear Waste Policy Act and Resolution Regarding DOE Default of Obligations Under the Nuclear Waste Policy Act of 1982, As Amended*, adopted at NARUC’s Winter 1998 Committee Meetings (Washington, DC: NARUC, 1998).

⁵⁰ See Margaret Kriz, “Nuclear Wind-Down,” *National Journal*, August 31, 1991, p. 2081, and Pete Domenici, “Future Perspectives on Nuclear Issues,” *Issues in Science and Technology*, Winter 1997-98, pp. 53-59.

⁵¹ Luther J. Carter and Thomas H. Pigford, “The World’s Growing Inventory of Civil Spent Fuel,” *Arms Control Today*, January/February 1999, pp. 8-14.

⁵² Nuclear Waste Technical Review Board (NWTRB), *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance* (Washington, DC: NWTRB, 1996, available at <http://www.nwtrb.gov/reports/storage.pdf>). Congress created the NWTRB in 1987 to evaluate scientific and technical issues related to management and disposal of spent nuclear fuel. As discussed further below, the Board argued that a central interim storage facility should ideally be located near the permanent repository, but should not be constructed until a decision had been made on the suitability of Yucca Mountain as a permanent repository.

⁵³ James Flynn et al, *One Hundred Centuries of Solitude: Redirecting America’s High-Level Nuclear Waste Policy* (Boulder, CO: Westview, 1995); Luther J. Carter and Thomas H. Pigford, “Getting Yucca Mountain Right,” *Bulletin of the Atomic Scientists*, March/April 1998.

⁵⁴ See “H.R. 45, An Environmental Disaster In the Making” (Washington, DC: Public Citizen, undated), at www.citizen.org/cmep/RAGE/radwaste/radwastefactsheets.html, and “Why We Call It ‘Mobile Chernobyl’” (Augusta, GA: Nuclear Information and Resource Service, undated), at www.nirs.org/factsheets.

and institutional issues that have framed these choices. It identifies several key lessons from the U.S. experience, and discusses which issues are specific to the United States and which may apply to other countries' decisions.

Policy Evolution, 1972–2000

Interim storage was first proposed in the United States by Atomic Energy Commission (AEC) chair James Schlesinger in 1972. At this point, official U.S. high-level waste policy (which had only existed as such for two years) was to reprocess spent fuel, immobilize the resulting high-level waste within five years, and deliver the solidified waste to a federal repository within ten years. Problems quickly became apparent with the main repository site under investigation, a salt dome at Lyons, Kansas. Schlesinger announced that the AEC would develop a Retrievable Surface Storage Facility (RSSF) to allow more time to investigate other sites. Schlesinger believed the RSSF could provide either temporary or indefinite storage—as did critics of the proposal, such as the Environmental Protection Agency, who feared that the RSSF would be a substitute for a permanent repository (although the AEC took pains to emphasize that it was still focused on geologic disposal). The policy was terminated when the AEC was abolished and was not renewed by its successor, the Department of Energy.⁵⁵

Over the next several years, public and industry concerns about managing spent nuclear fuel and nuclear waste increased. California passed a law in 1976 that placed a moratorium on new nuclear reactors until a technology was demonstrated and approved for permanently disposing of spent fuel and high-level radioactive waste. The law, which was invoked to block a new reactor in 1978, was ultimately upheld by the U.S. Supreme Court.⁵⁶ In April 1977, President Carter indefinitely deferred reprocessing and commercial development of breeder reactors. Recognizing that this policy could increase space problems at nuclear plants,

Carter later announced that he would seek Congressional authorization for the federal government to accept and take title to spent fuel from domestic utilities, with owners paying a one-time fee for both interim storage and final disposal once a repository was ready.⁵⁷ The administration hoped to persuade private industry to create and run the storage facilities under NRC licenses, but officials said that DOE would do it if no private companies stepped forward. Reprocessing plants in Illinois and South Carolina that were not operational were identified as potential sites.⁵⁸

After a major interagency review of U.S. nuclear waste policy, Carter significantly narrowed this proposal for interim storage in February 1980 and placed a greater emphasis on investigating multiple candidate sites for a permanent repository. Carter stated that:

... storage of commercial spent fuel is primarily a responsibility of the utilities. I want to stress that interim spent fuel storage is NOT an alternative to permanent disposal However, a limited amount of government storage capacity would provide flexibility to our national waste disposal program and an alternative for those utilities which are unable to expand their storage capacities.⁵⁹

Congress failed to act on Carter's proposal, and the states with unused commercial reprocessing facilities were reluctant to host interim storage facilities in the absence of clear progress toward opening a permanent repository. President Reagan's subsequent reversal of Carter's ban on reprocessing did little to help nuclear plant owners with storage problems, since no private companies viewed reprocessing as a commercially attractive prospect. Reagan also reversed Carter's offer to provide Federal interim storage for spent fuel.

In the Nuclear Waste Policy Act (NWPA) of 1982, Congress sought to create a comprehensive legal framework for managing spent fuel and high-level radioactive

⁵⁵ Luther J. Carter, *Nuclear Imperatives and Public Trust: Dealing With Radioactive Waste* (Washington, DC: Resources for the Future, 1987), pp. 61-76.

⁵⁶ *Pacific Gas & Electric Co. v. State Energy Resources Conservation and Development Commission*, 461 U.S. 190 (1983).

⁵⁷ Carter, *Nuclear Imperatives and Public Trust*, op. cit., pp. 133-34; Ted Greenwood, "Nuclear Waste Management in the United States," in E. William Colglazier, Jr., ed., *The Politics of Nuclear Waste* (New York: Pergamon, 1982), p. 19.

⁵⁸ J.P. Smith, "A-Waste Storage Strategy Unveiled," *Washington Post*, October 19, 1977, p. A4.

⁵⁹ Presidential Message, February 12, 1980, quoted in Colglazier, *The Politics of Nuclear Waste*, op. cit., p. 223.

waste. The NWPA set firm timetables for siting and licensing two geologic repositories, and required DOE to start accepting and disposing of radioactive waste by January 31, 1998, when the first repository was scheduled to enter operation. To address storage problems at reactors—which remained primarily the responsibility of private fuel owners—the act directed the Nuclear Regulatory Commission to help utilities develop dry storage technology and expand their onsite storage capacity. As a fallback, the law required DOE to provide up to 1,900 metric tonnes of emergency storage capacity at existing or new facilities at federal sites and commercial reactors for utilities faced with threats of shutdown due to lack of storage space. The storage was to be paid for as needed by its users. Finally, it required DOE to submit a study of the need for one or more monitored retrievable storage (MRS) facilities, along with designs, to Congress by mid-1985. In an effort to distribute responsibility for managing nuclear waste, the Act barred locating an MRS facility in any state under consideration as a permanent repository site.

The NWPA left unresolved the key question of whether MRS facilities were to provide (a) short-term interim storage for spent fuel en route to a geologic repository, or (b) longer-term storage, either to permit longer-term research on permanent disposal, or in lieu of geologic disposal if this option proved too difficult.⁶⁰ This issue, as well as DOE's site selection methods, took on increasing weight over the next five years as efforts to select a site for a permanent repository became mired in controversy.⁶¹

In 1985 DOE announced plans to build an MRS facility with a capacity of about 15,000 metric tonnes of heavy metal (tHM) at the site of the canceled Clinch River Breeder Reactor in Oak Ridge, Tennessee. The facility was to be used to consolidate and repackage spent fuel as well as to provide interim storage capacity. DOE selected the site

based on criteria such as location and federal ownership, but without consulting with state officials; additionally, it identified two backup sites, also in Tennessee.⁶² After some study, the city of Oak Ridge announced that it would accept an MRS subject to specific conditions, including compensation, a role in overseeing the facility, and accelerated cleanup of other DOE sites in Oak Ridge.⁶³ However, state officials denounced the proposal, filed suit against DOE for failing to consult with them in advance, and exercised their right under the NWPA to veto the site. While the MRS proposal was bound up in controversy, the NRC approved the first licenses for onsite dry cask storage, at operating reactors in Virginia and South Carolina.

Before Congress could act on its option to override Tennessee's veto of an MRS, further action on centralized interim storage was subsumed by the Nuclear Waste Policy Act Amendments (NWPAA) of 1987, which substantially revised U.S. high-level waste policy. The new law focused on Yucca Mountain, Nevada as the sole option for a permanent repository, and barred siting an interim storage site in Nevada. Responding to concerns that an interim storage facility would become permanent because of delays in the permanent repository program, the NWPAA revoked the Oak Ridge MRS siting proposal and forbade construction of an MRS until a permanent repository had been licensed. Finally, it established the Office of the Nuclear Waste Negotiator to solicit voluntary offers to host an interim storage site or a repository, and created an MRS Commission to report to Congress on the need for interim storage.

In its 1989 report, the MRS Commission found no compelling safety or technical arguments either for or against building an MRS. In terms of cost, the Commission calculated that proceeding without interim storage would be modestly less expensive (about 6 percent) on a discounted basis than building an MRS. This difference shrank

⁶⁰ U.S. Congress, Office of Technology Assessment, OTA-O-171, *Managing the Nation's Commercial High-Level Radioactive Waste* (Washington, DC: U.S. Congress, Office of Technology Assessment, March 1985), pp. 124-29.

⁶¹ A discussion of problems with the Yucca Mountain program is beyond the scope of this report, but see for example Flynn et al, *One Hundred Centuries of Solitude*, op. cit.

⁶² John Graham, "DOE Names Clinch River as Preferred MRS Site," *Nuclear News*, June 1985, p. 117.

⁶³ E. Brent Sigmon, "Achieving a Negotiated Compensation Agreement In Siting: The MRS Case," *Journal of Policy Analysis and Management*, vol. 6, No. 2 (1987), p. 173.

when major delays were projected in bringing a repository into operation, since costs for onsite dry storage would start to rise substantially if no repository or MRS became available until well into the 21st century.

The Commission stated that a facility of the size proposed for Oak Ridge was not needed, but that some limited capacity would be useful. It argued that this capability should not be linked to the licensing of a repository as Congress had done under the NWPAA, since doing so meant that interim storage capacity would become available no more than three years before the opening of a repository—at which point nuclear plant owners would likely have made other arrangements. Instead, the commission recommended creating two more modest options: a Federal emergency storage facility with 2,000 tHM capacity, paid for out of the Nuclear Waste Fund (since all utilities would benefit from having this capacity available), and a utility-funded interim storage facility with 5,000 tHM capacity, to be used by plants that had run out of onsite storage space or ceased operation. The Commission called for Congress to revisit the issue in 2000, when more information about a long-term repository would be available.⁶⁴

The first Nuclear Waste Negotiator, David Leroy, established a process that emphasized voluntary action by applicants and gave them full rights to withdraw at any time until applications were submitted to Congress. Under the NWPAA, host communities were entitled to receive annual payments of \$5 million prior to receiving spent fuel and \$10 million per year until the facility was closed. DOE received applications between 1991 and 1995 for \$100,000 Phase I study grants from four counties and 20 Native American tribes. None of the county applications proceeded further: of the three counties that were funded, two applications were blocked by their respective governors (who had initially assented to the process) and the responsible commissioners in the third county were removed from office in a recall

election by voters who had not been formally consulted.⁶⁵

The lack of interest from states left Native American tribes, whose special legal status as sovereign nations placed them essentially beyond state controls on this issue, as the main viable candidates. Five of the original tribal applications progressed to Phase II-A (\$200,000 grants), joined by four new applicants at that stage. Of this group, two tribes applied for \$2,800,000 Phase II-B grants: the Mescalero Apaches in New Mexico, and the Skull Valley Goshutes in Utah. Both applications incurred significant resistance from state officials who opposed siting interim storage facilities in their states. Congress canceled the study grant program in 1993, and the Clinton administration—which was lukewarm to the interim storage idea—redirected funding toward research on the Yucca Mountain repository. Critics of the negotiation process charged that although it was voluntary, it represented a form of environmental racism, since building noxious facilities on Native American land increased the burdens on deprived populations and took advantage of their lack of other viable economic options.⁶⁶ Authority for the Nuclear Waste Negotiator's Office expired in January 1995.

During this period, the NRC approved additional licenses for onsite dry cask storage in North Carolina, Colorado, Maryland, and Minnesota. In 1990 the Commission amended its regulations to make the process easier for nuclear plant owners by permitting holders of general operating licenses for nuclear power plants to establish onsite dry storage, provided they used NRC-approved casks, without obtaining site-specific dry storage licenses. Under this provision, utilities in Michigan, Wisconsin, and Ohio began loading spent fuel into dry casks in 1993-95. In many areas dry storage encountered scant local opposition, but several exceptions occurred in the Midwest, where local governments and regulators refused to approve as much dry storage capacity as utilities had requested (see box, next page).

⁶⁴ Monitored Retrievable Storage Review Commission, *Nuclear Waste: Is There a Need for Federal Interim Storage?* (Washington, DC: U.S. Government Printing Office, 1989), pp. 71, 99-101.

⁶⁵ M.V. Rajeev Gowda and Doug Easterling, "Nuclear Waste and Native America: The MRS Siting Exercise," *Risk: Health, Safety & Environment*, vol. 229 (Summer 1998), pp. 233-34.

⁶⁶ Nancy B. Collins and Andrea Hall, "Nuclear Waste in Indian Country: A Paradoxical Trade," *Law & Inequality Journal*, Vol. 267 (June 1994); Gowda and Easterling, "Nuclear Waste and Native America," *op. cit.*, pp. 246-48.

Onsite Fuel Storage Controversies

Palisades: In 1993, Consumers Power Company of Michigan began loading spent fuel into dry storage casks at its Palisades reactor on the shore of Lake Michigan. Consumers was the first utility to act under a 1990 amendment to NRC regulations that permitted holders of general operating licenses for nuclear power plants to establish onsite dry storage, provided they used NRC-approved casks, without obtaining site-specific dry storage licenses.⁶⁷ Local opponents argued that the storage site was vulnerable to erosion and blowing sand, and filed suit along with Michigan's Attorney General to prevent Consumers from putting spent fuel into casks. Courts ruled in 1995 that the NRC had acted within its discretion in approving use of the relevant cask design and was not obligated to conduct a site-specific environmental impact assessment at Palisades.⁶⁸

Consumers experienced further delays when weld failures were detected in one of its casks and in casks of the same model (Sierra Nuclear's VSC-24) at the Point Beach reactor in Wisconsin and a nuclear plant in Arkansas. The NRC directed utilities to stop loading spent fuel into VSC-24 casks in 1997, and in 1999 it barred a subcontractor that had failed to document welds on the casks from nuclear work for five years. Consumers and other utilities were authorized to resume loading spent fuel into the casks shortly afterward.⁶⁹

Prairie Island: In 1992, Northern States Power received permission from Minnesota's Public Utility Commission (PUC) for 17 dry casks at its Prairie Island nuclear plant (the utility had sought approval for 48 casks, which it said were necessary to allow it to operate until its license expired in 2013). A neighboring Native American community and a public-interest organization appealed the PUC decision in court, and in 1993 a Minnesota appeals court ruled that the proposed facility would be considered "permanent storage" under a state law, which in turn required legislative approval for such facilities. After several months of contentious debate in which the Minnesota House of Representatives voted to close Prairie Island, the

legislature approved a compromise plan under which NSP was allowed a total of 17 casks in three installments from 1994-99. In return, NSP was required to make a good faith effort to seek a second dry storage site; to build or contract for a total of 550 megawatts of wind and biomass power; and to pay \$500,000 per cask per year into a renewable energy development fund starting in 1999.⁷⁰ In 1999, the Minnesota PUC exercised an option in the law to order NSP to build or contract for an additional 400 MW of wind energy by 2012.⁷¹ The 1994 law is widely regarded as setting a framework for phasing out nuclear power at Prairie Island, where the two units are licensed to operate through 2013 and 2014. NSP currently projects that the 17 authorized casks will allow the plant to operate until at least 2007; the company has considered requesting additional casks from the legislature but thus far has opted not to reopen the debate.⁷²

Point Beach: In 1995, Wisconsin Electric Power Company (Wepco) requested permission to load spent fuel into 48 dry storage casks at its Point Beach station. The Wisconsin Public Service Commission (WPSC) limited the utility to 12 casks, in order to keep pressure on DOE to open a permanent repository, although it permitted constructing a pad to hold 48 casks (the number Wepco estimated were needed to allow the plant to run through its licensed operating life).⁷³

In May 1996, two hydrogen burns occurred during welding of dry storage casks. No injuries or radiation releases occurred, but the second burn was powerful enough to raise a three-tonne cask lid by several inches.⁷⁴ Wepco (which helped design the cask) acknowledged failing to consider that a zinc coating on the cask's fuel baskets would react with acidic water in the spent fuel pool, producing hydrogen, and that plant employees had not followed company procedures for reporting potential problems during the cask welding. The company paid \$325,000 in fines for these and other safety violations.⁷⁵ Wepco was allowed to resume loading spent fuel in the casks in 1998, and recently sought permission from the WPSC to install more containers beyond the 12 casks originally authorized. A decision is expected in 2001.

⁶⁷ Mary Beth Regan, "Nuclear Fuel Rods Along the Sand Dunes?" *Business Week*, May 10, 1993, p. 27.

⁶⁸ Kelley V. Selin, 42 F.3d 1501 (1995).

⁶⁹ Pam Newman-Barnett, "NRC Report Faults Sierra Nuclear on Casks," *Energy Daily*, April 21, 1997; Tom Harrison, "NRC Bars Cask Fabricator, Managers From Nuclear Work For Five Years," *Nuclear Fuel*, February 8, 1999, p. 4; "NRC Clears Palisades Cask Use Plan," *Nuclear Fuel*, May 31, 1999, p. 10.

⁷⁰ Robert Whereatt, "Full Senate, House Approve NSP Plan For Nuclear Waste," *Minneapolis Star-Tribune*, May 7, 1994, p. 1B; "NSP Wins Okay To Keep Prairie Island Open; Many Conditions," *Electric Utility Week*, May 16, 1994, p. 7.

⁷¹ "Minnesota PUC Orders NSP To Contract For 400 MW of Wind Energy Through 2012," *Utility Environment Report*, January 29, 1999, p. 1.

⁷² Robert Whereatt, "NSP Won't Seek To Fill More Waste Casks," *Minneapolis Star-Tribune*, December 6, 1997, p. 1.

⁷³ Dennis Wamstead, "Wisconsin PSC OKs Point Beach Storage Proposal," *Energy Daily*, January 6, 1995.

⁷⁴ Lee Bergquist, "Utility Criticized In Fire: Wisconsin Electric Misread Flames," *Milwaukee Journal Sentinel*, June 8, 1996, p. 1.

⁷⁵ Dave Airozo, "Point Beach Cask Incident Prompts Possible NRC Enforcement Action," *Nuclear Fuel*, September 9, 1996, p. 4; Lee Bergquist, "Utility gets OK On Spent Fuel," *Milwaukee Journal Sentinel*, August 15, 1998, p. 1.

As these controversies occurred, and with the Nuclear Waste Negotiator finding little interest in hosting a central interim storage facility, DOE stated publicly in 1995 that it would not be able to start accepting spent nuclear fuel by 1998 due to delays in the repository program.⁷⁶ In response, the U.S. nuclear industry embarked on a three-part strategy to address what it portrayed as an intensifying storage crisis, including:

- a campaign for legislation to require DOE to create a centralized interim storage facility on the surface at Yucca Mountain;
- lawsuits seeking court orders for DOE to accept spent fuel on schedule and to pay damages to utilities for costs resulting from delays in the repository program; and
- negotiations with Native American tribes and communities to host private interim storage facilities.

On the legislative front, Congress voted on several bills between 1995 and 2000 that would have required DOE to create a centralized interim storage site in Nevada near the proposed geologic repository site, and would have required DOE to start moving spent fuel to the interim facility as early as 2002.⁷⁷ None of these measures achieved majorities large enough to override the promised presidential vetoes, however. The Clinton administration asserted that creating an interim storage facility at Yucca Mountain would preempt the decision scheduled for 2001 on the site's suitability as a long-term repository. Environmental advocates argued in addition that transporting spent fuel posed major safety hazards (opponents of interim storage legislation dubbed the concept "mobile Chernobyl") and that spent fuel should not be shipped to Nevada before Yucca Moun-

tain had been approved as a permanent repository site.⁷⁸

Nuclear utilities received only partial relief in court. The U.S. Court of Appeals ruled in 1996 that DOE had an unconditional statutory obligation to start accepting spent fuel by January 31, 1998 (the date specified in the NWPA and its standard fuel acceptance contracts), regardless of whether a repository would be ready to accept fuel at that time.⁷⁹ In 1997, the court ordered DOE to comply with this obligation but refused to impose specific actions on DOE as requested by utilities, instead directing the department to work out settlements with utilities under its standard disposal contract. The U.S. Court of Claims ordered DOE to start paying fuel storage costs for three closed reactors in 1998, but another judge denied similar payments in 1999 to a utility whose reactors were still operating.⁸⁰

The Current Situation

As of mid-2000, fourteen U.S. nuclear stations were using dry storage onsite or expected to do so by the end of the year. Another dozen plants expect to start loading spent fuel into dry storage between 2001 and 2004.⁸¹ In July 2000, DOE reached its first agreement with a utility, PECO Energy Company of Pennsylvania, to allow PECO to reduce its projected Nuclear Waste Fund charges to reflect costs the company incurs due to DOE's delay in opening a repository on schedule. DOE argued that the Nuclear Waste Fund would still be adequate to cover the costs of the geologic disposal program even if utility payments to the fund were reduced to cover the costs of at-reactor dry cask storage.⁸² While the Nuclear Energy Institute, the nuclear industry's lobbying organization, supported the deal, eight utilities have sued to block it, arguing that reducing utility payments to pay for dry cask storage will inevitably require higher payments into the Nuclear Waste Fund in the future

⁷⁶ *Federal Register*, April 28, 1995, pp. 21, 793-94.

⁷⁷ For summaries see Mark Holt, *Civilian Nuclear Spent Fuel Temporary Storage Options*, CRS Report 96-212 ENR (Washington, DC: Congressional Research Service, March 27, 1998), and *Civilian Nuclear Waste Disposal*, CRS Issue Brief 92059 (Washington, DC: Congressional Research Service, May 24, 2000).

⁷⁸ For representative arguments for and against interim storage at Yucca Mountain, see Matthew L. Wald, "Senate Approves Temporary Site in Nevada for Nuclear Waste," *New York Times*, April 16, 1997, p. 16, and Brad Knickerbocker, "U.S. Lawmakers Collide Over Where to Dump Nuclear Waste," *Christian Science Monitor*, July 17, 1996, p. 1.

⁷⁹ *Indiana Michigan Power Company v. Department of Energy*, 319 U.S. App. D.C. 209 (1996).

⁸⁰ Michael A. Bauser, "Courts Say Take Or Pay," *Radwaste Solutions*, July/August 2000.

⁸¹ Nuclear Energy Institute, *U.S. Utilities With On-Site Dry Storage Commitments*, (Washington, DC: NEI, August 15, 2000).

⁸² "First Agreement Reached With Utility on Nuclear Waste Acceptance," DOE press release, July 20, 2000.

to cover the cost of geologic disposal.⁸³ Assuming that these issues are resolved and the agreement serves as a model for settlements with other utilities, as DOE intends, it will formalize the *de facto* U.S. policy of relying on expanded dry cask storage at reactors to handle spent fuel until a permanent repository becomes available.

In addition to paying the incremental costs of onsite dry storage, DOE proposed in 1999 to take title and assume management responsibility for spent fuel. However, several governors from states with nuclear plants opposed this onsite transfer of title, arguing *inter alia* that allowing DOE to manage spent fuel at reactors would create new federal waste facilities outside of state control that would likely become permanent disposal sites.⁸⁴ As a result, a provision authorizing DOE to take title to spent fuel at reactors was dropped from the most recent interim storage legislation, leaving primary responsibility with utilities.

At the same time, two private efforts to develop interim storage sites are under way. The more advanced project is run by Private Fuel Storage (PFS), a consortium of eleven utility companies headed by Northern States Power Company, which plans to build a private interim storage site with 40,000 tHM capacity on land leased from the Skull Valley Goshutes in Utah. PFS earlier sought agreement with the Mescalero Apaches—who, like the Goshutes, received study grants from the Nuclear Waste Negotiator to assess hosting a Federal interim storage facility—but negotiations broke down over financial issues. A license application for

the Skull Valley facility is pending with the Nuclear Regulatory Commission, which has issued a safety evaluation report concluding that the facility would be safe and would meet regulatory requirements, and the consortium hopes to open the facility as early as 2003.⁸⁵ PFS has reached a compensation agreement with Tooele County which includes annual payments of \$500,000 in lieu of taxes and up to \$3,250 per cask stored.⁸⁶ However, the state of Utah has passed two laws and one resolution seeking to block the facility, as well as forming an Office of High Level Waste Storage Opposition and working with Utah's congressional delegation, much as officials in New Mexico and Wyoming intervened in earlier applications to the Nuclear Waste Negotiator's Office.⁸⁷ At one point, Utah's governor sought to seize control of all the roads surrounding the Goshute reservation, to create a state-controlled "moat" that spent fuel could not cross.⁸⁸

A similar facility has been proposed at Owl Creek, Wyoming by NEW Corporation, a Wyoming-based company. The Owl Creek Energy Project would be built on a 100-acre private site with a capacity of up to 40,000 metric tonnes of spent fuel. Several nuclear companies are involved (NAC International, which builds dry storage casks, is the project manager, and Virginia Power is a technical advisor on NRC licensing issues), as well as environmental consultants, engineers, and two Wyoming manufacturing companies.⁸⁹ The project applied for permission in 1998 to conduct a preliminary feasibility study, and the

⁸³ Elaine Hiruo, "Eight Utilities Ask 11th Circuit to Block DOE-PECO Agreement; More May Join Action," *Nuclear Fuel*, December 11, 2000.

⁸⁴ Letter from Governors Bush (FL), Shaheen (NH), Dean (VT), Ventura (MN), King (ME), Vilsack (IA), and Kitzhaber (OR) to President Clinton, February 9, 2000, online at www.naruc.org/committees/Electricity/Electric/Lettergoverns.htm.

⁸⁵ For details and updates see the project's home page at <http://www.privatefuelstorage.com>. For the Nuclear Regulatory Commission's analysis, see *Safety Evaluation Report Concerning the Private Fuel Storage Facility*, Docket No. 72-22 (Washington, DC: U.S. Nuclear Regulatory Commission, 2000, available at <http://www.nrc.gov/NRC/NMSS/SFPO/SER/PFS/index.html>).

⁸⁶ *Nuclear News*, July 2000, p. 17; see also Private Fuel Storage's newsletter: "PFS, Tooele County in Historic Agreement," *Inside Look*, Summer 2000, available at <http://www.privatefuelstorage.com>.

⁸⁷ Kevin Fedarko, "In the Valley of the Shadow," *Outside*, May 2000; Brent Israelsen, "Pols Target N-Waste at Skull Valley," *Salt Lake Tribune*, September 5, 2000; Jenny Weil, "Utah's U.S. Senators Oppose Private Fuel Storage Project," *Nuclear Fuel*, October 2, 2000, p. 11. The web page of the waste opposition office is http://www.eq.state.ut.us/hlw_opp.htm.

⁸⁸ See, for example, Zack van Eyck, "State Takes Roads to Block N-Waste Plan," *Deseret News*, February 12, 1999.

⁸⁹ "Wyoming Receives Owl Creek Application," *Nuclear Fuel*, April 6, 1998, p. 10.

Nuclear Regulatory Commission expects to carry out technical and environmental analyses at the site in FY 2001. The Owl Creek Project reportedly has proposed a yearly state benefits package of up to \$20 million.⁹⁰ Prospects for state approval are unclear: some legislators support the project, while others have expressed strong opposition. Wyoming law bars submission of the required analyses to the legislature for approval until DOE has applied for a license for a Federal repository (a step currently expected in 2002.)⁹¹ If this requirement is not changed, the Owl Creek facility would only become available a few years before a repository at Yucca Mountain could start receiving spent fuel, if the repository remains on its currently projected schedule, reducing its usefulness to utilities with pressing spent fuel storage needs.

If either private facility is approved, it will face some of the same opposition that was directed at proposals for a federal centralized facility in Nevada. In particular, critics will argue that transporting spent fuel is dangerous, especially since most U.S. spent fuel is located in the eastern half of the country and would have to travel thousands of miles through dozens of states.⁹² It is unclear whether these protests would spark widespread public opposition to shipping spent fuel. DOE made nearly 5,000 shipments of radioactive materials by air, truck and rail in FY 1998, including wastes, medical and research isotopes, and spent fuel.⁹³ These shipments proceeded smoothly, even when cargoes such as spent fuel from foreign nuclear research

reactors were targets for protest by antinuclear groups.⁹⁴ A program to move thousands of tonnes of spent fuel across the United States for storage, however, would be a high-profile and larger-scale undertaking that could draw significant attention. Research suggests that while Americans perceive significant risks from transportation of spent fuel, a sizeable fraction and possibly a majority will tolerate spent fuel shipments through their communities, especially if the program provides detailed public information about shipments; gives state and local officials significant planning roles; and takes steps to compensate transit communities and to address safety concerns, such as providing special driver training and independent certification of cask designs.⁹⁵

Observations

In the United States, technical aspects of interim spent fuel storage have played a relatively small part in policy debates, compared to the central legal and political issues. While problems such as those detailed above at the Point Beach and Prairie Island nuclear plants should not be minimized, a general consensus exists, as described in Chapter 2, that if properly managed, spent fuel can be safely stored onsite in dry casks at nearly all reactors for several decades.⁹⁶ There is far less agreement over questions such as how decision authority over storing spent fuel should be allocated among different levels of government and who should bear the (actual or perceived) risks associated with various storage schemes.

⁹⁰ "Economic Analysis Out On Owl Creek Project," *Nuclear Fuel*, January 25, 1999, p. 5.

⁹¹ 2000 Wyoming State Statutes, 35-11-1504, at <http://legisweb.state.wy.us/titles/statutes.htm>

⁹² Anti-nuclear groups make this argument with respect to the proposed permanent repository at Yucca Mountain as well as interim storage. See information on the "Radioactive Roads and Rails Campaign" at <http://www.citizen.org/CMEP/RAGE/radwaste/radwaste.html>. In contrast, experts generally view risks from transporting spent fuel as manageable: see Chapter 2, and NWTRB, "Transportation of Spent Nuclear Fuel," *NWTRB Viewpoint* (Arlington, VA: NWTRB, March 1998).

⁹³ U.S. Department of Energy, National Transportation Program, *DOE Shipping Activity*, (Washington, DC: U.S. Department of Energy, March 1999).

⁹⁴ See for example Michael Hytha, Aurelio Rojas, and Bernadette Tansey, "Nuclear Rods Cross Bay Safely," *San Francisco Chronicle*, July 22, 1998, and Kathy Kellogg, "Nuclear Waste Being Shipped Out On Restored Rails," *Buffalo News*, July 30, 2000.

⁹⁵ Donald MacGregor et al, "Perceived Risks of Radioactive Waste Transport Through Oregon: Results of a Statewide Survey," *Risk Analysis*, vol. 14, No. 1 (1994), pp. 5-14; Hank C. Jenkins-Smith, Amy Fromer, and Carol L. Silva, *Transporting Radioactive Materials: Risks, Issues and Public Perspectives* (Albuquerque, NM: University of New Mexico Institute for Public Policy, January 1996); S. Summers and D.W. Hine, "Nuclear Waste Goes On the Road: Risk Perceptions and Compensatory Tradeoffs In Single-Industry Communities," *Canadian Journal of Behavioral Science*, vol., 29, no. 3 (July 1997), pp. 211-23.

⁹⁶ The Nuclear Regulatory Commission has stated that onsite dry cask storage is safe for up to 100 years. NRC, "Waste Confidence Decision Review," *Federal Register*, September 18, 1990, pp. 38474-38514.

Many spent fuel storage debates have revolved around the issue of which layer of government—Federal, state, local, or tribal—should have the power to decide policy and to what degree power should be shared among various levels of government. Under the Atomic Energy Act, the Federal government has exclusive power to regulate the safety aspects of nuclear reactor operation and high-level nuclear waste disposal. However, states have found ways to exert significant influence over spent fuel management decisions.

For example, in the 1983 *PG&E v. State Energy Resources* opinion, the Supreme Court held that states could regulate economic aspects of nuclear power, including the burdens that would be imposed by a buildup of spent fuel without a permanent means of disposal. In the wake of this decision Connecticut, Maine, Massachusetts, Montana, Oregon and Wisconsin passed laws similar to California's, linking new reactor licenses to satisfactory resolution of the nuclear waste issue. More recently, as discussed above, the 1994 Minnesota law that limited the amount of dry cask storage available to Northern States Power was triggered by a requirement in a previous law that no nuclear waste could be permanently stored in the state without the consent of the legislature. States can also pass laws affecting the timing of decisions, such as the Wyoming law linking legislative consideration of an interim storage facility to a Federal license application for the Yucca Mountain repository, or make it difficult to obtain permits and develop the infrastructure to support spent fuel storage facilities.

In sum, although final decision authority for managing spent fuel rests with the Federal government, states can make the process very difficult if they do not support policy decisions. As the 1999 governors' letter to President Clinton shows, states remain highly mistrustful of DOE's ability to develop a repository and reluctant to give up any leverage that may eventually move spent fuel off their territories.

The U.S. record illustrates the importance of carefully balancing national, state, local, and tribal prerogatives, so that it is clear who has the authority to make a final decision—the community or tribe, the state, or the national government. Finding a volunteer community is not enough, since neighbors may oppose the project and appeal

to higher levels of government. A volunteer strategy should include entire regions once a specific community or tribe has initiated discussions.

It also is important to avoid making a single state or community feel that it is being saddled with an unfair burden. Nevada's resistance to the Yucca Mountain project is an obvious illustration of this principle, but so is the Tennessee MRS episode, in which DOE chose three candidate sites in one state. There are obvious benefits to siting nuclear waste facilities at locations that already host nuclear activities, such as the Barnwell, South Carolina and Morris, Illinois communities that were considered for interim storage because they had reprocessing plants that were not in operation. But the perception that interim storage will add to a community's already-existing waste burden may outweigh benefits from using these locations. For example, South Carolina officials resisted accepting commercial spent fuel for interim storage, arguing that they already had far too much nuclear waste within their borders. These political concerns are likely to arise in other countries where decision authority is allocated comparably between national and regional governments; indeed, some countries where regional governments have more jurisdiction over nuclear policy decisions, such as Germany, have experienced greater political paralysis on nuclear waste issues.

The record of the Nuclear Waste Negotiator cautions against relying too heavily on poor or disadvantaged communities to host waste sites. Even if these communities volunteer, it is hard to avoid the perception that society is playing on their need to get rid of a noxious burden. (This issue is discussed in more detail in Chapter 5.) Poor communities often have little access to legal representation and low levels of political participation, making them vulnerable to exploitation by leaders who take control of negotiations with the government and may not represent all local views equally. This charge has been raised in relation to negotiations with Native American tribes. For example, the Mescaleros originally rejected hosting an interim storage site, then approved the measure in a second vote in which MRS opponents reportedly were threatened and coerced to vote for the program.⁹⁷ The Skull Valley Goshutes are

⁹⁷ Louis G. Leonard, "Sovereignty, Self-Determination, and Environmental Justice In the Mescalero Apache's Decision To Store Nuclear Waste," *Boston College Environmental Affairs Law Review*, vol. 24 (1997), pp. 662-64.

deeply divided over their agreement with PFS, and dissenters have been unable to acquire the text of the contract. Critics have charged that tribal leader Leon Bear controls payments that the tribe receives from the Private Fuel Storage consortium and distributes money only to project supporters.⁹⁸ While the unique legal status of Native American tribes in the United States makes these environmental justice issues particularly complex, the broader point is that imposing spent fuel management risks disproportionately on disadvantaged communities raises serious ethical questions (and issues of political sustainability as well), especially when political structures in these communities make it unlikely that all community views will be fairly represented in decisions.

The Nuclear Waste Negotiator's efforts also indicate that significant amounts of compensation may be required to persuade a host community to accept an interim storage facility, since the authorized levels of payment (\$10 million per year) were not enough to overcome state officials' opposition to an MRS. Several more recent arrangements, including the Minnesota law that gave Northern States Power limited permission for dry cask storage and the PFS agreement with Tooele County, Utah, have based compensatory payments in part on the number of spent fuel casks stored, suggesting that stakeholders are likely to require benefits that are explicitly proportional to the perceived risks of hosting an interim storage facility.

As with other nuclear policy issues, trust and credibility are key factors in the success or failure of efforts to site interim storage facilities. Opponents of U.S. interim storage proposals have repeatedly cited DOE's historically poor relations with states and communities, and its inability to shape and execute a coherent nuclear waste policy, as reason to doubt agency assurances that interim facilities will not become permanent. The more a lead agency is mistrusted, the more it will have to do to show that waste will not remain indefinitely, such as licensing storage facilities only for set periods with no automatic extension provisions, or signing contracts to pay compensation to affected communities if fuel is stored for longer than agreed. (Antic-

ipating this concern, the PFS contract with the Goshutes consists of a 25-year lease with a single 25-year renewal option, after which spent fuel stored at the site must be removed.⁹⁹)

Similarly, some critics argue that the Nuclear Regulatory Commission has not regulated dry cask storage stringently enough, particularly in the wake of the problems at Point Beach and Palisades discussed above. These groups argue that steps such as changing NRC regulations to allow holders of general operating licenses to use dry cask storage without applying for site-specific licenses have reduced opportunities for public participation in decisions about waste management and downplayed site-specific environmental issues that may affect the safety of dry cask storage.¹⁰⁰ These charges echo longstanding arguments by U.S. nuclear critics that the NRC is too solicitous of the nuclear industry and not sufficiently attuned to public concerns. Although dry cask storage is a relatively low-risk, low-impact undertaking compared to other civil nuclear activities (such as commercial reprocessing), it is not immune to technical problems. Failure to regulate interim storage facilities stringently and to involve affected communities in decisions about interim storage will only contribute to existing mistrust of nuclear power and of the responsible agencies.

Financing for interim storage is a key institutional question that is currently at issue in the United States. U.S. utilities pay most of the cost of high-level waste disposal through a fee on nuclear power, and view interim storage costs as double-billing for a service that they should be receiving already. DOE cannot spend fees from the trust fund without Congressional authorization, and Congress has only appropriated about half of the total fees collected to the nuclear waste program. This situation highlights the importance of agreeing on a sustainable funding mechanism for interim storage and on a fair and politically viable formula for allocating costs. If a government pursues interim storage and permanent disposition simultaneously, it should seek to keep funding separate so that one project does not undercut the other.

⁹⁸ Fedarko, "In the Valley of the Shadow"; Jim Woolf, "More Than Half of Goshutes Sue Tribe Over Waste Plan," *Salt Lake Tribune*, March 13, 1999; Jim Woolf, "Goshute Pact Will Stay Secret," *Salt Lake Tribune*, November 16, 1999.

⁹⁹ Private Fuel Storage web site, at <http://www.privatefuelstorage.com>.

¹⁰⁰ For a discussion of stakeholder concerns with NRC oversight of dry cask storage, see <http://www.nrc.gov/NRC/COMMISSION/TRANSCRIPTS/20000223a.html>, pp. 64-71.

Finally, the U.S. experience demonstrates the importance of maintaining a clear commitment to a final solution for managing spent fuel—in this case, developing a geologic repository. Interim spent fuel storage plans have been most contentious when offered as a substitute for geologic disposal (as with Schlesinger's 1972 RSSF concept) or when they were seen as undercutting the financial and programmatic commitment to geologic disposition (as were recent legislative proposals for a centralized interim storage site in Nevada near Yucca Mountain). Without clear progress toward a repository, and absent greater trust and confidence in DOE, states are unlikely ever to become more receptive toward hosting a centralized interim storage site for fear that it will become permanent.

If a permanent U.S. repository is severely delayed—for example, if Yucca Mountain is rejected as a repository site without clear agreement on next steps—even onsite dry storage could come under greater political pressure. In 1984 the NRC made a generic determination, referred to as the "Waste Confidence" rule, that spent reactor fuel could be safely disposed of in a geologic repository and that one or more repositories would be available within several decades; accordingly, it held that the environmental impact of spent fuel storage was not an issue to be considered in granting reactor operating licenses. The current rule holds that spent fuel can be safely stored for at least 30 years beyond a reactor's licensed operating life, and that at least one repository is likely to be available in the first quarter of the 21st century.¹⁰¹ However, if this prediction should be undercut, the NRC would quite likely come under pressure to revisit its forecast, especially in the context of decisions on reactor license extensions.

For all of these reasons, the future of interim spent fuel storage in the United States is bound up with action on

a permanent repository. If the Yucca Mountain site is deemed suitable (a decision currently scheduled for 2001) and DOE proceeds to submit a license application, it is conceivable that centralized storage advocates might renew calls for an interim storage facility near the repository, as proposed by the Nuclear Waste Technical Review Board in its 1996 report.¹⁰² However, if further delays occur at Yucca Mountain, it is difficult to envision a scenario in which states or communities would have sufficient confidence in DOE to host an interim storage facility. Private facilities may offer some relief, although contentious political battles are likely before either of the proposed facilities in Utah and Wyoming enters operation.

National plans for managing spent fuel vary: some countries plan to reprocess all or part of their spent fuel, and others that plan to rely on direct disposal are already using long-term interim storage in order to buy time for extended research on repositories. A common factor, however, is that most rest on high-level commitments by their national governments to develop long-term policies for managing spent fuel (even if it remains the responsibility of nuclear plant owners to fund this policy and operate interim storage facilities). Without such demonstrable national commitments, interim storage is likely to be difficult to implement as well, since potential hosts will ask the central question reiterated throughout this chapter: what is the final destination for spent fuel? As the Nuclear Waste Technical Review Board argued in the U.S. context, "one of the best ways to allay concerns about the creation of a de facto disposal site is by maintaining a viable, technically credible, site-characterization and repository development program for disposal that is open to public review and comment."¹⁰³ To be fully credible, interim storage must be part of a comprehensive plan for managing spent fuel.

¹⁰¹ 10 *Code of Federal Regulations* 51.23 (amended September 18, 1990).

¹⁰² NWTRB, *Disposal and Storage of Spent Nuclear Fuel — Finding the Right Balance*, op. cit.

¹⁰³ *Ibid.*, p. 35.

4. International Approaches to Spent Fuel Storage

WHILE THIS REPORT HAS FOCUSED on ways in which Japan and the United States can manage spent fuel within their own borders, both countries have been involved over many years in discussions of various proposals for international sites to store or dispose of spent fuel or nuclear waste from multiple countries. This chapter reviews key issues surrounding the concept of such international sites; analyzes pros and cons of such approaches; summarizes the main proposals that have been offered in the last decade, particularly those related to Russian sites, which are currently the most active; and draws some brief conclusions.

Interest in international storage and disposal concepts has increased significantly over the past decade, for a number of reasons. Most importantly, storage needs have become much more pressing worldwide, especially in countries that have canceled or postponed reprocessing programs or that have experienced delays in their work on geologic repositories. As a result, spent fuel ponds at many reactors are nearing maximum capacity. As discussed in previous chapters, some governments and reactor operators have had political difficulties establishing additional storage capacity. The prospect that some reactors might have to shut down if no additional storage options could be developed has spurred interest in establishing an international site or sites that could accept spent fuel on a commercial basis, especially since reactor operators appear willing to pay high prices for a solution to their spent fuel storage problems.

Second, progress on geologic repositories for spent fuel or high-level waste around the world has been slow, and the costs of these programs have grown. As the costs and political burdens of domestic repository programs mount, the possibility of reducing costs through economies of scale and international cooperation become increasingly appealing. It is not likely to be either feasible or efficient for every country with even a single power or research reactor to have its own nuclear waste repository—particularly in cases where countries may have few suitable geological sites available.

Third, as it became clear that the costs of addressing the Cold War nuclear legacy in the former Soviet republics (including urgent disarmament, nonproliferation, and cleanup initiatives) would run to billions of dollars, some analysts and officials have identified spent fuel storage or disposal as a means of generating revenues to address these key issues.

Despite these factors, however, the idea of one country accepting nuclear waste or spent fuel from other countries remains intensely controversial. This concept has been discussed for decades, but no such facility has been established. It is not apparent whether the new incentives cited above will overcome the significant obstacles that have prevented such facilities from being established in the past.¹

A wide range of views exists on the idea of international spent fuel storage or disposal. Advocates contend that cooperative approaches are sensible, desirable, and

¹ Useful recent publications on the concept of international sites for storage or disposal of spent fuel or nuclear waste from multiple countries include: Atsuyuki Suzuki, chair, "An International Spent Fuel Facility and the Russian Nuclear Complex," in Sam Nunn, chair, *Managing the Global Nuclear Materials Threat: Policy Recommendations* (Washington, DC:

would be beneficial for both the future of nuclear energy and the future of nonproliferation and disarmament.² Skeptics argue that there will be enormous difficulties in establishing and operating such an international site, and further that each country that operates nuclear power reactors should bear the burden of storage and disposal of the resulting spent fuel and nuclear wastes.³ Numerous proposals have failed to resolve this basic tension between the efficiency that multinational sites offer and the serious implementation and equity issues that they raise in practice.⁴

Key Issues for International Storage or Disposal

The basic concept of international spent fuel storage or disposal may appear simple: material would be transported from the countries of origin, and either stored or disposed of in a repository in the host state. However, many complex questions will determine the viability and desirability of any such proposals.

What service would be offered?

A variety of specific services related to spent fuel or nuclear waste management could be offered on an international basis, including:

- **Temporary storage.** Typical proposals involve contracting to store spent fuel in dry casks, or nuclear waste in some similar safe containers, for a specified period, perhaps 30-50 years. Often, such proposals envision that material would be returned to the country of origin at the end of the agreed period if no further agreements between the parties were reached. This would require two rounds of international transport, first from the country of origin to the host state, and then back when the storage period was completed.
- **Permanent storage or disposal.** The site for permanent transfers might be either a geologic repository or surface or near-surface storage

Center for Strategic and International Studies, January 2000); Kate O'Neill, *(Not) Getting to 'Go': Recent Experience in International Cooperation over the Management of Spent Nuclear Reactor Fuel*, BCSIA Discussion Paper 98-22 (Cambridge, MA: Kennedy School of Government, Harvard University, October 1998); Fred McGoldrick, "Proposals for an International Spent Fuel Facility: U.S. Law and Policy," presentation to the Carnegie International Nonproliferation Conference, March 16-17, 2000 (available at <http://www.ceip.org/files/events/Conf2000McGoldrick.asp?p=8>); Harold Bengelsdorf and Fred McGoldrick, "Proposals for Regional Management of Spent Fuel and High Level Waste: Their Potential for Assisting the Disposition of Excess Russian Weapons Plutonium," in *Proceedings of Global '99: Nuclear Technology- Bridging the Millenia* (La Grange Park, IL: American Nuclear Society, 1999); Frans Berkhout, *International Spent Fuel Storage*, Second Report (Sussex, UK: Science Policy Research Unit, Sussex University, December 16, 1994); Lewis A. Dunn and Stephen Carey, *Internationalizing Spent Fuel Storage: Concepts, Issues, and Options* (McLean, VA: Science Applications International Corporation, February 25, 1998); and H.P. Dyck, "Regional Spent Fuel Storage Facility," in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999. Publications on specific proposals are discussed below.

² Richard L. Garwin, for example, has long argued that nuclear waste should be managed in several competitive, commercial mined geologic repositories, open to customers from any country. See, for example, "The Post-Cold-War World and Nuclear Weapons Proliferation," presented at the 29th Japan Atomic Industrial Forum Annual Conference, Nagoya, Japan, April 19, 1996 (available at <http://www.fas.org/rlg>).

³ For discussions of the likely difficulties facing such concepts, see O'Neill, *(Not) Getting to "Go"*, op. cit., and Bengelsdorf and McGoldrick, "Proposals for Regional Management of Spent Fuel and High Level Waste," op. cit.; for a typical expression of opposition to the very concept of international sites, see L. Popova, A. Yablokov, E. Kriusanov, and David A. Kraft, "Declaration Statement of Non-Governmental Environmental Organizations On the Plan to Export-Import Spent Nuclear Fuel" (no date, available as of December 2000 at <http://www.atomsafe.ru/engl/index.html>): "We hold that countries, in which long-term radionuclides were obtained in reactors, should take full responsibility for their safe storage during the time it is necessary for full decay of all long-term radionuclides... We categorically come out against the import and export of spent nuclear fuel and radioactive waste."

⁴ The recent Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management reflects both of these differing views in a single sentence of the preamble, which states on the one hand that the parties are "convinced that radioactive waste should, as far as is compatible with the safety of the management of such material, be disposed of in the State in which it was generated," while at the same time recognizing "that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through

site designed to last until a repository becomes available (or to store material indefinitely).⁵

- **Reprocessing.** Britain, France, and Russia already accept power reactor spent fuel from other countries for reprocessing, but all three require that the products and wastes from reprocessing be returned to the customer (although Russia is considering changes in the law mandating this approach, as discussed below). An international facility might store spent fuel for a period, then reprocess it, and return only those products the customer wanted, with the host country using or disposing of the rest.
- **Fuel leasing.** Traditionally, reactor operators have bought fuel from suppliers and then had responsibility for managing it once it was irradiated. A different approach would be for a supplier to “lease” fresh fuel to reactor operators with a promise to take it back after irradiation. Assuming this take-back obligation would require having a site willing to accept the irradiated fuel. Leasing proposals differ from other international site concepts in that the spent fuel management service would apply only to leased fuel, not to older spent fuel generated before the leasing arrangement. (Of course, in principle, if one had an international site available, one could offer both leasing services and management of previously generated spent fuel.)

Who bears the liability?

A related question is who will own and bear the liability for the spent fuel or nuclear waste in question—in particular,

whether ownership and liability will remain with the reactor operator, or be transferred to the host of an international site. Typically, proposals for temporary storage leave ownership and liability with the customer that generated the spent fuel, while permanent storage or disposal concepts transfer ownership and liability to the institution managing the international site. Variations on both approaches are possible, however.

If ownership and liability is transferred, assuming liability for the spent fuel will be a fundamental part of the service offered. Indeed, once the host has taken ownership and liability for the spent fuel, some customers may be willing to let the host decide whether the fuel will ultimately be stored indefinitely, disposed, or reprocessed.

The political difficulties of gaining public acceptance in a host country for establishing a permanent international site, which takes on all the long-term liability for the spent fuel or nuclear waste from customers, are likely to be even higher than the difficulties of establishing a temporary site without liability transfer. By the same token, however, reactor operators are likely to be willing to pay higher prices for a service that would take their spent fuel or nuclear waste off their hands forever. Difficulties in working out arrangements for ownership and liability have been a key factor in many past discussions of international storage or disposal approaches.

How would the host state be chosen?

Finding a willing *and* suitable host state has long been the biggest obstacle to international spent fuel storage or nuclear waste disposal. Key criteria for a host state include:

- **Willingness.** The most fundamental requirement is that the prospective host be willing to serve in that role. In a domestic waste manage-

agreements among Contracting Parties to use facilities in one of them for the benefit of the other Parties, particularly where waste originates from joint projects.” International Atomic Energy Agency, *Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management*, INFCIRC 546 (Vienna, Austria: IAEA, Dec. 24, 1997, available at <http://www.iaea.org/worldatom/Documents/Infircs/1997/infirc546.pdf>). The second part of the sentence, apparently contradicting the first, was grafted on after then-IAEA Director-General Hans Blix publicly expressed concern that the convention should not be seen to bar international storage or disposal approaches. For a summary of Blix’s remarks and their background, see Mark Hibbs, “Examine International Repository, Blix Urges Fuel Cycle Symposium,” *Nuclear Fuel*, June 16, 1997.

⁵ For a detailed comparison of the long-term advantages and disadvantages of storing material indefinitely vs. disposing of it in geologic repositories, see Marion Hill and Martin Gunton, *A Multi-Attribute Comparison of Indefinite Storage and Geologic Disposal of Long-Lived Radioactive Wastes*, Pangea Technical Report PTR-01-02 (Baden, Switzerland: Pangea Resources International, 2001, available at <http://www.pangea.com.au/PTR-01-02.pdf>), as well as sources cited therein.

ment context, national governments may be able to impose waste management facilities on unwilling communities in some cases. But in an international context, if a national government does not want to serve as a host for such a facility, there is no international power that could impose it. Historically, very few governments have been willing even to explore the idea of hosting storage or disposal facilities for other countries' spent fuel or nuclear waste. Those that have been interested have usually (but not always) been in dire economic straits, and seen this business as a way to generate much-needed revenue—which raises the issue of the propriety of having impoverished nations bear the burden of hosting spent fuel and nuclear waste from more affluent countries.

A fundamental issue is who has the authority to commit a state to hosting such a facility. In a democracy, should elected representatives make such decisions, or should the issue require a national referendum, or a referendum in the communities and regions most affected? In Russia's case, the national government appears to support hosting an international facility, but it is not at all clear what the majority of Russians think (or what the majority of those in potential host regions think), and the government has rejected calls for a referendum. What of a non-democracy whose authoritarian leaders support hosting a site? In either case, how can the decision be made in a way that is seen as legitimate, and be made sufficiently binding that customers can plan their spent fuel or nuclear waste management policies around the continued availability of the site? These questions have never been fully

addressed because so few states have even begun discussions of hosting such a facility.

- **Geologic and geographic suitability.** A potential host state should have sites that are suitable for the service being offered and can ensure safety. A wide range of sites may be suitable for temporary spent fuel storage, but for a permanent repository designed to provide effective long-term isolation of the radionuclides from the accessible environment, the geologic characteristics of the site are crucial.⁶ Given the costs and risks of international transport of spent fuel and nuclear wastes, it would be optimal for the host state to be relatively close to potential customers, and for the site to be reasonably accessible by ship, train, or truck.⁷
- **Effective technical and regulatory infrastructure.** The host state should have the technical capacity and infrastructure to provide the relevant service, or should be willing to develop it. Ideally, the host state would have its own nuclear reactors and a domestic cadre of personnel experienced in managing spent fuel or nuclear wastes; alternatively, the relevant personnel and infrastructure might be provided by others, such as the entities proposing the facility. The host state should also have independent regulatory agencies with adequate expertise and authority to ensure the facility's safety and security, or arrangements should be made for the international community to help provide appropriate independent regulation.⁸ Finally, the host state should be a party to the various international regimes designed to promote nuclear safety, such as the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the

⁶ Debate is ongoing over what types of sites are most suitable for geologic disposal: some countries are pursuing dry, oxidizing environments, while others are studying wet, reducing environments (such as in granite rock below the water table), and still others favor salt.

⁷ Geographic proximity is by no means an iron-clad requirement, however: for example, Japan has sent spent fuel across the world to France and Britain for reprocessing for years.

⁸ An international regulatory structure might be created to oversee such facilities, as described below; if effective, such an international structure might reduce the requirements on the host state's national regulators.

Safety of Radioactive Waste Management.

- **Political stability.** Even temporary storage of spent nuclear fuel or nuclear wastes would typically be expected to last for decades, so the host state should be a country that is expected to be politically stable. Political collapse or large-scale unrest could compromise the safety and security of the storage facility. Changes of government could lead to repudiation of past agreements related to the facility, possibly including decisions to close the facility or send the material back to its original owners, or separating plutonium without prior agreement and consent. The long time-scales involved make political stability a serious concern in some potential host countries, notably Russia. It should be recalled, however, that Russia already has thousands of nuclear weapons and hundreds of tonnes of weapons-usable nuclear materials on its territory, along with thousands of nuclear weapons experts. A few thousand tonnes of spent fuel in secure dry casks would be among the least of the nuclear safety and security concerns in the event of a large-scale political collapse or unrest in Russia.
- **Strong nonproliferation credentials.** Ideally, given the proliferation sensitivity of the plutonium in spent fuel, the host state should have strong nonproliferation credentials. At a minimum, it should be a member in good standing of the relevant nonproliferation regimes (such as the Nonproliferation Treaty, the Nuclear Suppliers' Group, the Zangger Committee, and the Convention on Physical Protection of Nuclear Materials), and there should be no concern about its nuclear weapons ambitions.

To be acceptable to many potential customers and states with consent rights over fuel shipments, the host state would have to place the storage or disposal site and the materials in it under international safeguards to verify peaceful use; provide substantial transparency in the management of the facility and materials placed in it; and ensure high levels of security for the material against theft or sabotage.⁹

- **Agreement of customer states and consent-right states.** Obviously, for an international facility to be successfully established, other states must agree to send their spent fuel or nuclear waste there. Host and customer states will have to agree on contractual details relating to services provided, time frames, prices, and liability. Unless complete ownership and liability for the spent fuel is transferred, some agreement will usually be required on what will happen to the spent fuel at the end of the contract period. If particular customer states have serious political conflicts with a potential host state, it may be very difficult to reach the relevant agreements.¹⁰ In addition, some nuclear supplier states maintain "consent rights" over what will be done with spent fuel from material they supply. The United States maintains consent rights over spent fuel if it contains uranium that originated in the United States, was enriched in the United States, was fabricated in the United States, or was irradiated in a U.S.-origin reactor. Some 33,000 tonnes of spent fuel around the world (more than half of all the unprocessed spent fuel outside the former Soviet Union and Eastern Europe, which are already Russia's traditional clients, and the

⁹ Some analysts have argued that it would be best for the host state to be a nuclear-weapon-state (NWS) member of the Nonproliferation Treaty (NPT), so that it would not need to recover plutonium from the stored material for use in its own weapons arsenal. An NWS would also be a major military power able to protect the material adequately under virtually any circumstances. Others, however, have argued that the host should be a non-nuclear-weapon state (NNWS) party to the NPT, so that full-scope safeguards would be in place on all nuclear facilities in the host state. Either approach appears possible and acceptable, if appropriate arrangements are made to meet stringent nonproliferation requirements.

¹⁰ The continuing Russo-Japanese territorial dispute over the Kurile Islands, for example, may make agreement between those two states on possible Japanese use of a Russian site more difficult.

United States and Canada, which are unlikely to send their fuel to Russia) is subject to such U.S. consent rights.¹¹ The United States would have to give its approval for this fuel to be shipped to any international facility, and would not be likely to do so unless it was fully satisfied with the associated nonproliferation arrangements. The United States cannot give consent unless it has an Agreement for Cooperation under the Atomic Energy Act (which requires specific nonproliferation commitments) in place with the host country. Even for fuel over which the United States has no consent rights, a U.S. seal of approval—in the form of an Agreement for Cooperation and approval for fuel to be shipped to the site—may be crucial to establishing the political credibility of the potential host state in the minds of customers. These issues may pose less of a constraint for “fuel leasing” approaches, since such approaches could be designed to ensure that the fresh fuel provided did not include elements that brought such consent right requirements into play; to avoid the consent rights issue, however, the leases would have to be sold only to reactors that were not U.S.-origin.

- **Democracy.** Ideally, the host nation should be a democracy, which would increase the likelihood that those who would potentially be affected by a storage or disposal facility had voices in weighing the balance of risks and benefits of hosting such a facility. Many customer states may be reluctant to send their spent fuel

or nuclear waste to a facility that was imposed on some local community by authoritarian diktat, and doing so could create substantial political controversies in the customer states.

Nevertheless, if a non-democratic government offered to host a facility, some countries and reactor operators would probably be receptive. China is a frequently mentioned possibility: it has large, sparsely populated and geologically stable desert regions that could be used for such a facility, and its government has pursued other large projects (such as the Three Gorges Dam) despite significant public opposition.

One author of this report (Atsuyuki Suzuki) has developed a draft system for rating the suitability of various countries for hosting either an international storage facility or an international repository, using criteria similar to those outlined above.¹² On most counts, the United States would be perhaps the ideal host country—but politically, there is no chance that the United States will agree to serve as the host for such a facility in the foreseeable future.¹³ Russia compares well to other possible host states by some criteria, but scores poorly on political stability and technical and regulatory infrastructure.

The criteria outlined above illustrate what has been called the “host state paradox”: countries that are best suited to host a facility (i.e., advanced, stable democracies with substantial technical and regulatory infrastructures) may be among the least willing. The fundamental problem of finding a suitable and willing host state has stymied essentially all international spent fuel or nuclear waste storage or disposal initiatives to date. Whether it will be overcome in the near future remains to be seen.

¹¹ Data on fuel with U.S. obligations provided by Thomas B. Cochran of the Natural Resources Defense Council, who received it from the U.S. Department of Energy, August 2000; world stock outside of the United States, Canada, the former Soviet Union, and Eastern Europe estimated to be just under 60,000 MTHM as of early 2000, based on calculations from data provided by the IAEA. The total world stockpile of unprocessed spent fuel, including these countries, is more than twice as large, in the range of 150,000 MTHM.

¹² Atsuyuki Suzuki, “Strategic Views on Back-End of Nuclear Fuel Cycle: Flexibility and Transparency are the Key,” presentation to the Pacific Forum CSIS and Sandia National Laboratories “Workshop for Asia Nuclear Experts on Transparency in the Back End of the Fuel Cycle,” Albuquerque and Carlsbad, New Mexico, July 24-27, 2000.

¹³ Even the U.S. decision in the mid-1990s to renew its long-standing takeback policy for spent HEU research reactor fuel provoked substantial controversy and strong legal challenges, which were only overcome because the amount of material was small, it was to be taken back only for a fixed period, the material had originated in the United States, the action continued a previous already established policy, and there was a very strong nonproliferation argument for doing it. This will not be repeated.

What institutional arrangements?

Institutional arrangements will be crucial to ensure that an international facility operates safely and securely; that the spent fuel or nuclear waste will be managed appropriately over long time spans; that customers and the host fulfill their commitments; and that budgets are appropriately managed and controlled. A variety of mechanisms have been proposed, which could be pursued singly or in combination:

- **Management by a commercial firm or firms.** Several recent proposals envision a site run by one or more commercial firms, operating under the laws and regulations of the host state. The firm(s) would arrange for transporting the fuel, build and operate the site, and manage all aspects of the operation. The host state would establish a legal and regulatory framework, oversee the site, and negotiate whatever government-to-government agreements might be necessary. A variety of approaches to ownership and liability are possible; for example, the commercial firm might be liable for the fuel or waste until after it had built a repository, disposed of the materials, and closed the repository, after which remaining long-term liability might be borne by the host state. Management by a commercial firm would take advantage of the company's industrial experience and put an entity with a profit motive to overcome any obstacles in the driver's seat. By the same token, however, some analysts fear that commercial motives could crowd out legitimate safety concerns, and scientific and technical analyses could come to be unduly influenced by commercial interests. Moreover, since spent fuel or waste might be stored for centuries, arrangements would be needed in case the operating firm went bankrupt or otherwise failed to fulfill its obligations.
- **Management by the host state.** The host government could play the lead role in building and managing a facility, perhaps in partnership with private industry. This appears to be what the United States envisioned in the 1970s when it considered serving as a host state for some

nuclear fuel, and what Russia's Ministry of Atomic Energy envisions today. This approach relies more heavily on the host state's technical, managerial, and regulatory infrastructure. In some countries, a government-led approach might be more credible than a commercial approach. In Russia, however, it has raised concerns over political stability and corruption.

- **Management by a consortium of states or an international organization.** A group of states could form an organization that would build and manage a site in one of the partner states (as envisioned in some Asiatom or Pacatom proposals, for example), or some other international organization such as the IAEA could play this role. This approach would help ensure that all participants' interests are taken into account, and that international standards are applied, but at the same time it would require even more complex negotiations and agreements before a facility could be established.
- **An international framework and "rules of the road."** Some analysts argue that whatever approach is taken to constructing and operating a facility, it would be highly desirable to put in place an internationally agreed framework of safety standards, safeguards and security approaches, and transparency and monitoring requirements. Such a system could ameliorate concerns over whether countries such as the Marshall Islands had the needed regulatory capability to ensure adequate safety and security for such a facility. The international acceptance implied by such agreement might make individual states more willing to host such a facility.

What customers—regional, or international?

An international site might accept spent fuel or nuclear waste from all over the world, or from a particular region, such as East Asia or the European Union. Some analysts favor a regional facility on the grounds that it would minimize the distances over which material would have to be transported; the interests of the participating states are likely to be more closely aligned; and the participating states

may have broader interests in building cooperation among themselves.¹⁴ Many current proposals, however, are for sites that would accept material from essentially any customer willing to pay, and their proponents argue that there is no *a priori* reason to limit a site, once established, only to customers from its immediate region. The preference of the host state, should one ever be found, is likely to decide this question.

Where does the revenue go?

A wide range of analyses suggest that reactor operators would be willing to pay much higher fees to an international site for long-term storage or disposal of spent fuel than it would cost to provide those services. Profits could be split in some mutually satisfactory way between the host state and the commercial firms involved. Alternatively, a portion of the revenues could be used to accomplish specific disarmament, nonproliferation, or cleanup objectives. Such an approach could potentially raise billions of dollars in new revenue for these purposes, and might increase support for the facility in the host state if it were perceived as making a substantial contribution to the betterment of the world. If an advanced industrial democracy is ever to be host to such a facility, plausible arguments of both these kinds are likely to be necessary.

Advantages, Disadvantages, and Obstacles

Key Advantages

Achieving Economies of Scale

Intuitively, it seems clear that managing the world's spent nuclear fuel and nuclear wastes in a few large facilities would be cheaper and simpler than establishing small facilities in many countries. This is a more compelling argument for permanent disposal than for temporary storage,

however. Dry cask storage (the technology proposed for most international concepts for temporary storage concepts) offers few economies of scale: the cost per kilogram for storing fuel from a single reactor is only modestly higher than the cost per kilogram for storing fuel from dozens of reactors.¹⁵ In contrast, there is a strong economy-of-scale argument for geologic repositories. A large fraction of the estimated costs of most national repositories (including development, analysis, licensing, and providing appropriate infrastructure) is fixed, independent of the quantity of material to be disposed, or nearly so. Hence the estimated cost per kilogram for disposal of spent fuel from small nuclear programs is much higher than that for disposal from large programs such as that in the United States.¹⁶

Combining Rather than Duplicating Efforts

Building geologic repositories in every country now operating nuclear power reactors would involve large-scale duplication of efforts. International cooperation could avoid such duplication and draw on expertise from many countries, conceivably producing better repositories at less cost. A repository program is "big science," involving billions of dollars and extremely complex scientific analyses; in many other areas of big science, from fusion to high-energy physics to space, international cooperation has been found to be the key to efficient progress.

Here too, the argument is not as strong for international facilities designed only for temporary storage. Such facilities require little if any R&D, and are not very costly, so building them in each country using nuclear energy would not be an undue burden.

Providing an Option for Countries That Cannot Build Their Own Repository

It may be difficult or impossible for some countries that operate nuclear power plants to construct domestic geologic repositories cost-effectively. Some national nuclear power

¹⁴ See, for example, O'Neill, *(Not) Getting to "Go"*, op. cit.

¹⁵ There might, however, be significant cost advantages in providing facilities where fuel could be consolidated from countries with very small nuclear programs—such as nations with only research reactors and no power reactors, or nations such as Italy, where all the power reactors have been shut down.

¹⁶ See, for example, OECD Nuclear Energy Agency, *The Cost of High-Level Waste Disposal in Geologic Repositories* (Paris, France: OECD/NEA, 1993), hereinafter OECD/NEA 1993. The very large U.S. nuclear program has a correspondingly high estimated cost for a repository, but among the lowest estimated costs-per-kilogram. In the most recent DOE analysis of the costs for disposal of spent fuel and HLW at Yucca Mountain, the share of the total disposal program allocated to spent fuel is \$32.7 billion for 86,300 metric tonnes HM of spent fuel, or \$379/kgHM. See *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (Washington, DC: DOE, December 1998).

programs may be too small to justify the large fixed expense of developing geologic repositories. It simply does not make economic sense for every country that operates a single nuclear power reactor—let alone a research reactor—to have its own geologic repository.¹⁷ Similarly, some countries operating nuclear power plants may not be able to find any suitable sites for a permanent nuclear waste repository on their territory: for example, Taiwan is both tectonically active and densely populated. An international approach, in principle, would make it possible to build repositories only at sites that were geologically well-suited for the task.

Here again, the argument is less compelling for storage facilities than for disposal facilities. Virtually all countries can afford to provide temporary storage (which is not very costly) for their spent fuel and nuclear wastes, and have suitable locations for temporary above-ground storage. Research reactor fuel may be an exception, as the fixed costs of establishing a long-term storage site (while not very large in the context of a large power reactor) are quite large on the scale of typical research reactor budgets, so that some countries may have trouble affording adequate storage for research reactor fuel.

Providing an Option for Countries Facing Insuperable Political Obstacles

While providing adequate interim storage for spent fuel is neither expensive nor technically challenging, in a number of countries it has proved to be a substantial *political* challenge. And siting and building permanent repositories for nuclear wastes has proved to be an enormous political challenge wherever it has been attempted. An international site could provide an option for reactor operators that have been unable to provide sufficient spent fuel storage capacity domestically, and might otherwise be forced to shut down operating reactors for lack of spent fuel storage space. The spent fuel storage problem has been particularly troublesome in Taiwan and Eastern Europe; Japan and South Korea have also faced significant political resistance.

If the politics of storage and disposal of spent fuel and nuclear wastes is difficult within a single country, it is reasonable to ask why anyone would advocate international proposals that can be expected to be even more complicated. As John Holdren has written, “certainly a part of the difficulty with radioactive wastes in the United States up until now has been due to the diversity of levels of political organization—local, regional, state, national—that need to agree on a solution; in this situation, adding another (international) layer is not likely to help.”¹⁸ However, if one or a few countries can agree internally on hosting international storage or disposal sites, they could provide options for many countries. Political, economic and regulatory obstacles would no longer have to be addressed in every country using nuclear energy. Nevertheless, the complications introduced by involving multiple countries are likely to be substantial.

In this case, the argument in favor of an international approach is strong for both storage and disposal facilities. It is even stronger for disposal facilities, however, since they face even greater political obstacles in countries around the world.

Avoiding Unneeded Accumulation of Separated Plutonium

Whether one sees spent fuel as a waste or a potential energy resource, it does not make sense to incur the costs and risks of reprocessing long before reactor operators need or want the resulting plutonium. Yet some reactor operators have felt forced to enter into reprocessing contracts because they have no other place to send their spent fuel, even absent any near-term use for the plutonium. An international storage or disposal facility would offer an alternative destination for spent fuel, reducing the proliferation hazard associated with unneeded plutonium separation. Such an option could reduce tensions in regions such as Asia, where China has voiced concerns over Japan’s plutonium programs. This argument is equally strong for international storage or disposal facilities.

¹⁷ Managing spent fuel can be a major burden for operators of small research reactors who do not have take-back arrangements with the original supplier, particularly as the reactors shut down and move toward decommissioning. See Dyck, “Regional Spent Fuel Storage Facility,” *op. cit.*

¹⁸ John P. Holdren, “Radioactive Waste Management in the United States: Evolving Policy Prospects and Dilemmas,” *Annual Review of Energy and the Environment*, 1992.

Providing an Option to Remove Material From Countries of High Proliferation Risk

An international storage or disposal facility would also provide an option for removing fuel from countries of particularly high proliferation risk. The international community faced this problem several times in the 1990s, and each time solutions were negotiated ad hoc, often with considerable difficulty:

- After the Gulf War, Iraq's remaining HEU research reactor fuel was removed to Russia, to eliminate the possibility that Iraq would carry out its plan to use it in a nuclear weapon.
- In 1994, some 600 kilograms of HEU was airlifted from Kazakhstan to the United States, after months of secret preparations, because the Kazakh and U.S. governments agreed that it was not adequately protected from theft in Kazakhstan.¹⁹
- The 1994 U.S.-North Korean Framework Agreement calls for North Korea's spent fuel ultimately to be removed from North Korea, but specific arrangements for who will take it have not yet been announced.
- In 1998, several kilograms of HEU research reactor fuel (including both fresh and irradiated material) was removed from Georgia to the United Kingdom after agreement that it could not be adequately protected in Georgia.²⁰
- There have been extensive discussions of the possibility of removing the tens of kilograms of weapons-grade HEU research reactor fuel that still exists in Yugoslavia (at the institute where

many veterans of Yugoslavia's past secret nuclear weapons program still work, and which the Yugoslav government itself believes is not adequately secured).²¹

- In an attempt to address U.S. concerns, Russia has publicly indicated that it will take back spent fuel from the light-water reactor it is building in Iran, a country which the United States suspects of having an active nuclear weapons program²²—but Russia will not be legally able to do so unless the currently proposed amendments to its laws are fully approved.

An international storage or disposal facility could make a major contribution to nonproliferation by providing a ready place to send material from countries of high proliferation concern in such cases.

Promoting Transparency

Currently, spent fuel stored in non-nuclear-weapon state parties to the NPT is under IAEA safeguards, but the IAEA tradition is to maintain confidentiality, so none of this monitoring information is made public. Fuel in nuclear-weapon states is typically not even under IAEA safeguards. Fuel can be moved, reprocessed, or otherwise modified at will, with no requirement for discussion with or notification of other states. For fuel in an international facility with an international transparency regime, by contrast, it would be possible for any participant in the regime to maintain near-real-time knowledge of the status and location of the material. Such increased transparency in management of spent fuel and the plutonium it contains could reduce security concerns in key regions.²³

¹⁹ See William C. Potter, "Project Sapphire: U.S.-Kazakhstani Cooperation for Nonproliferation," in John M. Shields and William C. Potter, eds., *Dismantling the Cold War: U.S. and NIS Perspectives on the Nunn-Lugar Cooperative Threat Reduction Program* (Cambridge, MA: MIT Press, CSIA Studies in International Security, 1997).

²⁰ See, for example, Michael R. Gordon, "U.S. and Britain Relocate a Cache of Nuclear Fuel," *New York Times*, April 20, 1998.

²¹ See, for example, William Potter, Djuro Milanjic, and Ivo Slaus, "Tito's Nuclear Legacy," *Bulletin of the Atomic Scientists*, March-April 2000; Ann MacLachlan, "No Progress Reported in Management of 'Orphan' Russian-Origin Research Fuel," *Nuclear Fuel*, April 17, 2000; and John Diamond, "Yugoslavia's Nuclear Legacy Alarms U.S.," *Chicago Tribune*, February 29, 2000.

²² See, for example, remarks of First Deputy Minister of Atomic Energy, Seventh Annual International Nuclear Materials Policy Forum, Exchange Monitor Publications, Alexandria, VA, September 8, 2000.

²³ See discussion in Suzuki, "Strategic View on Back-End of Nuclear Fuel Cycle," op. cit. Of course, it might be possible to create an improved transparency system for spent fuel management even if the fuel remained primarily in domestic

Creating the Potential for Large Profits

From a commercial point of view, the key advantage of an international storage or disposal facility is that it might make large profits. Reactor operators who face serious problems in storing or disposing of spent fuel appear willing to pay fees ranging from \$300-\$600/kgHM for a temporary storage service, or \$1,200-\$2,000/kgHM for a permanent service that retained fuel and wastes.²⁴ Actual storage and disposal costs would be a fraction of this amount, leaving substantial room for profit. In the case of the Nonproliferation Trust concept described below, to take one example, total revenues for storage and disposal of 10,000 tonnes of spent fuel are projected at \$15 billion (\$1,500/kgHM), and total costs of providing the service are estimated at \$4 billion.

Creating a New Revenue Source for Disarmament, Nonproliferation, and Cleanup

The nuclear legacy of the Cold War in the United States and the former Soviet Union includes tens of thousands of nuclear weapons, many hundreds of tonnes of weapons materials, scores of contaminated facilities, and thousands of underemployed nuclear weapons experts. This legacy poses urgent risks to international security, which are only beginning to be addressed. The United States is spending some \$1 billion annually on “cooperative threat reduction” activities in the former Soviet Union, and other states are also contributing on a smaller scale. But there remains an urgent need for additional steps to address these nuclear legacies, and for new sources of revenue to fund them.²⁵

If the entities involved in establishing an international storage or disposal site were willing, a portion of the excess revenue from an international storage or disposal facility could be used to finance nonproliferation, disarmament, and cleanup initiatives. This is the principal purpose of the Nonproliferation Trust proposal, for example, which envisions spending 100% of the excess revenue on such efforts. Other proposals described below have also held open the possibility of providing financing for particular disarmament and nonproliferation projects, such as disposition of excess weapons plutonium.

On the other hand, a strong argument can be made that governments should not rely too heavily on such privately-financed initiatives to pay for key international security actions, before the private initiatives have even become successfully established. Some analysts argue that linking a solution to the many complexities of disposition of excess weapons plutonium, for example, to the separate complexities of establishing international sites for storage or disposal of spent fuel and nuclear wastes may make both issues more difficult to resolve than dealing with them one-on-one, rather than less.²⁶

Key Disadvantages and Obstacles

Provoking “Not in My Backyard” Politics on an International Scale

The most important obstacle to establishing international storage or disposal facilities has always been finding a host state that is both suitable and willing. Many governments

facilities—but the internationalization of actual control and decision-making authority over the material that might be incorporated in international facilities could itself be an important contribution to confidence-building. For an account of the transparency system developed for the U.S. Waste Isolation Pilot Plant (WIPP), the world’s only operating geologic repository for nuclear materials, see “Nuclear Transparency at the Waste Isolation Pilot Plant,” Sandia National Laboratories, http://www.cmc.sandia.gov/Nuc_Trans/wipp/wipp_a.htm.

²⁴ These are the figures estimated in First Deputy Minister of Atomic Energy Valentin B. Ivanov, *Technical-Economic Basis for the Law of the Russian Federation: “On the Proposed Amendment to Article 50 of the Law of the RSFSR ‘On Environmental Protection’”* (Moscow, Russia: Ministry of Atomic Energy, 1999, leaked and translated by Greenpeace International). Private discussions with other market participants suggest similar estimates.

²⁵ For summaries of this situation, see Matthew Bunn, *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Washington, DC: Harvard Managing the Atom Project and Carnegie Endowment for International Peace, April 2000), available at <http://ksgnotes1.harvard.edu/BCSIA/Library.nsf/pubs/Nextwave>; and Sam Nunn (chair) *Managing the Global Nuclear Materials Threat: Policy Recommendations* (Washington, D.C.: Center for Strategic & International Studies, 2000), Executive Summary available at <http://ksgnotes1.harvard.edu/BCSIA/Library.nsf/pubs/nuclearthreat>.

²⁶ For example, Bengelsdorf and McGoldrick, “Proposals for Regional Management of Spent Fuel and High Level Waste,” *op. cit.*, suggests that this may be the case, without necessarily concluding that it is.

and populations are fiercely opposed to any suggestion that they serve as “world’s nuclear dumping ground.” Indeed, a number of countries have outlawed the import of nuclear wastes: Britain, France, and Russia, for example, require that wastes generated by their commercial reprocessing services must be returned to foreign customers.²⁷ The level of “not in my backyard” (NIMBY) opposition to nuclear waste facilities in many countries is difficult to overstate. Moreover, past experience with siting hazardous waste facilities suggests that communities are more often willing to accept a site for waste from their own region of a country than waste from other regions or other countries.²⁸ The politics of hosting a site for other countries’ spent fuel and nuclear wastes are particularly problematic given that transport of spent fuel and nuclear wastes is often a troublesome political flashpoint. This fundamental problem remains a major obstacle to international storage or disposal, and effectively rules out some potential host states (including the United States).

Raising Ethical and Fairness Issues

Some analysts argue that each country which has enjoyed the benefits of activities that generated spent fuel or nuclear wastes should bear the burden of storing and disposing of those wastes. They argue that it is unethical and unfair to transfer that burden to another country, even if the host country is compensated for providing that service.²⁹ In many countries, there is a strong presumption that nuclear wastes should be managed in the country that generated them. Germany, Sweden, and Canada, for example, all have laws banning permanent shipments of their nuclear wastes abroad.³⁰

Others argue that while ethical and fairness issues must be addressed with care, it is possible to establish

appropriate arrangements for international storage or disposal of nuclear materials. The IAEA’s *Safety Fundamentals* series outlines some useful general principles:

- Human health and the environment must be protected;
- Future generations must not be unduly burdened;
- Third party countries, which are not participants either as hosts or customers in the international arrangement, must not be unduly burdened;
- There must be equity or balance among the participating countries.³¹

The objective of protecting human health and the environment applies equally to national and international facilities. The objective of avoiding undue burdens on future generations is an important issue for international facilities, and has raised substantial controversy with respect to some current proposals.³² Such facilities would involve decisions by the current generation in the host state to accept burdens that will affect future generations there. For such a decision to be equitable in an inter-generational sense, the additional burdens on future generations must be minimized, and balanced by benefits that future generations will also receive.³³ Impacts on third-party countries that may be affected by spent fuel transportation or trans-boundary radiation risks have also sparked substantial controversy.

The issue of balance among the participating countries is perhaps the most complex. Many would argue that if a country agrees to participate under the terms negotiated, it views those terms as fair and equitable. However, if negotiations take place among countries that are not equally powerful, wealthy, or politically and technically sophisti-

²⁷ Russia is considering eliminating this requirement, as described below.

²⁸ See discussion in O’Neill, *(Not) Getting to “Go”*, op. cit., p. 44.

²⁹ See Yablokov, Kriusanov, and Kraft, “Declaration Statement of Non-Governmental Environmental Organizations,” op. cit.

³⁰ See O’Neill, *(Not) Getting to “Go”*, op. cit., p. 26.

³¹ See discussion in Dyck, “Regional Spent Fuel Storage Facility,” op. cit.

³² For example, the Bellona Foundation headlined its account of the Russian Duma’s decision to give preliminary approval to legislation permitting Russia to serve as a host state “Duma Sells Out Next 200,000 Years.” See Igor Kudrik, “Russia’s Last Big Sale Was Alaska: Duma Sells Out Next 200,000 Years,” *Bellona*, December 21, 2000.

³³ Of course, decisions are made in every country every day which will have impacts on future generations. Ideally similar considerations of inter-generational equity should be applied to all of these.

cated, some parties may not be fully able to protect their interests. Moreover, if disadvantaged countries with few other economic options are most likely to consider hosting such facilities, an international approach could impose much of the burden of storing or disposing of nuclear wastes (which are predominantly generated in advanced developed countries) on less developed countries. Similar environmental justice concerns underlie the Basel Convention's prohibition on dumping of hazardous chemical wastes from Northern countries in Southern states.³⁴ On the other hand, some critics argue that it is paternalistic to prevent disadvantaged states or communities from hosting waste facilities if they freely choose to do so. This issue is discussed in more detail in Chapter 5.

Ultimately, legitimate differences of opinion can be expected about the ethics and fairness of any particular proposal for management of spent fuel and nuclear waste, and concepts will have to be judged on the merits of the specific arrangements proposed.

Distracting Attention, Support, and Funding From National Programs

Another frequent objection to international site concepts is that the possibility of shipping spent fuel or nuclear wastes abroad will only distract attention from national spent fuel and waste management programs, undermining public willingness to accept and pay for national facilities.³⁵ This is potentially a serious concern in some countries. It would be unfortunate if national projects were derailed or greatly delayed because of hopes for an international facility that then never came to fruition. For this reason, international concepts should be pursued and discussed with considerable care, and reliance should not be placed on them until they actually open for business, if they ever do.

Further Complicating the Politics of Nuclear Waste Management

Shifting nuclear waste and spent fuel management from the domestic to the international level could make these diffi-

cult policy challenges even more complicated if negotiations over nuclear waste management are sidetracked by political disagreements between key countries over extraneous issues.³⁶ Conversely, however, the political complexities of establishing an international facility only have to be addressed once, or a few times, to provide the benefits described above, while in the absence of an international facility or facilities, the domestic political complexities have to be successfully addressed in every country that operates nuclear reactors.

While international facilities could promote cooperation between participating countries, they could also have the opposite effect. Over the long time-scales involved in building and operating an international storage or disposal facility, disagreements among the parties can be expected, and these issues may cause or add to friction between host and customer states. Recent disagreements between Germany and France over Germany's take-back of vitrified HLW from French reprocessing of German fuel are an example.³⁷ As discussed above, participants in international arrangements will have to agree on complex issues including liability, funding assurances, and dispute resolution procedures, and on whether spent fuel will ultimately be stored, disposed of, or reprocessed. Given the wide range of national policies toward the back end of the nuclear fuel cycle, these agreements may be difficult to reach.

Increasing Transportation Requirements

Any international storage or disposal facility will involve large-scale transportation of spent fuel or nuclear wastes from other countries and will require the relevant infrastructure, such as ships, ports, rail lines, roadways, and regulatory bodies. In the case of temporary storage, arrangements will have to be made for ultimately transporting the material back to the customer state. These activities will inevitably involve some costs, risks, and management complexities. Recent cases, such as shipments of spent fuel, plutonium, and high-level wastes between Japan and European reprocessing plants, have also generated major political controversies.

³⁴ See discussion in O'Neill, (*Not*) *Getting to "Go"*, op. cit., p. 41.

³⁵ See, for example, Ann MacLachlan, "Swedes Panic as Taboo Drops From Multinational Repositories," *Nuclear Fuel*, October 18, 1999.

³⁶ For example, as discussed below, proposals for sending spent fuel and waste to Russia are currently blocked by the dispute between Washington and Moscow over Russian nuclear cooperation with Iran.

³⁷ See, for example, Ann MacLachlan, "France Again Warns Fischer It Wants HLW Sent to Germany," *Nuclear Fuel*, September 18, 2000.

Past and Current Proposals

Concepts for some form of international management of all or part of the nuclear fuel cycle stretch back to the Baruch Plan in 1946. Many proposals for international sites to process, store, or dispose of spent fuel or nuclear waste have been debated; indeed, the current intense sensitivity toward accepting another country's nuclear wastes appears to be a phenomenon that has developed, or at least intensified, since nuclear power became more politically controversial in the 1970s. In the 1950s and 1960s, the United States routinely contracted to supply fuel to research reactors around the world and took back spent fuel; the Soviet Union routinely took back spent fuel from power reactors in client states, with no provision for returning wastes, uranium or plutonium after reprocessing; early French and British reprocessing contracts did not include returning wastes to the customer; and Belgium agreed to host the Eurochemic multinational reprocessing demonstration facility, which both reprocessed fuel from other countries without return of wastes (which are ultimately to be disposed of in a Belgian repository) and offered contracts for storage of spent fuel from other countries (the only example known to the authors of such a commercial international storage facility actually being operational and offering contracts).³⁸

Interest in regional or international spent fuel or nuclear waste storage or disposal facilities grew significantly in the 1970s and early 1980s, spurred by international discussions over the future of nuclear energy and proliferation dangers of the nuclear fuel cycle (which in turn were prompted by India's 1974 nuclear test and the U.S. decision not to reprocess in 1976-1977). Secretary of State Henry Kissinger proposed regional fuel cycle centers in the mid-1970s, as an alternative to purely nationally controlled reprocessing and enrichment facilities that then seemed on

the verge of proliferating to a large number of countries. This led to an IAEA-led examination of such regional centers, which reported in 1977 that such centers were feasible and would offer considerable nonproliferation and economic advantages. The International Nuclear Fuel Cycle Evaluation (INFCE) considered these issues, and was followed by the establishment of IAEA expert groups on international plutonium storage and international spent fuel management, both of which issued their reports in 1982. During the same period, the United States considered offering to take back Japan's spent fuel as an alternative to Japanese pursuit of reprocessing. Washington and Tokyo jointly carried out a study which examined the possibility of creating a storage site on Palmyra Atoll, a remote U.S.-owned island in the Pacific.³⁹

By the 1980s, however, after the Three Mile Island accident reinforced concerns over nuclear safety, no state was willing to host a facility. The Pacific Basin idea was doomed by domestic U.S. opposition, resistance from Pacific nations, and Japan's commitment to reprocessing. Interest in international spent fuel or nuclear waste storage and disposal concepts abated until the 1990s, when a range of different proposals were raised.

The International Monitored Retrievable Storage System (IMRSS)

Developed in the mid-1990s by Wolf Häfele (a long-time leader of Germany's nuclear program) and Chauncey Starr (former President of the Electric Power Research Institute in the United States), the International Monitored Retrievable Storage System (IMRSS) envisioned international sites where spent fuel, and possibly also excess separated plutonium, could be stored under monitoring for an extended period but could be retrieved at any time for peaceful use or disposal.⁴⁰ The sites would be managed by an international consortium of states, but operated on a commercial basis as

³⁸ See Berkhout, *International Spent Fuel Storage*, op. cit.

³⁹ Ibid, and Bengelsdorf and McGoldrick, "Proposals for Regional Management of Spent Fuel and High Level Waste," op. cit.

⁴⁰ For a description, see, for example, Wolf Häfele, "The Concept of an Internationally Monitored Retrievable Storage System," presented at the Uranium Institute Symposium, London, August 1996; see also Chauncey Starr and Wolf Häfele, "Internationally Monitored Retrievable Storage Systems: A Step Toward World Peace in the Nuclear Age," presented at the "East Asia Seminar," sponsored by Lawrence Livermore National Laboratory, Las Vegas, NV, March 7-9, 2000. A similar concept has been put forward by Luther J. Carter and Thomas H. Pigford, who suggest (unrealistically, from a political point of view) that the United States agree to host the first such facility. See "The World's Growing Inventory of Civil Spent Fuel," *Arms Control Today*, January/February 1999, pp. 8-14.

profit-making enterprises. The concept aimed to develop an international regime under which multiple facilities would be governed by a single board and would be subject to common standards for safety, monitoring, and security.⁴¹ Host states were to be sought after the regime was established, on the assumption that nations would be more likely to participate if a broadly accepted framework was already in place. A series of international conferences fleshed out the broad outlines of the regime, but the concept did not proceed to actual negotiations.

In recent years, the IAEA has sponsored exchanges of views on international approaches to storage or disposal of spent fuel or nuclear wastes, and may be a forum for developing rules for an IMRSS-like regime, although the IAEA has not taken a position supporting or opposing such international approaches.⁴²

A Marshall Islands Site

In 1994, the first President of the newly independent Republic of the Marshall Islands, Amata Kabua, suggested that the Marshall Islands might host an international repository for spent fuel and nuclear waste. In addition to porous coral, parts of the islands have basaltic rock which has been geologically stable for tens of millions of years, where the disposal facility would be based. Revenues from the facility were to be used to clean up the islands contaminated by nuclear testing in the 1950s, and to boost the

economy of the Marshall Islands, which is heavily dependent on U.S. aid, so that the net effect, it was hoped, would be both an environmental and an economic benefit.⁴³ The proposal provoked considerable controversy within the Marshall Islands, and strong opposition from other Pacific nations and the United States. While negotiating with U.S. firms for a feasibility study to be carried out, President Kabua promised that no facility would be established without a national referendum on whether to go forward.

Kabua died in December, 1996, and was replaced by Imata Kabua (a cousin), who also supported the project, and negotiated a secret agreement with the U.S. firm Babcock and Wilcox Environmental Services in early 1997 to carry out a feasibility study of a nuclear waste repository on the islands.⁴⁴ In June, in the face of mounting opposition, including formal opposition from the U.S. government, President Kabua announced a “freeze” on the effort.⁴⁵ In April 1998, however, it was announced that the Cabinet had approved a new feasibility study by the U.S. firm Enviro-Care Services.⁴⁶ Kabua’s party was defeated in elections in late 1999, and the parliament unanimously elected an opponent of the project as President.⁴⁷

U.S. Fuel and Security

Concurrently with the Marshall Islands proposal, a U.S.-based entrepreneurial group called U.S. Fuel and Security sought to establish a repository on another Pacific island,

⁴¹ This distinction between “regime-based” and “site-based” proposals is described in O’Neill, *(Not) Getting to “Go”*, op. cit.

⁴² Differences exist among IAEA member states: some, including Finland, Sweden, and France, oppose such international concepts. For an IAEA summary of international concepts, see Dyck, “Regional Spent Fuel Storage Facility,” op. cit.; for a summary of the difficult situation in which the IAEA finds itself on this topic, see H.P. Dyck and Arnold Bonne, “International Storage and Disposal Facilities—Considerations in the IAEA Context,” presented at the “East Asia Seminar,” sponsored by Lawrence Livermore National Laboratory, Las Vegas, NV, March 7-9, 2000.

⁴³ See, for example, Ann MacLachlan, “Marshall Islands Confirm Offer to Host Waste Repository,” *Nucleonics Week*, April 20, 1995, and Berkhout, *International Spent Fuel Storage*, op. cit. A useful short summary of the history of this project, with links to some relevant news stories, can be found in Aenet Rowa, “This Week in Marshall Islands History: July 16-July 22: Nuclear Waste Storage Was the ‘Hot’ Topic,” *Yokwe Online*, available at <http://www.yokwe.net/history/history0716.html>.

⁴⁴ See, for example, the criticism of this agreement by Senator Ataji Balos, chairman of the foreign affairs and trade committee of the Marshall Islands’ parliament, June 13, 1997, carried in *Pacific Islands Report* (available at <http://pidp.ewc.hawaii.edu/pireport/text.htm>).

⁴⁵ “Marshall Islands President ‘Freezes’ Nuclear Waste Site Study,” *Pacific Islands Report*, June 23, 1997 (available at <http://pidp.ewc.hawaii.edu/pireport/text.htm>).

⁴⁶ Rowa, “This Week in Marshall Islands History,” op. cit.

⁴⁷ David Strauss, “Kessai H. Note Elected President of the Marshall Islands,” *Pacific Islands Report*, January 3, 2000 (available at <http://pidp.ewc.hawaii.edu/pireport/text.htm>).

Palmyra Atoll, an uninhabited U.S.-owned island a few hundred kilometers from Hawaii that had been the focus of the U.S.-Japanese Pacific Basin study in the 1970s. U.S. Fuel and Security proposed to lease fresh fuel to reactor operators and dispose of it on Palmyra after the fuel was irradiated. By offering a complete bundled fuel cycle service, the group hoped to capture a substantial fraction of the world nuclear fuel market. As an additional selling point, the group proposed to store or dispose of excess weapons plutonium at the island facility as well, and envisioned bringing Russia's Ministry of Atomic Energy in as a partner and supplier of uranium and enrichment services. Advocates argued that the proposal would undercut commercial reprocessing, reducing its attendant proliferation risks; provide a cost-effective option for securing or disposing of excess weapons plutonium stockpiles; provide substantial revenues to Russia that could be used to improve security for nuclear materials; and offer Russia a commercial incentive to abandon its nuclear cooperation with Iran.⁴⁸

The concept was supported by Russia's Ministry of Atomic Energy, but was strongly opposed by the Clinton Administration, which did not wish to see such a facility established on U.S. territory and objected to legislation sought by U.S. Fuel and Security that would have short-circuited review provisions of the National Environmental Policy Act.⁴⁹ After some years of effort—including a switch from Palmyra to Wake Island as the proposed site—its supporters ultimately abandoned the idea in favor of the Non-proliferation Trust proposal, based on a Russian site, described below.

A South African-led Group

During the mid-1990s, with little fanfare, the South African Atomic Energy Corporation assembled a group of nuclear-related companies from around the world to flesh out concepts for an international storage and disposal system for both spent fuel and nuclear wastes. This grew out of an IAEA-led discussion in the early 1990s that focused on the possible need for regional repositories to handle wastes from countries with very small nuclear programs, with a specific focus on a Southern African facility.⁵⁰ Participants included firms from South Africa, Germany, Australia, China, and Switzerland. The group outlined a complete back-end service, including storage and permanent disposal, with full ownership and liability for the material transferred to the host state when the material was shipped there. The participants produced an extensive report outlining their concept,⁵¹ and when the approach was revealed in a speech at a 1997 international IAEA symposium on the future of the nuclear fuel cycle, it was widely rumored that South Africa would announce its willingness to serve as the host for the facility. But South Africa has not announced any such policy to date, and there has been relatively little public activity associated with this concept in recent years.

An East Asian Regional Site

Since the mid-1990s, increasing difficulties in storing spent nuclear fuel in Taiwan, South Korea and Japan have spurred discussions of some form of regional facility for managing spent fuel and nuclear waste in East Asia.⁵² One author of this report (Atsuyuki Suzuki) was among the first to propose

⁴⁸ For a summary of the proposal, see Wilson Dizard III, "New Entrant Has Sweeping Plans For Shipping, Fuel and Cask Leasing," *Nuclear Fuel*, November 6, 1995, and Kathleen Hart, "International Proposal for Commercial Spent Fuel Site Gets Mixed Review," *Nuclear Fuel*, March 10, 1997. For a skeptical account of the project and its backers, see Ken Silverstein, "Nuclear Burial in the Pacific: Plans for Nuclear Waste Dump on a Pacific Island," *The Progressive*, November 1997.

⁴⁹ Dave Airozo, "White House Advisors Shoot Down Proposal for Palmyra Waste Dump," *Nuclear Fuel*, September 23, 1996.

⁵⁰ Discussed in Berkhout, *International Spent Fuel Storage*, op. cit.

⁵¹ *A Concept for an International High-Level Waste Management System* (compiled by an international working group of representatives of nuclear companies, unpublished, September 1996); this report is summarized in P.J. Bredell and H.D. Fuchs, "International Cooperation With Regard to Regional Repositories for Radioactive Waste Disposal," in *Nuclear Fuel Cycle and Reactor Strategies: Adjusting to New Realities: Contributed Papers*, IAEA-TECDOC-990 (Vienna, Austria: International Atomic Energy Agency, December 1997); and P.J. Bredell, "Closing the Gap Between Spent Fuel Storage and Final Disposal in a Multinational Management System," in *Storage of Spent Fuel from Power Reactors*, IAEA-TECDOC-1089, July 1999.

⁵² There are many different specific versions of such concepts; see, for example, Jor-Shan Choi, *A Regional Compact Approach for the Peaceful Use of Nuclear Energy; Case Study: East Asia* (Stanford, CA: Center for International Security and Arms Control, Stanford University, 1997), and Pacific Basin Nuclear Council Steering Group on HLW/SF Management, "The International Interim Storage Scheme (IISS) of High Level Radioactive Waste and Spent Fuel" (unpublished draft, spring 2000). See also Margaret L. Ryan, "Pacific Nations Try, Can't Agree on Start to Off-Shore HLW Storage," *Nuclear Fuel*, May 18, 1998.

“an Asian equivalent of Euratom,” including both an “East Asian Collaboration for Intermediate Storage” of spent fuel, and an “East Asian Collaboration for Underground Research” on geologic disposal.⁵³ Most discussions of such concepts have been unofficial, as the governments of these states have sought to avoid undermining their domestic nuclear spent fuel and waste management programs—or being perceived as seeking to impose their wastes on others—by officially endorsing such international concepts. Fora for these discussions have included the unofficial Council for Security Cooperation in the Asia-Pacific (CSCAP) and the Pacific Nuclear Council (PNC), among others.

Substantial interest exists in Asia in exploring concepts for regional nuclear cooperation—sometimes referred to as “Asiatom” or “Pacatom”—but given the long-standing rivalries and distrust in the region, many analysts believe that such an organization should begin with smaller-scale, less controversial steps than a regional spent fuel or nuclear waste facility.⁵⁴ To date, no state in the region has offered to host such a regional facility, and it appears unlikely that South Korea, Japan, or Taiwan will do so. North Korea’s agreement with Taiwan in 1997 to accept low-level nuclear waste⁵⁵ provoked a storm of opposition and had to be abandoned; moreover, it is almost inconceivable that a North Korean site would be acceptable as long as its government remotely resembles the current one.

China, with its large, remote, and geologically stable deserts, is an obvious possibility as a host for such a facility. While it has not publicly participated very actively in recent discussions, in the past China was among the few states that formally agreed to accept spent fuel from another country

for storage. In 1987, China and Germany signed a nuclear cooperation agreement that called, among other things, for storage of a limited quantity of German spent fuel in China—a provision that was never implemented, reportedly because of political opposition from outside China.⁵⁶ China has publicly offered to accept low-level waste from Taiwan, under certain conditions, and in private discussions, Chinese officials have indicated that they consider Taiwan’s spent fuel to be Chinese, and would be prepared to take over its management in the context of broader understandings between the island and the mainland, but Taiwanese officials report that China has never formally offered to accept Taiwan’s spent fuel.⁵⁷ A number of independent foreign analysts, in response to frequently expressed Chinese concerns over the possible military implications of Japan’s civilian plutonium programs, have suggested that China offer to host a facility that could store or dispose of Japan’s spent fuel, on a commercial basis, which could provide Japanese utilities with an alternative to near-term reprocessing.⁵⁸ China could generate much-needed revenues and address some of its security concerns with such an approach. But to date, there is no evidence that China is seriously considering offering to host such a facility.

Pangea

In 1998 a plan by a commercial consortium called Pangea for an international geologic repository for both spent fuel and nuclear wastes was leaked to the news media.⁵⁹ Pangea’s initial investors were British Nuclear Fuels, Limited (BNFL); Enterra Holdings (parent firm of Golder Associ-

⁵³ Atsuyuki Suzuki, “A Proposal on International Collaboration with Nuclear Power Development in East Asia” (paper presented at the Energy Workshop of Northeast Asia Cooperation Dialogue V, Institute of Foreign Affairs and National Security [IFANS], Seoul, 11–12 September 1996).

⁵⁴ See, for example, Robert A. Manning, “PACATOM: Nuclear Cooperation in Asia,” *Washington Quarterly*, Spring 1997.

⁵⁵ Sheryl WuDunn, “North Korea Agrees to Take Taiwan Atom Waste for Cash,” *New York Times*, February 7, 1997.

⁵⁶ Berkhout, *International Spent Fuel Storage*, op. cit.

⁵⁷ Mark Hibbs, “China One of Several Options to Dispose of Taipower Waste,” *Nucleonics Week*, March 16, 2000, and Mark Hibbs, “Taiwan Planning on Dry Storage For Its Spent Fuel Inventory,” *Nuclear Fuel*, November 1, 1999, supplemented with interviews.

⁵⁸ Interviews.

⁵⁹ The Pangea proposal is described in Charles McCombie and Ralph Stoll, “The Pangea Proposal for International or Regional Disposal Facilities,” presented at the “East Asia Seminar,” sponsored by Lawrence Livermore National Laboratory, Las Vegas, NV, March 7–9, 2000, and on their website, <http://www.pangea.com.au>. For a news account based on the information available immediately after news of the project leaked to the public, see Elaine Hiruo, Anne MacLachlan, and Mark Hibbs, “U.S. Company Looks to Australia As Potential Site for Global Repository,” *Nuclear Fuel*, December 14, 1998.

ates, an international waste-management consulting firm based in Canada); and Nagra, a Swiss nuclear waste management firm. Pangea argues that nuclear waste should be disposed of in areas that are geologically and hydrologically simple, and that if the “best” geologic sites are chosen, a repository can be developed which is much safer and much cheaper than the national repositories currently planned. By offering an option for disposal of excess materials from dismantled weapons, Pangea argues that it would also offer important disarmament and nonproliferation advantages; proponents of the concept have also suggested that some of the revenue from such an approach might be directed to support nonproliferation and disarmament projects.⁶⁰

As an initial design figure, Pangea envisions a facility for disposing of 75,000 metric tonnes heavy metal (MTHM) of spent fuel (or high-level waste equivalent). The capital cost of the repository and associated facilities and transport ships is estimated at \$6 billion, with an annual operations cost of \$500 million over 40 years of operation, for a total undiscounted cost of \$26 billion. If the price for the service that the market would bear were \$1000 per kilogram of heavy metal (kgHM), comparable to the price of reprocessing but without having to deal with taking back plutonium or high-level wastes, total revenue would be \$75 billion.⁶¹

Pangea initially selected Western Australia as the best site for its proposed repository. After news of the project leaked, however, it encountered substantial political opposition in Australia. Pangea continues to conduct scientific studies related to the Australian site, but is now examining other sites around the world, and is headquartered in Switzerland.⁶² It emphasizes that it is only exploring the

feasibility of the international repository concept, and that much more study and public discussion would be required before moving forward with any particular site.

Russian Site I: The Nonproliferation Trust

A variety of current proposals involve sites in Russia—both because Russia’s government appears interested in hosting such a site, and because such a site might help raise revenue for urgently needed disarmament, nonproliferation, and cleanup initiatives. One concept, the Nonproliferation Trust (NPT), calls for establishing a dry cask storage facility in Russia that would accept 10,000 tonnes of spent fuel from other countries on a commercial basis. At a projected price of \$1,500/kgHM (based on proponents’ assessment of utilities’ willingness to pay), this would raise \$15 billion in revenue. Project advocates estimate total costs for transportation, storage, and eventual disposal of the spent fuel in the range of \$4 billion (\$400/kgHM), leaving \$11 billion in excess revenue, which they would allocate almost entirely to disarmament, nonproliferation, and cleanup initiatives in Russia.⁶³

Under its plan, the U.S.-based Trust would control construction and operations, and entities linked to the Trust would control the funds, with virtually none of the revenues going to the Russian government or Ministry of Atomic Energy (MINATOM) to spend on their own favored projects. In the Trust’s proposed contract, reprocessing of spent fuel would be banned, and Russia would be prohibited from entering into new contracts for foreign reprocessing (which would compete for the same spent fuel the Trust sought to store.)

In addition to promoting security goals such as disposition of excess plutonium, NPT advocates assert that the

⁶⁰ McCombie and Stoll, “The Pangea Proposal,” *op. cit.*, refers to such facilities providing “a commercial source of financing to address non-proliferation goals which are currently difficult for governments to fund.”

⁶¹ Because of the time cost of money, one cannot simply subtract these undiscounted revenue and cost figures, but nonetheless it seems clear that if these estimates are accurate, such a facility would generate substantial sums for some combination of benefits to the host nation and community, profit to the firms involved, and expenditures on other activities.

⁶² Ann MacLachlan, “Spurned in Australia, Pangea Looks Elsewhere for Potential Disposal Sites,” *Nuclear Fuel*, January 24, 2000.

⁶³ The Nonproliferation Trust proposal is described in Joseph Egan, *The Nonproliferation Trust Project: Frequently Asked Questions* (Washington, DC: Nonproliferation Trust, 2000), and on their website, <http://www.nptinternational.com>. For an analysis supporting the NPT approach from analysts independent of the project, see Matthew Bunn, Neil J. Numark, and Tatsujiro Suzuki, “To Preserve, and Not to Reprocess,” *Nezavisimaya Gazeta- Nauka*, July 19, 2000 (available in the original English version at <http://ksgnotes1.harvard.edu/BCSIA/Library.nsf/pubs/MB-preserve>).

Trust would provide net environmental benefits, because the project would generate revenues for environmental cleanup that would far outweigh any hazards posed by 10,000 tonnes of spent fuel in dry casks. Project advocates have endeavored to convince Russian officials that NPT is the only approach likely to win U.S. government approval, since such approval would require a commitment not to reprocess the fuel, and would likely also require that the proposal have substantial disarmament and nonproliferation benefits. NPT's officers and board include a number of senior Reagan-era U.S. government officials, including William Webster (former Director of both the CIA and the FBI), Admiral Daniel Murphy (former commander of the Pacific Fleet and chief of staff to then-Vice President George Bush), and William van Raab, former director of the U.S. Customs Service. Thomas B. Cochran of the Natural Resources Defense Council (NRDC), a U.S.-based environmental group, has also played a key role in shaping and promoting the project.

Despite the substantial constraints embodied in NPT's proposal, MINATOM has expressed support for continued exploration of the idea, and in 2000 Russian Deputy Prime Minister Ilya Klebanov strongly supported the concept.⁶⁴ However, Russian officials also continue to pursue other concepts inconsistent with the NPT approach, as described below, and it is uncertain which approach Russia may ultimately support.

The U.S. government has not yet taken a firm public position on NPT or other Russia-based international storage and disposal approaches. A number of U.S. officials have privately expressed support for approaches such as NPT's that could provide new revenues to finance disarmament and nonproliferation projects, while expressing concern over relying too heavily on the success of such a private entity for projects that are critical to U.S. security objectives.⁶⁵ However, the U.S. government is unlikely to approve

any Agreement for Cooperation with Russia (a prerequisite for approving shipment of U.S.-obligated spent fuel to Russia) without a settlement of the U.S.-Russian dispute over Russia's continued nuclear cooperation with Iran, as described below. A very large fraction of the potential market for a Russian site is U.S.-obligated spent fuel—including nearly all the fuel in countries such as Taiwan, South Korea, and Japan—so it is unlikely that the NPT concept or other Russian site proposals will succeed without U.S. agreement, and therefore without a deal on Iran.

Russian environmentalists fervently oppose the NPT proposal and other proposals for international spent fuel management in Russia, as do some major international environmental groups (such as the Bellona Foundation and Greenpeace), and many U.S. environmental groups. They argue that it will be impossible for NPT to keep MINATOM from spending revenues on its favored projects, including new reactors and reprocessing facilities; that MINATOM will inevitably reprocess the fuel, increasing rather than decreasing nuclear contamination and security hazards in Russia; and that endemic corruption in Russia makes it virtually inevitable that a substantial fraction of the money will be bled off into shady projects. After decades of Soviet-era contamination and lies, many environmentalists are so distrustful of MINATOM that they understandably do not see any plausible means to cooperate with it toward common goals.⁶⁶

Russian Site II: MINATOM's Reprocessing Plans

MINATOM's own concept for an international spent fuel service involves offering two different services: temporary storage with later return of the spent fuel for the minority of customers who would prefer that, or reprocessing without return of plutonium or wastes for most customers. MINATOM envisions importing 20,000 tonnes of spent fuel over 10 years, generating \$21 billion in total revenue (at

⁶⁴ Ilya Klebanov, letter to Daniel Murphy, July 15, 2000. Klebanov indicates that it "would be expedient for us to use all possible means to further develop the NPT project," and expresses his "hope that the NPT project, organized by prominent U.S. public figures, will find support in contemporary Russia."

⁶⁵ Interviews with State Department, Department of Energy, and National Security Council officials.

⁶⁶ See, for example, the official Bellona statement on NPT, Thomas Jandl, "The Transfer of Spent Nuclear Fuel to the Russian Federation for Intermediate Storage: Implications for Environmental Security, U.S. Non-Proliferation Policy, Human and Environmental Health in Russia," *Bellona*, August 1999 (available at <http://www.bellona.no/imaker?sub=1&id=8668>) which argues that it is inevitable that money will be bled off to corruption, that MINATOM will ultimately reprocess the material, that safety will be mishandled, and that more wastes will be created as a result.

an estimated temporary storage price of \$300-\$600/kgHM, and an estimated price for reprocessing without return of wastes and plutonium of \$1,200-\$2,000/kgHM).⁶⁷ MINATOM projects actual costs of providing the services at roughly \$10.5 billion. Another \$3.3 billion would go to national and regional taxes and other payments to governments, leaving \$7.2 billion available for addressing “social-economic and ecological problems.”⁶⁸ Table 4.1 compares expected revenues and allocations for the NPT proposal and MINATOM’s study.

Russian Minister of Atomic Energy Evgeniy Adamov has acknowledged that traditional reprocessing approaches

pose a proliferation hazard and should be phased out,⁷¹ and has entered into negotiations with the United States over the idea of a 20-year moratorium on such plutonium separation. But MINATOM hopes to develop new, proliferation-resistant reprocessing technologies and then build new reprocessing plants to implement them using revenues generated by importing spent fuel, beginning in 2020 or later. Retaining plutonium and wastes would make the service much more attractive than that offered by Britain and France, which requires customers to take back these products. MINATOM believes that there would be a huge market for a service that took all liability for spent fuel and all of

Table 4.1 Proposed Revenue Allocations: MINATOM and NPT Approaches⁶⁹

	MINATOM study (billions of U.S. dollars)	NPT (billions of U.S. dollars)
Total projected revenue	\$21 (20,000 MTHM)	\$15 (10,000 MTHM)
Storage and transport costs	\$1.1	\$3.4
Disposal and decom. costs	\$0	\$2.3
Reprocessing costs	\$6.8	\$0
Taxes	\$3.3	\$0
Environmental cleanup	\$7.2 ⁷⁰	\$3
Securing nuclear material	\$0	\$1.5
Jobs for weapons workers	\$0	\$2
Regional economic support	\$0	\$0.5
Pensioners and orphans	\$0	\$2.2
R&D	\$2.6	\$0

⁶⁷ Ivanov, *Technical-Economic Basis for the Law*, op. cit.

⁶⁸ Ibid.

⁶⁹ Adapted from *ibid.*, and data on the Nonproliferation Trust web page (<http://www.nptinternational.com/Allocation.htm>).

⁷⁰ The MINATOM study described \$7 billion as being available for “social-economic and ecological problems,” which could include a variety of other spending including jobs for former weapons workers, but the discussion in the Duma reportedly focused on expending 35% of total revenue (approximately \$7 billion) on ecological issues.

⁷¹ Adamov has said publicly that the risk of theft of weapons-usable nuclear material is “one of the key problems of the non-proliferation regime,” and that therefore “no matter how efficient the inspection and safety regime in different countries may be it is necessary to pass on to a different kind of technological cycle in nuclear energy that has built into it a mechanism to prevent the development of weapons-grade materials.” *Official Kremlin International Broadcasts*, press conference transcript, November 25, 1998.

its contents off of reactor operators' hands forever.⁷² (This would also mean, however, that all the wastes would ultimately be disposed of in Russia, just as if the spent fuel had been imported for direct disposal.)

This approach is official Russian policy and has strong government support, but has virtually no supporters in the U.S. government, and is fervently opposed by Russian and international environmentalists. It would be impossible for MINATOM to meet its 20,000-tonne target in the near term unless it could receive U.S.-obligated spent fuel, given which countries are most interested in off-shore spent fuel management services.⁷³ The United States is certain to insist on retaining veto power over any reprocessing of the fuel, so MINATOM's reprocessing plans will never come to fruition unless it develops a technology sufficiently proliferation-resistant to win U.S. support. Moreover, U.S. approval would require resolution of the issue of Russian-Iranian nuclear cooperation.

Russian Site III: Russian Fuel Leasing

MINATOM is also pursuing a complementary fuel leasing concept, drawing on recent proposals by German and British firms to fabricate excess Russian weapons plutonium into reactor fuel in Russia; lease the fuel to reactor operators in Europe and Asia; and take back the spent fuel to Russia or to a Pangea repository.⁷⁴ These initiatives sought to put disposition of excess weapons material on a sustainable commercial footing while generating substantial profits for both MINATOM and Western partners. In the year

2000, MINATOM officials began to speak publicly in favor of such a leasing concept to finance plutonium disposition,⁷⁵ and a senior official was appointed to attempt to negotiate such an arrangement.⁷⁶

Leasing faces somewhat different issues and obstacles than other Russian international site concepts. Some MINATOM officials believe that taking back fuel that originated in Russia would incur less domestic opposition than accepting foreign-origin fuel.⁷⁷ On the other hand, this approach would put Russia in competition for nuclear fuel markets now held by Western firms, which could oppose such concepts through trade restraints and other means. Fuel leasing might face fewer obstacles related to U.S. consent rights: if the nuclear material originated and was enriched and fabricated outside of the United States, and was irradiated in reactors that were not of U.S. origin and whose major components were not of U.S. origin, then the United States would have no formal voice over its fate.⁷⁸ On the other hand, given that MINATOM is focusing initially on leasing fuel made from material from dismantled weapons (which is subject to agreements with the United States), it is unlikely that large-scale leasing arrangements with U.S. allies in Europe and Asia could be worked out without at least U.S. acquiescence—but that acquiescence might conceivably be forthcoming even without a resolution of the Iran issue.

In principle, fuel leasing, which involves Russia providing both front-end and back-end fuel cycle services on a large scale, could bring in more revenue than would be

⁷² Ivanov's study estimates that the total potential market for this service by 2010 would be over 70,000 MTHM worldwide—roughly two-thirds of the total quantity of spent fuel projected to exist outside the United States and Canada at that time. *Ibid.*

⁷³ In Ivanov's study, the vast majority of the spent fuel to be imported is in "potential customer countries" such as Japan, Taiwan, South Korea, Switzerland, and Germany. All of the spent fuel in Taiwan, virtually all of the spent fuel in Japan, all but a small fraction of the LWR spent fuel in South Korea, and substantial quantities of spent fuel in Switzerland and Germany is U.S.-obligated.

⁷⁴ For a German version of such a scheme, see, for example, Erwin Häckel and Karl Kaiser, "Eliminating Russian Weapons Plutonium: A Cooperative Effort Towards Nuclear Disarmament," report of a workshop (Berlin, Germany: Deutschen Gesellschaft für Auswärtige Politik, May 10, 2000). British analyses of the scheme are mostly proprietary. See also Ann MacLachlan, "Scheme to Burn Russian Weapons Pu as MOX in West Hinges on German OK," *Nuclear Fuel*, October 16, 2000.

⁷⁵ See First Deputy Minister of Atomic Energy Valentin B. Ivanov, "Management of Plutonium Derived from Military Programmes," presented at the Uranium Institute 25th Annual Symposium, London, August 30-September 1, 2000.

⁷⁶ Interviews with Andrei Bykov and others.

⁷⁷ Interviews.

⁷⁸ The exception is Taiwan, whose agreement with the United States specifies that *all* fuel in Taiwan is subject to U.S. obligations, regardless of its origin.

available from the provision of back-end services alone. On the other hand, leasing would address only new fuel, not the vast market for management of fuel that has already been irradiated and is stored in reactor pools around the world. Hence, the two MINATOM-supported approaches, fuel leasing and import for storage or reprocessing, are complementary, designed to maximize MINATOM's position on the international fuel market.

Other Russian Site Concepts

In addition to the three proposals described above, a variety of other concepts for storage or disposal of spent fuel in Russia have been proposed. Atsuyuki Suzuki has outlined an ambitious concept dubbed the "Global Peace Project," which involves international storage in Russia, as well as additional sales of LEU blended from HEU, to finance disposition of Russia's excess plutonium and accelerate the elimination of its excess HEU stockpile.⁷⁹ Matthew Bunn of Harvard University, U.S. consultant Neil Numark, and Tatsujiro Suzuki (then of Tokyo University) have proposed storing East Asian spent fuel in Russia's Far East, using revenues to build a MOX plant for excess weapons plutonium, and using much of the fabricated MOX to fuel Japanese reactors.⁸⁰ Within Russia, the Kurchatov Institute has developed its own proposals for international spent fuel storage in Russia. Kurchatov envisions a large storage facility at the closed city of Zheleznogorsk (formerly Krasnoyarsk-26), and has also been involved in proposals for waste storage in Russia's Far East.⁸¹ None of these proposals, how-

ever, is being promoted as actively as the NPT project and the two official MINATOM proposals. It is likely, however, that the Kurchatov Institute—whose leaders have worked closely with MINATOM on this issue and provided key testimony to the Duma on behalf of legislation to allow an international site in Russia—will play an important role if and when any international spent fuel management initiatives in Russia do ultimately come to fruition.)

Special Issues Facing the Russian Proposals

Status of Russian Government Decision-Making

Russian Minister of Atomic Energy Evgeniy Adamov has been promoting concepts for importing spent fuel into Russia since he took office. The Russian law on environmental protection, however, bans import of spent fuel or nuclear waste for storage or disposal in Russia. (Fuel can be imported for reprocessing with return of the resulting wastes.) Hence, MINATOM has sought to amend the law to eliminate this prohibition.

After more than a year of internal government discussion, studies, and debate, MINATOM's proposed legislation gained support from President Putin and his representatives in the government in 2000. On December 21, 2000, the Russian Duma gave preliminary approval to three pieces of legislation.⁸² The first, an amendment to the environmental protection law, would eliminate the prohibition on importing spent fuel and nuclear waste. The second, an amendment to the atomic energy law, reportedly would

⁷⁹ See Atsuyuki Suzuki, remarks on "The End of the Cold War and the Emerging Nuclear Era," in Sam Nunn, chair, *Global Nuclear Materials Management* (Washington, DC: Center for Strategic and International Studies, December 4, 1998).

⁸⁰ Matthew Bunn, Neil J. Numark and Tatsujiro Suzuki, *A Japanese-Russian Agreement to Establish a Nuclear Facility for MOX Fabrication and Spent Fuel Storage in the Russian Far East*, BCSIA Discussion Paper 98-25 (Cambridge, MA: Kennedy School of Government, Harvard University, November 1998). Much of the MOX from Russia would go to reactors that otherwise would have been burning MOX made from the plutonium from the spent fuel sent to Russia, after it had been reprocessed at Rokkasho-mura.

⁸¹ See, for example, Evgeniy P. Velikhov, Nikolai N. Ponomarev-Stepnoi, and S. Malkin, "The International Spent Fuel Storage Facility Creation in Russia" (Moscow, Russia: Russian Research Center "Kurchatov Institute," 1999), and Evgeniy P. Velikhov, "Current Status and Prospects for Acceptance in Russia of Spent Nuclear Fuel and Radioactive Waste," presented at the "East Asia Seminar," sponsored by Lawrence Livermore National Laboratory, Las Vegas, NV, March 7-9, 2000. A specific Kurchatov proposal for a waste disposal facility on the Kurile Islands, reportedly to handle Taiwanese material, was voted down by the Sakhalin regional Duma (see "Deputies Dump Kuriles Nuclear Tomb Plan," *ITAR-TASS*, September 13, 2000).

⁸² The Duma approved the concept in a vote on the "first reading." Two more readings are required before Duma approval is complete, after which the legislation goes to the Federation Council (the upper house of Parliament), and from thence to the President for signature before it can become law. A great deal can and often does happen between

establish procedures for fuel leasing operations. The third, a new law, would regulate expenditures from funds generated by importing foreign spent fuel, reportedly requiring a substantial fraction to be spent on environmental cleanup programs.⁸³

A second vote on these laws was originally scheduled for February 22, 2001, but was then postponed to March 22, in part because of the large number of different amendments proposed. The situation was further complicated by the release, after the first vote, of a detailed report from a Duma committee charging Adamov with large-scale corruption, which highlighted concerns over the adequacy of controls over the billions of dollars in revenue such a scheme could generate.⁸⁴ A variety of issues remain to be considered before final passage, including the extent to which MINATOM will control revenues from the operations; the role of the national and regional governments in deciding how much fuel to import and when; and maintaining effective independent regulation of safety by GOSATAMNADZOR (the Russian nuclear regulatory agency, known as GAN in the United States).⁸⁵

The legislation incurred broad popular opposition, but in the Duma only the liberal democratic Yabloko party opposed it. GAN also strongly opposed the legislation.⁸⁶

Overall, it appears very likely that in 2001 Russia will complete the process of amending its legislation to make it possible to host an international spent fuel facility in Russia.

Status of U.S.-Russian Discussions

While the U.S. government has taken no formal public position on storage of spent nuclear fuel in Russia, Washington and Moscow have been holding private discussions of spent fuel storage, reprocessing, and related issues for some time. As noted earlier, because a very large fraction of the spent fuel held by reactor operators that might be most interested in sending it abroad is under U.S. obligations, U.S. agreement is crucial to the success of any of the proposals involving sites in Russia.

A number of requirements will have to be met for the United States to give its consent for shipment of spent fuel to Russia.⁸⁷ First, under the Atomic Energy Act, the United States and Russia would have to negotiate an agreement for cooperation covering the transfer of the U.S.-obligated spent fuel. For years, the United States has refused to negotiate an agreement for cooperation with Russia because of its continued cooperation with Iran on sensitive nuclear technologies.⁸⁸ The new Bush foreign policy team and Republicans in Congress have generally been even more

the first reading of legislation and its eventual passage into law or rejection—including a wide range of amendments that could still be attached. For useful accounts of the vote, see Dmitry Kovchegin, "The Duma and Arms Control: December 2000," (Moscow, Russia: PIR Center, December 2000); John Daniszewski, "Russia Gives Initial OK To Nuclear Waste Storage Plan," *Los Angeles Times*, December 22, 2000; Oksana Yablokova, "Deputies Back Plan to Import Fuel Rods," *Moscow Times*, December 22, 2000; and "Russian Duma Passes Nuclear Fuel Imports Bills on First Reading," *Russia Today*, December 22, 2000.

⁸³ Formally, the bills were "On Amendments to Article 50 of the RSFSR Law 'On Environmental Protection'" (passed 319-38), "On Amendments to the Federal Law 'On Nuclear Energy Uses'" (passed 318-32) and "On Special Environmental Rehabilitation Programs for Radiation-Polluted Regions of the Russian Federation Financed with Funds Obtained from External Economic Transactions with Irradiated Nuclear Fuel" (passed 320-30). See Kovchegin, "The Duma and Arms Control," *op. cit.*

⁸⁴ See Andrei Zolotov, Jr., "Duma Report: Adamov Corrupt," *St. Petersburg Times*, March 6, 2001.

⁸⁵ Kovchegin, "The Duma and Arms Control," *op. cit.*

⁸⁶ GAN Chairman Yuri Vishnevsky told a U.S. reporter that GAN was not represented at the Duma session, and warned that "the deputies were blinded by generous promises, or they hopelessly made a decision for which the next generation will have to pay." Quoted in Daniszewski, "Russia Gives Initial OK To Nuclear Waste Storage Plan," *op. cit.*

⁸⁷ An excellent discussion of U.S. legal and policy requirements for approving transfers of U.S.-obligated spent fuel to Russia can be found in McGoldrick, "Proposals for an International Spent Fuel Facility: U.S. Law and Policy," *op. cit.* For the only official and public statement of U.S. criteria for accepting such an arrangement known to the authors (which includes some, but not all, of the criteria discussed here), see Alex R. Burkhart, Deputy Director for Safeguards and Technology, Office of Nuclear Energy, U.S. Department of State, "International Overview," presentation to the Nuclear Energy Institute Nuclear Fuel Supply Forum, January 2001.

⁸⁸ To resolve U.S. concerns, the United States wants Russia to agree not to provide any further reactors beyond the first unit now being built at Bushehr, not to provide other sensitive technologies (particularly technologies related to uranium enrichment and plutonium production), and to strengthen enforcement of export controls limiting such exports. The

critical of Russia's cooperation with Iran and are unlikely to change this policy. Indeed, it would be difficult for the United States to shift on this point, as it forced both China and Ukraine to back away from their lucrative nuclear cooperation programs with Iran in order to get agreements for cooperation with the United States, and the governments of both countries would be understandably critical if the United States entered into such an agreement with Russia without a comparable Russian action.

While Russia has agreed not to carry out some particularly sensitive elements of its cooperation with Iran (such as the transfer of a laser isotope separation system)⁸⁹ it has showed no willingness to end the larger components of the program, and indeed has announced that it is ready to sign a contract for construction of a second reactor at Bushehr whenever Iran is ready to sign.⁹⁰ With neither Russia nor the United States inclined to change its position, Iran looms large as an obstacle to negotiating a U.S.-Russian agreement that would allow Russian import of U.S.-obligated spent fuel. While U.S. officials hope that the billions of dollars associated with spent fuel import will be enough to convince Russia to bargain away its less-lucrative nuclear trade with Iran, other analysts view this scenario as unlikely, given Russia's strategic interests in maintaining a strong relationship with the Islamic Republic.⁹¹

Even if the United States and Russia reach agreement on the Iran issue, under the Atomic Energy Act, the United States will have to insist on a number of other points in any

U.S.-Russian agreement on transferring U.S.-obligated spent fuel:

- **No reprocessing without U.S. consent.** The agreement will have to give the United States veto power in perpetuity over any reprocessing of U.S.-obligated spent fuel after it arrived in Russia—and Washington would surely use that veto to prevent any reprocessing, unless a new reprocessing technology was developed that did not separate weapons-usable plutonium and met with U.S. approval. Indeed, U.S. officials have indicated publicly that the ultimate destination of any fuel shipped to Russia should be a repository, not reprocessing.⁹² Moreover, given the U.S. policy of not encouraging civilian plutonium reprocessing, the United States would likely seek to ensure that the arrangement did not contribute to reprocessing of other fuel not covered by U.S. obligations (for example, by providing financing for construction of reprocessing facilities, which is precisely what MINATOM plans to do with a substantial fraction of the revenue).
- **No military use.** U.S. law requires that agreements for cooperation include guarantees that the U.S.-obligated material will never be used for nuclear weapons or any other military purpose.

U.S. view is not so much that a light-water reactor is a proliferation hazard in itself, but that it may provide cover for other cooperation. As one official put it: "We were and still are opposed to this [Bushehr] reactor, not because we believe such a light-water power reactor under International Atomic Energy Agency Safeguards itself poses a serious proliferation threat, but because of our concern that the Bushehr project would be used by Iran as a cover for maintaining wide-ranging contacts with Russian nuclear entities and for engaging in more sensitive forms of cooperation with more direct applicability to a nuclear weapons program." John Barker, Deputy Assistant Secretary of State for Nonproliferation Controls, testimony to the Senate Foreign Relations Committee, October 25, 2000.

⁸⁹ See, for example, Judith Miller, "U.S. Asks Putin Not to Sell Iran A Laser System," *New York Times*, September 19, 2000; and *Nucleonics Week*, March 8, 2001.

⁹⁰ Minister of Atomic Energy Evgeniy Adamov, press conference, January 16, 2001.

⁹¹ See, for example, Brenda Shaffer, "Washington Cannot Stop Russian Nuclear Deals With Tehran," *International Herald Tribune*, December 28, 2000. See also Andrei Zbov, *Iran-Russia Cooperation in the Nuclear Area* (Moscow, Russia: Kurchatov Arms Control and Nonproliferation Analysis Center, forthcoming). Alternatively, some argue that U.S. law could simply be changed to allow the Administration to give consent without an agreement for cooperation—but if such a legislative change were perceived (correctly) as allowing Russia to get the revenue it wanted while continuing nuclear cooperation with Iran, it would have little political support.

⁹² See Burkart, "International Overview," *op. cit.*

- **Safety and security.** The Atomic Energy Act requires that agreements for cooperation include guarantees that adequate physical protection will be maintained on any U.S.-obligated material that is transferred. Given long-standing concerns over security of nuclear materials in Russia, arranging measures to provide this assurance will take some negotiation. At the same time, the United States will need to be assured that U.S.-obligated material will be handled safely, both in the short term (potentially an issue in Russia given the number of accidents on Russian roads and railroads, and issues relating to the strength and independence of the Russian nuclear regulator), and in the long term (a difficult issue given the very modest progress toward establishing a geologic repository in Russia). To give its approval for such a project, the United States will also want to have confidence in the entities that will manage both the fuel itself and the revenues generated from it, be they agencies of the Russian government or private commercial or non-profit entities—a potentially troubling issue given U.S. concerns over MINATOM’s behavior in a variety of other areas, and the lack of large-scale industrial experience of some entities proposing to participate in such efforts. Concerns over Russia’s long-term political stability will also be a factor in considering Russia’s ability to serve as a safe and secure host for thousands of tonnes of foreign nuclear material.
- **Transparency and safeguards.** Since Russia is a nuclear weapon state, U.S. law does not require that Russia maintain IAEA safeguards on U.S.-obligated material transferred to Russia. As a matter of policy, however, the United States is very likely to want to ensure some level of international transparency over the material, and may seek Russian agreement to have IAEA safeguards over it. Customer states or other states with consent rights over some material may wish the facility storing the material to be under IAEA safeguards as well. It is at least possible that this would require Russia to negotiate a new safeguards agreement with the IAEA, as the existing voluntary offer agreement would not be adequate to maintain safeguards over material in perpetuity, as they would be in a non-nuclear-weapon state.⁹³
- **No transfers of nuclear weapons-related technologies or reprocessing technology.** The Atomic Energy Act forbids the United States to enter into agreements for cooperation with any state that has “assisted, encouraged or induced any non-nuclear weapon state to engage in activities involving source or special nuclear material and having direct significance for the manufacture or acquisition of nuclear explosive devices,” unless the President judges that the state has taken adequate steps toward ending this assistance or encouragement. Similarly, cooperation with any state that has entered into an agreement “for the transfer of reprocessing equipment, materials or technology to the sovereign control of a non-nuclear weapon state” is prohibited unless the transfer was pursuant to an international fuel cycle evaluation or agreement to which the United States was a party. These provisions may be waived if the President determines that not carrying out the cooperation envisioned would be seriously prejudicial to U.S. nonproliferation objectives. The U.S. government would have to consider whether Russian transfers to Iran bring this section of U.S. law into play.
- **No impacts “inimical to the common defense and security”—control of the funds.** U.S. law requires that before allowing the transfer of U.S.-obligated material, the government must determine that the transfer would not be inimical to the common defense and security. This raises the issue of whether revenue from importing spent fuel would be used to support the Russian nuclear weapons program, including potential development of responses to

⁹³ See McGoldrick, “Proposals for an International Spent Fuel Facility: U.S. Law and Policy,” *op. cit.*

planned U.S. national missile defenses—an outcome many U.S. critics would identify as being inimical to the defense interests of the United States. At the same time, if billions of dollars of revenue are to result from an activity that can only go forward with U.S. approval, U.S. policymakers may feel it is incumbent on them to put in place institutional mechanisms to ensure that sufficient revenue is provided for safe and secure management of the spent fuel in both the near term and the long term, rather than being lost to corruption and theft or spent on other governmental purposes. And the United States would like to see a substantial portion of whatever excess revenue there may be devoted to activities that serve U.S. interests, such as improving security for nuclear material and reducing excess weapons plutonium stockpiles. Thus, it appears inevitable that one important and difficult part of the U.S.-Russian negotiation over possible import of U.S.-obligated spent fuel will focus on U.S. efforts to control how the revenue is spent, and Russian efforts to avoid such U.S. control.

It appears inevitable that the United States and Russia will enter into negotiations toward an agreement for cooperation—Russia wants to start talks as it sees such a deal as the key to unlocking billions of dollars in profit, while the United States sees it as potentially the key to addressing Russia's nuclear cooperation with Iran. But negotiating an agreement for cooperation that would allow Russia to import U.S.-obligated spent fuel will inevitably be controversial. Any such agreement will have to pass muster with the U.S. Congress, which under U.S. law has the authority to block all agreements for cooperation. Many U.S. groups, including environmentalists and critics of bilateral cooperation with Russia, are likely to oppose U.S. approval for such an operation—and will seize on any weaknesses related to the above points that an eventual negotiated agreement may have to try to block it in Con-

gress. The Bush administration is not likely to be willing to expend the necessary political capital and endure the political headaches of negotiating such an agreement and putting it before Congress unless there are seen to be dramatic benefits for U.S. security—such as a deal on Iran, and billions of dollars for improved nuclear security. At the same time, however, while the United States will have substantial leverage in such a negotiation, neither Russia nor the United States can expect to get everything it wants. The Bush administration will have to carefully consider where to spend the U.S. leverage—whether, for example, to put more emphasis on seeking Russian acceptance of exactly the U.S.-desired approach on Iran, or on a greater degree of control or transparency over the revenues. These complex decisions have not yet been made.

While negotiation of an agreement for cooperation has not yet begun, the United States and Russia have been engaged in intensive discussions related both to Russian domestic storage and disposal of spent fuel and nuclear wastes, and the possibility of Russian imports of foreign spent fuel. In early 2000, the U.S. Department of Energy announced that it was seeking to negotiate with Russia a 20-year moratorium on separation of plutonium by reprocessing, which would be coupled with both assistance for dry cask storage of the spent fuel that would not be reprocessed, and funding for joint research and development on proliferation-resistant nuclear fuel cycles for the future (potentially including reprocessing approaches that did not fully separate weapons-usable plutonium).⁹⁴ The United States and Russia agreed to establish a working group on these issues, which reached agreement in principle on a 20-year reprocessing moratorium (though the deal was not completed before the Clinton Administration left office), and which also fleshed out approaches to dry cask storage of non-reprocessed fuel. The group also began discussing the issues that would be involved in Russian import of foreign spent fuel, especially U.S.-obligated spent fuel. In addition, cognizant that imports of foreign spent fuel would ultimately require a repository whether the fuel was reprocessed or not, the United States and Russia initiated

⁹⁴ The initiative, part of the "Long-Term Nonproliferation Initiative for Russia," is described in Bunn, *The Next Wave*, op. cit., pp. 70-71. The United States made it clear that the joint R&D was contingent on a resolution of the Iran issue, just as U.S. approval for Russian import of U.S.-obligated spent fuel would be.

joint discussions of repository science. None of these discussions, however, progressed to the point of actual signed agreements.

To summarize, U.S.-obligated spent fuel is crucial to the success of an international site in Russia, and is unlikely to go to Russia unless: (a) there is a resolution of the Iran nuclear cooperation issue; (b) basic criteria such as ensuring safety, security, and the credibility of the key participants are met; (c) there is agreement that there would be no reprocessing of the fuel without U.S. consent; (d) there is agreement on safeguards or transparency arrangements acceptable to both sides; (e) there is a meeting of minds over control over the revenues from the project; and (f) the project provides sufficient benefits to U.S. security to convince the Bush Administration to go ahead and negotiate the agreement, and to allow it to sell the agreement to Congress. These criteria will not be easy to meet.

Environmental and Public Opposition

Russian environmentalists fiercely oppose all proposals for importing spent fuel from abroad.⁹⁵ They are strongly supported by influential international environmental groups, such as the Bellona Foundation (based in Norway) and Greenpeace, and by a wide range of U.S. environmental groups.⁹⁶ Russian environmentalists have launched a wide array of critiques and protests against these plans, acquiring and leaking to the press relevant MINATOM documents, organizing regional opposition in areas where such sites might be located,⁹⁷ and even dumping radioactive dirt

from contaminated areas of Mayak on the Duma's doorstep.⁹⁸ Most importantly, they organized a national petition drive which gathered 2.5 million signatures calling for a national referendum on the waste import proposal. Under Russian law, if at least 2 million petitioners call for such a referendum, it must be put on the ballot. Russia's Central Electoral Commission, however, invalidated 600,000 of the signatures on a variety of technicalities, bringing the petition just below the 2 million threshold required to force a vote.⁹⁹

We are not aware of any reliable polls available on how much support the environmentalists have on this issue among the broader Russian public. Yabloko leader Grigory Yavlinsky, commenting on his party's vote against the measure, argued that the Russian people, like the environmentalists, were overwhelmingly opposed: "We are not greens, we are politicians. And politicians have one rule: if 99% of the population are against the waste import, we have no further arguments in favor of the project."¹⁰⁰

Moving forward with an international site in Russia in the face of such intense and united environmental opposition, with the Russian government refusing to submit the matter to the will of the people in a referendum, would raise deeply troubling questions about Western support for grass-roots democracy and civil society in Russia. Moreover, Russian environmentalists predict with some plausibility that they will be able to block construction of a final repository in Russia that is designed to include foreign nuclear waste.¹⁰¹ Advocates of the NPT concept have

⁹⁵ For example, protesting against nuclear waste imports was a key focus of Earth Day activities in Russia in 2000. See "Russian Earth Day Events to Focus on Radioactive Waste Imports," press release, Anti-Nuclear Campaign, April 21, 2000.

⁹⁶ See, for example, the very long list of groups who signed a December 13, 2000 letter to the U.S. Secretary of State and Secretary of Energy asking them to deny U.S. approval for such proposals, available at <http://www.nirs.org/intl/russianimportwasteltr.htm>. Earlier, in late 1999, 47 leading Russian environmentalists, led by Alexei Yablokov (formerly President Yeltsin's chief environmental adviser and member of the Russian Security Council) wrote to U.S. officials outlining their opposition to spent fuel imports to Russia generally, and the NPT proposal specifically. (Alexei Yablokov et. al., letter to U.S. officials, 1999). For the perspective of Russian anti-nuclear environmentalists on these and other issues, see the webpage of the "Anti-Nuclear Campaign" co-sponsored by the Socio-Ecological Union and EcoDefense, at <http://www.ecoline.ru/antinuclear/eng/index.htm>. For the perspective of a key international group, see Bellona's webpage, at <http://www.bellona.no/imaker?>.

⁹⁷ See, for example, "Chelyabinsk Authorities Speak Out Against Nuclear Waste Import," press release, Anti-Nuclear Campaign, August 9, 2000.

⁹⁸ "Russian Villagers Dump Radioactive Dirt on Duma's Doorstep," *Environmental News Service*, October 10, 2000.

⁹⁹ See Anna Badkhen, "Greens' Signatures Dumped by CEC," *Moscow Times*, November 30, 2000.

¹⁰⁰ Quoted in Kudrik, "Russia's Last Big Sale Was Alaska," *op. cit.*

¹⁰¹ Letter to Albright and Richardson, December 13, 2000, *op. cit.*

worked hard to convince Russian environmentalists that their project would substantially benefit Russia's environment by financing cleanup of a wide variety of problems for which no money would likely be forthcoming from any other source. But so far they have won no converts. How this issue will play out in the future remains very much in doubt.

Russian Stability and Credibility

Russia currently is far from an ideal location to host a storage site or repository for spent fuel and nuclear waste. There are only two reasons to consider Russian sites seriously: (a) the Russian government may be the only major government in the world that is willing; and (b) Russian sites may offer the opportunity to raise a substantial non-government revenue stream for addressing nonproliferation and cleanup problems in Russia. Despite these rationales, however, Russia will have to work hard to demonstrate that it is a credible recipient for spent fuel from around the world.¹⁰²

First, Russia's technical infrastructure for managing spent fuel is in poor shape. There are few major highways to some locations where fuel might be stored, so fuel would likely be shipped by train—but underinvestment in Russia's railroads has left them increasingly prone to accidents and delays.¹⁰³ Russia has had difficulty arranging sufficient certified trains and transport casks even to ship relatively limited quantities of naval spent fuel to Mayak for processing. GAN has charged that the most recent spent fuel transport casks manufactured in Russia do not meet safety standards.¹⁰⁴ Environmental risks from inadequate storage of spent fuel from Russia's nuclear-powered ships and submarines have raised global concern. Russia's civil reprocessing plant at Mayak has contributed to one of the most contaminated nuclear sites on earth, and has both inadequate material protection, control, and accounting (MPC&A) and inadequate management of at least some of its radioactive

wastes. In short, substantial infrastructure investments are likely to be needed for a Russian option to proceed safely.

Secondly, the regulatory agency charged with ensuring nuclear safety in Russia is weak and under attack. GAN has never had remotely as much power as MINATOM, and its ability to enforce high standards of safety for such a project is open to serious question—particularly as GAN has earned MINATOM's bitter enmity by publicly opposing the entire concept of spent fuel imports. Some form of effective and independent regulation—either Russian or international, or both—to ensure high safety standards would be essential to the credibility of such an enterprise, and does not yet appear to be in place.

Third, Russia's economy is ill-suited for investment in long-term projects. Participants in a spent fuel management venture in Russia will have to contend with endemic crime and corruption; a complex, punitive, and ever-changing tax structure; high and constantly changing inflation; very high costs of capital; and a court system that does not yet have a reputation for strong and fair enforcement of contracts (especially between Russians and foreigners). Additionally, the site for spent fuel management is likely to be one of Russia's closed nuclear cities, which poses another layer of difficulties relating to security and access to the site.

Fourth, Russia's basic social and political stability is open to question over the long time frames involved in such a project. Russia has existed as an independent nation for less than a decade, and has undergone sweeping transformations over that time, including two rounds of a bitterly fought civil war in Chechnya. President Putin himself has repeatedly warned that if his reforms are not successful, the alternative could be the collapse of the Russian state. In 1998, when Russia was failing to pay its nuclear missile officers, Alexander Lebed, the governor of the Krasnoyarsk region (and then-President Yeltsin's former security advisor) threatened to take over control of the nuclear forces in his region.

¹⁰² The underlying irony of projects such as the NPT proposal—"we're concerned over poor management of nuclear material in Russia, so we propose to import another 10,000 tonnes of nuclear material into Russia"—highlights Russia's basic credibility problem, despite strong arguments in favor of such an approach.

¹⁰³ Russian anti-nuclear critics have prepared a report on transportation accidents involving nuclear material in Russia. See "Nuclear Transport Is Dangerous And Unacceptable, New Report Says: Minatom Lies About Safe Transportation Of Nuclear Waste," press release, Socio-Ecological Union and EcoDefense, January 27, 2001 (available at <http://www.ecoline.ru/antinuclear/eng/press-release/010127.htm>).

¹⁰⁴ Thomas Nilsen, "GAN Says 40-tonne Casks Unsafe," *Bellona*, April 5, 2000.

In sum, potential customer states and consent-right states will justifiably demand very specific arrangements in place to ensure long-term safety and security of all the operations, and appropriate management of the relevant funds, under a wide range of possible future conditions, for Russia to be truly credible as a host state for receiving large quantities of spent fuel. These arrangements will be difficult to negotiate. As noted earlier, however, it should be remembered that if one is concerned about Russia's long-term stability, 10,000 tonnes or even 20,000 tonnes of imported spent fuel in dry casks should be among the least of one's concerns, given the presence of thousands of nuclear weapons, hundreds of tonnes of weapons material, and thousands of nuclear weapons experts, spread across scores of nuclear sites.

Conclusions

Proposals for international sites for storage or disposal of spent fuel and nuclear waste offer a number of important potential benefits, but have a number of significant disadvantages as well. Each such proposal needs to be evaluated carefully on its merits. The obstacles to establishing such an international facility are substantial, and it remains unclear whether they can be overcome in the near term. Nevertheless, we believe that it would be highly desirable to establish one or several such facilities over the next couple of decades. If appropriately managed, such sites could contribute both to stemming the spread of nuclear weapons and to the future of civilian nuclear energy.

In particular, such international facilities could make it possible to remove spent fuel from countries of acute proliferation concern and enhance transparency and confidence-building in spent fuel management. And over the long term, establishing one or more international disposal sites will be essential, at least for material from countries with small nuclear programs and geologies offering few sites suited to permanent disposal. The ultimate trend should be toward consolidating spent fuel in a smaller number of locations worldwide.

We believe, however, that advanced countries with large and sophisticated nuclear programs, such as the United States and Japan, should continue to plan on storing and

disposing of their spent fuel and nuclear wastes domestically. Both the United States and Japan have the technical capacity and wealth to manage their own storage facilities and repositories. While we would not rule out the possibility that some limited amount of Japanese spent fuel might be sent to an international site, the primary focus in Japan, as in the United States, should remain on domestic options for managing spent fuel and nuclear wastes. Both countries have a responsibility to manage the wastes resulting from the large quantities of nuclear electricity they have produced, and the issue is too pressing in both countries to delay the search for domestic solutions until an international option may become available.

Issues associated with a possible international facility in Russia are especially complex and inter-related. Such a facility could make a substantial contribution to international security and would deserve support *if*:

- Effective arrangements (including independent regulation) were in place to ensure that the entire operation achieved high standards of safety and security;
- A substantial portion of the revenues from the project were used to fund disarmament, non-proliferation, and cleanup projects that were agreed to be urgent, such as securing nuclear material and eliminating excess plutonium stockpiles;
- The project did not in any way contribute to separation of additional unneeded weapons-usable plutonium, or to Russia's nuclear weapons program; and
- The project had gained the support of those most likely to be affected by it, through a democratic process, including giving them ample opportunity to ensure that their concerns were effectively addressed.

Whether an arrangement that meets these criteria can be put in place in Russia—and what the reaction will be if a proposal advances which meets the first three criteria but not the fourth—remains to be seen.

5. Key Issues, Tensions, and Approaches to Overcoming Obstacles

IN THIS CHAPTER, WE EXPLORE key policy choices and tensions regarding interim storage of spent nuclear fuel. Following that exploration, we outline a set of approaches designed to increase the chances of overcoming the most important obstacle—gaining agreement on siting of spent fuel interim storage facilities.

Key Policy Choices and Tensions

Interim storage of spent nuclear fuel involves choices among: (a) wet or dry storage; (b) at-reactor, centralized, or distributed but away-from-reactor storage; (c) domestic or international approaches; and (d) relying primarily on government or private actors (or mixes of the two). Other key issues include how long interim storage will last, and the linkages between interim storage and more permanent solutions. For most of these questions, there is no one right answer, but rather a set of factors to consider in choosing the best approach for each particular situation.

Technology: Wet vs. Dry

Current reactor types inevitably require at least a brief period of wet storage of spent fuel to allow the fuel to cool after it is discharged from the reactor. If more prolonged interim storage is to be pursued as a central element of the nuclear fuel cycle, a key question is whether the fuel should remain in wet pools, or be moved to dry storage facilities (and if so,

what type of dry facilities—casks, silos, or vaults). The technical issues are described in Chapter 2. In general, the initial capital costs of providing dry storage facilities are higher, but the continuing operational costs and complexities of dry storage are significantly lower than those of wet storage. Either approach is acceptable, and either may be preferable in particular situations. In recent years, however, reactor operators have increasingly been choosing dry casks, and it is the authors' judgment that in many cases, dry casks, with their flexibility, safety, and low long-term costs, will prove to be the preferable approach.

Siting: At-Reactors, Multiple Away-From-Reactors, or Centralized

Siting interim storage facilities is a crucial and difficult process, laden with political and institutional implications. The basic choice is whether fuel should continue to be stored at or near the many reactor sites, or should be transported to other facilities—either a single centralized facility or multiple facilities at several sites. Table 5.1 summarizes important advantages and disadvantages of each approach,¹ each of which is discussed briefly below.

Technical Factors

- **Transportation.** Transportation of spent nuclear fuel inevitably involves at least some costs and risks. This is a much more significant

¹ For a similar table—with somewhat more technical factors and somewhat fewer political factors included—see Nuclear Waste Technical Review Board, *Disposal and Storage of Spent Nuclear Fuel—Finding the Right Balance* (Washington, DC: Nuclear Waste Technical Review Board, 1996), p. 37 (available at <http://www.nwtrb.gov/reports/storage.pdf>). This report includes an in-depth discussion of the issues regarding at-reactor vs. centralized storage, for the U.S. case.

issue for the United States—where fuel has to be shipped thousands of kilometers by rail and truck, through many communities and states—than in Japan, where fuel is transported between coastal nuclear installations by sea, using ships and casks that have already been purchased. Continuing to store spent nuclear fuel at the reactor sites where it was generated allows these costs and risks to be postponed into the future.² A centralized storage facility located where the permanent solutions are to be implemented—a geologic repository under current U.S. plans, a reprocessing plant under current Japanese plans—requires near-term transportation of the fuel from the reactors, but avoids a later second shipment from the interim facility to the permanent facility. Centralized facilities at other locations, or away-from-reactor facilities distributed at several sites, would require both near-term transport and future transport to the facility for permanent management. A distributed approach, however, could locate interim storage facilities near reactors that generated the fuel, minimizing distances over which near-term transportation would be required.

- **Safety.** At-reactor, centralized, and distributed away-from-reactor storage sites all have the potential to be very safe if well designed and operated. At-reactor and away-from-reactor approaches each offer some modest safety advantages. As just noted, at-reactor storage postpones whatever safety risks there may be in transporting spent fuel, keeping the fuel at sites that are already licensed for safe operation of nuclear reactors (a much more hazardous activ-

ity than storing spent fuel). Away-from-reactor storage, however, makes it possible to choose the safest sites (if these locations will accept a spent fuel storage facility). Such a safety-based choice is not inevitable, however, as recent efforts in the United States to locate a spent fuel storage site at Jackass Flats, an area of high surface seismicity, make clear.³ One argument for away-from-reactor storage, at least in some cases, is that not all existing reactor sites may be ideal locations for long-term interim storage of spent nuclear fuel; critics have expressed concern, for example, that some U.S. at-reactor sites are in areas susceptible to erosion and earthquakes.⁴ Any site which has been licensed as acceptable for the operation of a reactor, however, is likely to be suitable, with appropriate storage design, for the much less challenging role of storing the spent fuel from that reactor.

- **Economics.** Here, too, advocates of both at-reactor and centralized storage have argued that their preferred approach is likely to be cheaper. Centralized storage could realize significant economies of scale if vault-type facilities were used, but most proposals for both centralized and at-reactor storage involve dry casks, whose costs are roughly constant per unit of spent fuel regardless of how much spent fuel is located at one site. In the United States, the nuclear industry argued in the late 1990s that several billion dollars would be saved by consolidating storage of spent fuel at a single centralized site near Yucca Mountain, but this reflected an unrealistic assumption that a centralized site would have available the same casks that would ultimately be used for disposal (and therefore no

² In the U.S. case, where the costs of transportation to a central site could be hundreds of millions of dollars, the ability to postpone these costs for several decades and thereby discount them potentially represents a significant savings.

³ For discussion of these seismicity issues and their impact on surface interim storage, see Allison Macfarlane, "Interim Storage of Spent Fuel in the United States," *Annual Review of Energy and the Environment*, forthcoming.

⁴ See, for example, testimony in U.S. Nuclear Regulatory Commission, "Briefing on the Status of Spent Fuel Projects," February 23, 2000, p. 65 (available at <http://www.nrc.gov/NRC/COMMISSION/TRANSCRIPTS/20000223a.html>).

additional cask purchases would be necessary), whereas at-reactor sites would have to purchase additional storage casks for all the spent fuel. This industry estimate also failed to include discounting of the substantial costs of transportation in the calculation. Other analysts (including one of the present authors) have concluded that for the United States, the costs of at-reactor and centralized storage would be roughly comparable without considering transportation, and centralized storage would be more expensive if transportation and the effect of discounting in delaying those costs into the future were included. In effect, the modest economies of scale from a centralized facility are counterbalanced by the modest additional capital costs for providing facilities at the centralized site for loading and unloading casks and handling fuel, tasks which at-reactor facilities can perform with existing reactor equipment and pools.⁵

- **Monitoring, security, and safeguards.** Advocates of centralized storage argue that consolidating spent fuel in a single site or a small number of sites would greatly ease the tasks of safeguarding and securing the material compared to storing it at dozens of reactor sites.⁶ While this argument has some logical appeal, the advantages should not be overstated. As long as reactors continue operating, there will continue to be tens of tonnes of spent fuel, containing hundreds of kilograms of plutonium, in the storage pools at each reactor site, which must still be safeguarded and secured. Addi-

tional spent fuel in dry casks is a modest addition to the safeguards and security task at these sites. By creating a new facility that did not previously have to be guarded and safeguarded, a centralized site might add as much to the total safeguards and security burden as would dry casks at the reactor facilities. And near-term transportation to a centralized site creates a significant temporary safeguards and security burden while the fuel is being moved.

- **Fuel management.** Leaving fuel in at-reactor storage minimizes fuel handling, allowing the fuel to be shipped directly to a permanent destination once permanent solutions are ready. At-reactor storage can also provide more flexibility in matching the expansion of storage capacity to meet needs as they arise. A centralized site located where the permanent solution is to be implemented could also minimize the need for repeated packaging and transport—but establishing a spent fuel storage site when the suitability of that location for implementation of a permanent solution is still in doubt (as was proposed for a storage site near Yucca Mountain in the United States, for example) could prejudice the outcome of that larger decision.⁷ If the permanent solution at that site did not work out, re-transport to another site would be needed. If the permanent management approach planned is direct disposal in a geologic repository, interim storage near that repository could maximize the flexibility available in loading the repository, making it possi-

⁵ See Allison Macfarlane, “The Problem of Used Nuclear Fuel: Lessons for Interim Solutions From a Comparative Cost Analysis,” *Energy Policy*, forthcoming. In discussions of a centralized Federal site, which was the focus of this analysis, DOE has argued that such fuel handling facilities would be necessary. Current private proposals for centralized storage facilities in Utah and Wyoming, however, envision sites which would have no need for or capacity to open casks or handle fuel. In the event that a cask developed a problem (which is not expected), it would be appropriately packaged and sent back to the reactor from which it came to be addressed. This approach would reduce the projected capital cost of the proposed facilities.

⁶ See, for example, Luther J. Carter and Thomas H. Pigford, “The World’s Growing Inventory of Civil Spent Fuel,” *Arms Control Today*, January/February 1999, pp. 8-14.

⁷ This issue of pre-judging the Yucca Mountain decision—and perhaps undermining perceptions of the credibility and lack of bias of the scientific assessment of Yucca Mountain—was a key factor in opposition to the proposed legislation to mandate a facility there.

ble to implement optimal arrangements of “hot” and “cool” spent fuel, for example, and would also provide a ready facility for storage should it become necessary to retrieve fuel from the repository to deal with any problems that may arise. (These objectives, however—particularly the first—could probably be achieved with an above-ground facility of relatively modest size.)

Political and Institutional Factors

- **Relation to permanent solutions.** Establishing a large centralized facility (or multiple away-from-reactor facilities) capable of providing decades of spent fuel storage would, in some sense, appear to “solve” the nuclear waste problem. Such an approach might be perceived as an alternative to, rather than a complement to, serious pursuit of permanent solutions. If that is not the intent, enormous care will be required to link the interim approach to continuing progress toward permanent spent fuel management solutions. If this is not done, establishing major away-from-reactor facilities could reduce both political support and available funding for more permanent approaches, even though continuing progress toward such permanent approaches is likely to be crucial to gaining local acceptance for an interim facility. As long as spent fuel remains stored at reactor sites, the reactor operators and the communities and regions near reactors have an incentive to support permanent solutions that will ultimately remove spent fuel from the reactor sites. Once the fuel is moved, however, much of that support could disappear. Moreover, the cost of establishing a large centralized site or sites could reduce the funds available for development of permanent approaches (a concern that

supporters of Yucca Mountain in the United States have frequently expressed).⁸ In either an at-reactor or an away-from-reactor approach, it will be crucial to establish mechanisms to build confidence that there will continue to be progress toward permanent solutions, and that therefore the interim storage facilities will not become permanent ones.

- **Impact on the politics of nuclear energy.** Although there are only modest technical differences between at-reactor and centralized storage, establishing a large centralized facility (or multiple away-from-reactor facilities) may create a stronger perception that serious steps are being taken to address the problem of safe management of nuclear waste. By offering the possibility of removing the spent fuel from reactors, such an away-from-reactor approach could improve local political support for existing and new reactors. This possibility clearly reinforces U.S. and Japanese nuclear advocates’ very strong support for centralized facilities (and nuclear critics’ very strong opposition to centralized storage).⁹ The issue of how a centralized facility will affect local political support for reactors is particularly important in Japan, where commitments have been made to local communities near reactors that spent fuel will be removed promptly.
- **Difficulty of siting/approvals.** This issue cuts differently in the United States and Japan. In the United States, decades of effort to find a site host for a centralized facility have so far failed (though two proposals are still in development), but many utilities have successfully established on-site dry storage facilities. In Japan, by contrast, utilities’ nuclear safety agreements with local governments include commitments to remove spent fuel promptly,

⁸ See, for example, the discussion in Nuclear Waste Technical Review Board, *Disposal and Storage of Spent Nuclear Fuel—Finding the Right Balance*, op. cit.

⁹ In the United States, for example, nuclear energy critics have devoted a large fraction of their effort in recent years to opposing establishment of a centralized interim storage facility in Nevada. Some of the critics’ arguments can be found on the web page for the Nuclear Information Resource Service’s project opposing the centralized site: <http://www.nirs.org/dontwasteamerica/dtwsam.htm>.

and the Japanese government and utilities are currently attempting to establish a large centralized storage facility rather than to revise these local agreements to allow expanded reliance on on-site storage. This presumably reflects in part a judgment that it is easier to site one large centralized facility than to reverse previous commitments at many reactor sites. Whether this judgment is correct remains to be seen. It is at least possible that in Japan's case, too, it will turn out to be extraordinarily difficult to find a site that will accept a large centralized facility, and easier to gain acceptance for expanding storage at reactor sites, where local communities have already accepted nuclear power plants, and have an incentive to take the actions necessary to maintain the flow of financial benefits they are receiving from the reactors' operation.

- **Impact on perceptions of geographic fairness.** Political acceptance of spent fuel storage facilities is significantly influenced by perceptions of whether the burden of serving as host for such facilities has been allocated fairly. In the United States, the proposed centralized storage facility in Nevada is considered unfair by many (particularly in Nevada), as Nevada has no nuclear power plants of its own, and was chosen as a repository (and possible interim storage) site largely because of its sparse population, dry conditions, and lack of political power to resist. Indeed, to spread the burden more fairly, previous legislation (still official U.S. law) prohibited establishing an interim storage facility in the same state being considered for a permanent repository. Continued storage of spent fuel at the reactor sites—which have had the benefit of the revenue generated by irradiating that fuel—is seen by many as fairer.¹⁰ But in both Japan and the United States (as in most other countries), reactors tend to be in rural areas, while the electricity they generate is primarily

consumed in cities; storing spent fuel in rural areas may create a perception that rural people are being unfairly forced to bear the cities' burden. While the mayor of Tokyo has remarked that he would be willing to consider a reactor within Tokyo (an unlikely prospect), and spent fuel storage facilities pose fewer hazards than power reactors, nonetheless political acceptance for a spent fuel storage facility in a major urban area appears highly unlikely.

- **Flexibility/Managing Uncertainty.** The history of nuclear power demonstrates that the future often turns out to be different from predictions, and that therefore flexibility to respond to changing circumstances is crucial. In this respect, pursuing both at-reactor storage and at least a modest centralized site for special cases might offer maximum flexibility. Complete reliance on a single centralized site has the significant disadvantage that if that site is not approved (or some unforeseen event forces it to stop accepting additional fuel after it opens), no immediate fall-back would be available and reactors whose spent fuel ponds filled to capacity might be forced to shut. Complete reliance on at-reactor storage has the significant disadvantage of not offering an alternative way to store fuel from “problem” sites—for example, fuel from shut-down reactors that are being decommissioned, or fuel from reactors whose local communities will not permit additional spent fuel storage on-site. Politically, however, the option of doing both may be difficult to achieve, as communities at both the reactor sites and the centralized sites may not be convinced there is any need for them to accept the burden of spent fuel storage in their communities if another alternative is available.
- **Concerns of utilities and local and regional governments.** In both the United States and Japan, utilities and local communities have a number of legitimate concerns about storing

¹⁰ See, for example, the discussion in Nuclear Waste Technical Review Board, *Disposal and Storage of Spent Nuclear Fuel—Finding the Right Balance*, op. cit.

fuel at reactor sites. In the United States, both the law and contracts with utilities obligated the Department of Energy (DOE) to remove fuel from utility sites and ship it to a permanent repository. Utilities are understandably eager that this commitment be fulfilled. Even if DOE pays utilities for additional costs incurred because of on-site storage, utilities are concerned about the potential impact on political support for their reactors if spent fuel continues to build up with no end in sight; about the obstacles to decommissioning and cleaning out sites if there is no place to send spent fuel; and about planning uncertainties that inevitably arise without a date certain at which fuel can be removed. Moreover, a few states and local communities are reluctant to allow spent fuel storage to build up at existing sites without realistic assurance that it can soon be moved to a permanent repository. They argue that they agreed to host a power reactor, not a semi-permanent nuclear waste site. It is conceivable that absent some centralized storage capacity, the political difficulty of getting acceptance for additional storage could force a utility to shut a reactor. That possibility, however slim, creates large financial uncertainties for utilities.

Summary. Arguments exist in favor of at-reactor, centralized, and distributed away-from-reactor interim storage of spent fuel. Ultimately, whichever type of site can find political acceptance will likely serve the purpose adequately. The option of combining at-reactor storage with at least some centralized storage has a number of attractions and should be seriously considered.

Approach: Domestic vs. International

Another important issue, discussed in Chapter 4, is whether to focus on domestic storage of spent fuel, or on the possibility that some international site will be established to which the fuel could be shipped. In the authors'

judgment, while it is highly desirable for the international community to explore possibilities for international storage and disposal of spent fuel and nuclear waste, both Japan and the United States, as countries with large and sophisticated nuclear programs, should focus on storing their spent fuel and disposing of their spent fuel or nuclear wastes domestically. Both countries clearly have the financial and technical resources to establish safe storage and disposal facilities of their own. The United States also has a very large territory with a wide selection of possible geologies for ultimate disposal. Japan is not in such a favorable geologic position, but there are many adequate sites for safe interim storage in Japan, and it seems very likely that it will be possible to identify safe sites for permanent waste disposal within Japan as well.¹¹ At the same time, the authors believe Japan and the United States should both continue to participate in discussions of international approaches. As leading nuclear countries, both can make important contributions, and an international site could supplement Japan's domestic program.

Responsibility: Balance Between Government and Private

A key institutional question is whether the national government, private firms, or some other entity (such as a non-profit organization established for the purpose) should bear primary responsibility for managing storage of spent fuel and disposal of nuclear wastes—or whether different entities should be responsible for different parts of the job. In the United States, utilities pay a per-kilowatt fee to the federal government, which has full responsibility for taking the spent fuel from the reactor sites and managing it.¹² In Japan, by contrast, essentially the entire responsibility for both interim and permanent spent fuel management rests on private utilities and on private organizations that they fund and manage (with government playing a variety of roles, including helping to develop technologies and providing oversight).

A good argument can be made that it is useful for the national government to shoulder at least a portion of the

¹¹ See, for example, *Project to Establish the Technical Basis for HLW Disposal in Japan* (Tokyo, Japan: Japan Nuclear Fuel Cycle Development Institute, 1999).

¹² The reality, however, given the government's failure to begin taking the spent fuel on the January, 1998 date specified by law, is that utilities have had to take responsibility for organizing approaches to interim storage of their own spent fuel until the government ultimately fulfills its obligations. Moreover, Congress has recently mandated a new study of how, specifically, the government's responsibility for long-term management of spent fuel should be managed and controlled.

Table 5.1: At-Reactor vs. Away-From-Reactor Storage

Issues	Advantages of At-Reactor Storage	Advantages of a Centralized Site	Advantages of Multiple Away-From-Reactor Sites
<i>Technical Issues</i>			
Safety		Can choose “best” sites	Can choose “best” sites
Transportation	U.S.: Postpones transport costs and hazards Japan: Less important due to sea transport	No additional transport needed if site is at same location as permanent solution	Could have regional transportation arrangement
Economics	At-reactor likely cheaper when transportation is included	May have lower costs if permanent solution greatly delayed	
Monitoring, security, and safeguards	Transport risks postponed, no new sites created	Modest advantage of consolidating fuel at single site	
Fuel management	Minimizes handling, since fuel transported directly to repository or reprocessor Provides flexibility with capacity added when and where needed	If located at repository, allows maximum flexibility for repository emplacement schedule, facilitates retrieval if needed and monitoring to detect problems	
<i>Political and Institutional Issues</i>			
Progress toward permanent solutions	Maintains pressure for progress on permanent solutions, avoids prejudicing repository site decisions		
Political support for nuclear energy		Removes fuel from reactor sites, “looks like a solution”	Removes fuel from reactor sites, “looks like a solution”
Difficulty of siting	U.S.: At-reactor generally simpler, new license not necessarily required	Japan: Fulfills past commitments to remove fuel from reactor sites promptly, but still faces difficulty of finding host site	
Flexibility	Avoids reliance on success of one central facility	Avoids reliance on success in extending storage at every site	Avoids reliance on success of one central facility
Geographic fairness	Keeps fuel close to areas that benefited from the electricity (though still an urban-rural divide)		Burden can be shared more widely and fairly than with single central site
Utility and local concerns		U.S.: Fulfills DOE past commitment to take title to fuel and ship it away from reactors; removes fuel from shut-down reactor sites Japan: Fulfills past commitments to remove fuel from reactor sites Both: reduces planning uncertainties for utilities; reduces burdens associated with hosting reactors	U.S.: Fulfills DOE past commitment to take title to fuel and ship it away from reactors; removes fuel from shut-down reactor sites Japan: Fulfills past commitments to remove fuel from reactor sites Both: reduces planning uncertainties for utilities; reduces burdens associated with hosting reactors

responsibility for interim storage of spent fuel (and still more for final disposal of nuclear wastes). In the process of gaining political acceptance for siting, for example, it is sometimes useful to be able to frame the issue as a *national* priority, part of an overall national plan, rather than an activity that only serves the interest of the particular utility or utilities involved. On the other hand, too strong a government role may undermine the credibility of other parts of the government as objective regulators of such facilities. Some segments of the public remain unconvinced that their governments can effectively regulate and promote an activity simultaneously (even if different agencies perform these duties). Moreover, in the United States, and to a growing degree in Japan, past nuclear problems, accidents, and cover-ups have undermined the public credibility of the government agencies involved in managing spent nuclear fuel and nuclear wastes, to the point that their involvement may in some cases have a negative rather than a positive effect on public attitudes toward a particular facility.

In short, there is a role for both government and the private sector in managing spent nuclear fuel and nuclear wastes, and the best balance of government and private responsibility should be decided case-by-case, on the basis of specific political and institutional circumstances in each country. Even within a particular country, the best mix may change over time, and to the extent possible, institutional arrangements should remain flexible so that they too can adapt as circumstances change.

One possible role for government is in providing a limited amount of centralized storage capacity in specified cases. In the United States, for example, the 1982 Nuclear Waste Policy Act called for the establishment of a small (1,900 tonne) federal government facility for storage of spent fuel in cases of particularly urgent need; the 1989 Monitored Retrievable Storage Commission endorsed this concept, and the Nuclear Waste Technical Review Board has recommended renewing the expired authority to establish such a facility.¹³

Time Frame and Relation to Permanent Solutions

A key issue for interim spent fuel storage is how long that interim period should be—and how to ensure that allowance for such interim storage will not undermine progress toward more permanent arrangements.

Strong arguments can be made both for specifying a particular period of storage and for leaving the time open. The history of the nuclear age is littered with unmet deadlines, and such failures to make progress on promised schedules (whether or not these milestones are realistic) can undercut the public credibility of nuclear waste programs. Schedule-driven programs may rush or compromise technical decisions.¹⁴ Moreover, technically, interim storage of spent fuel can be extended for many decades, with no particular time limit forcing it to end. On the other hand, at least some specificity as to how long spent fuel is expected to remain in storage is important, both for planning and putting in place a credible program leading toward that permanent solution, and for convincing local communities to accept interim storage facilities.

After considering the various issues, the authors believe that, except where a specific permanent approach is expected with good confidence to be implemented sooner, interim storage facilities should generally be planned to operate for a period in the range of 30–50 years. In the United States, the Nuclear Regulatory Commission currently only issues licenses for 20 years of interim storage, so a storage period of the suggested length will require license renewals. Even as material is placed in storage, adequate funds should be set aside in secure accounts to implement the planned permanent solution at the end of the planned storage period (to avoid placing an unfunded burden on the next generation), and institutional arrangements should be put in place to maintain progress toward permanent solutions. Some flexibility should be maintained to shrink or expand the planned 30-50 year period, as circumstances dictate.

¹³ See Nuclear Waste Technical Review Board, *Disposal and Storage of Spent Nuclear Fuel—Finding the Right Balance*, op. cit.

¹⁴ Many critics of the US repository program at Yucca Mountain make this charge. See James Flynn et al, *One Hundred Centuries of Solitude* (Boulder, CO: Westview, 1995), pp. 91-92.

Overcoming the Obstacles to Siting Interim Storage Facilities

The key obstacles to providing adequate capacity for interim storage of spent nuclear fuel are political, legal, and institutional. Engineering is not the main issue; politics is. But as Albert Einstein once said: “Politics is harder than physics.” Establishing adequate interim storage capacity for spent fuel is likely to be difficult in Japan, the United States, and in a number of other countries. This section provides suggestions for overcoming some of the obstacles to siting interim storage facilities, based on “best practice” lessons from siting of radioactive and hazardous waste facilities in the past, with brief descriptions of their application in the United States and Japan.¹⁵

There are no magic solutions, however. Approaches that may work well in one legal, political, and cultural context may not work as well in others. Even where suggestions such as these are followed, it must be recognized that siting such facilities raises fundamental issues for the management of policy in democracies. Central questions include both procedural and substantive *fairness* (between those who receive the benefit of the electricity generated and those asked to host the facility, and in determining who will be asked to host the facility); *trust* (especially between those proposing a facility and potentially affected communities—a critical problem in the United States, where public trust of both government and industry nuclear institutions is quite low); *sovereignty* (including national, regional, local, and even tribal power); *democratic governance* (particularly

whether to seek consensus or rely on majority rule); and clashes of *values and beliefs* (particularly between those who fundamentally oppose reliance on nuclear energy and those who support it). Siting such facilities also raises complex issues of what information and expertise is relevant. The “technical facts” presented by proponents of a facility are rarely considered by affected communities to be the whole story, yet other perspectives, other sources of information and expertise, often have difficulty making themselves heard and taken seriously.

In the United States, experience suggests that the guidelines offered in this section are much more important for establishing *new*, large centralized facilities than they are for simply adding dry cask storage to existing nuclear power plant sites. Many U.S. reactors have established on-site dry storage facilities, and only in a couple of cases has there been substantial local controversy, while *all* proposals for centralized storage or disposal facilities have encountered fierce controversy and opposition. As noted above, however, the relative ease of gaining acceptance for on-site facilities may be quite different in Japan, where commitments have been made to the communities where reactors are sited that fuel will be removed promptly. In that case, the guidelines below are likely to be important for both the at-reactor and centralized cases.

The Need for Democratic Approaches

Fundamentally, the record in recent years appears to demonstrate that open, democratic processes are more likely to succeed in identifying sites for hazardous and nuclear

¹⁵ We do not pretend to have fully surveyed the vast literature on the siting of nuclear and hazardous waste facilities. It is clear, however, that some lessons learned from successful siting of hazardous waste facilities are applicable to spent nuclear fuel, while others are not; and similarly, that some issues related to permanent waste disposal sites may be significantly different when considering temporary storage facilities for material that may be considered either as a waste or as a potential resource for the future. For a selection of some of this literature, see, for example: Riley E. Dunlap, Michael E. Kraft, and Eugene A. Rosa, eds., *Public Reactions to Nuclear Waste: Citizens Views of Repository Siting* (Durham, NC: Duke University Press, 1993), which provides a detailed review of the U.S. case; the papers collected in the “Fairness in Siting Symposium,” International Institute of Applied Systems Analysis, Laxenburg, Austria, 1995 (available at <http://www.fplc.edu/risk/siteIdx.htm>), published in *Risk: Health, Safety, and Environment* (Vol. 7, Spring 1996), which discuss siting of both hazardous and nuclear facilities from a variety of perspectives; Howard Kunreuther, Kevin Fitzgerald, and Thomas D. Aarts, “Siting Noxious Facilities: A Test of the Facility Siting Credo,” *Risk Analysis*, Vol. 13, No. 3 (1993), pp. 301-315, which attempts to use the lessons learned from past hazardous and nuclear waste siting experiences to pull together a set of recommendations for successful siting processes; P.J. Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities* (UK: Geosciences for Development and the Environment, March 1998, prepared for Sweden’s nuclear waste program and available at <http://www.radgiv-karnavf.gov.se/publikat/incitame.htm>), which, as the title implies, reviews various incentives offered to communities to accept nuclear waste facilities worldwide; Chris Zeiss and Lianne Lefsrud, “Making or Breaking Waste Facility Siting Successes With a Siting Framework,” *Environmental Management*, Vol. 20, No. 1 (January-

waste and spent fuel facilities where public support (or at least acquiescence) can be built and sustained than do secret, autocratic processes. There once was a time (and may still be, in a few countries) where it was possible for a government or a utility to choose a site for a major nuclear facility and build it, with little public involvement and discussion. In most countries, those times are long past. Today, because of public concerns over nuclear energy in general and the spent fuel and radioactive wastes it generates in particular, success in siting spent fuel storage facilities is likely to require a truly democratic process that puts a well-informed public in a position to ensure that its key concerns are heard and effectively addressed.

Yet many in the nuclear industry still instinctively attempt to keep plans for new facilities secret until important decisions are already made, and negotiations with selected key parties are already complete. This pattern typifies Japanese utilities' past efforts to establish a centralized interim storage facility, for example—though the increased openness shown in recent Japanese decision-making (such as the preparation of the long-term plan) suggests that new approaches may be taken in future efforts to site such a facility. While such approaches avoid public discussion (and attack) before the idea is fully developed, secrecy itself often becomes an issue contributing to public distrust. Moreover, arrangements originally developed in secret often do not adequately address concerns that arise once the project is revealed. In recent years, in a variety of countries, attempts to simply decide that a facility will be located at a particular place, announce that decision, and then ram the project through over local opposition—what is

sometimes referred to as the “decide, announce, defend” approach—have repeatedly failed.

The U.S. process for siting the Yucca Mountain repository, and efforts to put through legislation to establish a centralized interim storage site there, are cases in point. The U.S. Congress, by short-circuiting the scientific process to choose repository sites that it itself had created, and arbitrarily imposing Yucca Mountain on Nevada through the votes of representatives of other states, with little effort to soften the blow, ensured that Nevada would be resolutely opposed to the repository in perpetuity. Whether the federal government will succeed in opening Yucca Mountain over Nevada's determined opposition remains uncertain. The recent efforts to have Congress also impose a centralized storage facility on Nevada have only inflamed sentiment in Nevada further, and have so far failed. In Japan, too, given the increased public concerns over nuclear facilities in the wake of recent accidents and cover-ups, it appears unlikely that a major facility such as a centralized interim storage facility for spent fuel could be sited without an open and democratic process to address public concerns, as described below. The failure to site such facilities in the United States stands in sharp contrast to the comparatively open and voluntary process followed in Finland, to take one example, which led to the unprecedented situation of two communities actually competing against each other in their desire to host a permanent repository site—and the community that was *not* chosen for the site being the one that complained about the choice.¹⁶ The question, in short, is not whether to pursue a democratic process or not, but how best to structure a democratic process that works.

February, 1996), which discusses primarily Canadian cases; Felix Oberholzer-Gee, Iris Bohnet, and Bruno S. Frey, “Fairness and Competence in Democratic Decisions,” *Public Choice* Vol. 91, 1997, pp. 89-105, which discusses Swiss nuclear waste siting approaches; and the impressive report of the Canadian advisory panel on nuclear waste management (including detailed proposals for public participation processes for concept development and siting, and surveys of the international experience), *Nuclear Fuel Waste Management and Disposal Concept: Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel* (Ottawa, Canada: Canadian Environmental Assessment Agency, February 1998, available at http://www.ceaa.gc.ca/0009/0001/0001/0012/0001/report_e.htm). The process followed and topics covered by this panel, and the siting process it recommends, contrast sharply with the approaches that have been taken in the United States and Japan, which have generally been much less accessible to public input and broad discussion of issues of concern to the public.

¹⁶ See, for example, Ann MacLachlan, “Finnish Government Approves Eurajoki Repository Project,” *Nuclear Fuel*, December 25, 2000, and Ariane Sains, “Olkiluoto Signs Exclusive Agreement to Take Finnish Spent Fuel Repository,” *Nuclear Fuel*, May 31, 1999. The Finnish nuclear waste management firm, Posiva Oy, had launched a substantial educational and public

The Facility Siting Credo—And Some Additional Points

A 1990 U.S. workshop on approaches to siting hazardous and nuclear waste facilities produced a “Facility Siting Credo” with “best practice” suggestions designed to contribute to siting success, focused on both steps in the siting *procedure* and aspects of the *desired outcome* for siting.¹⁷ The elements of the credo are provided in Table 2 (slightly adapted for clarity). While this “credo” was developed in the U.S. context and is now a decade old, we believe that it offers very useful guidance for siting spent fuel interim storage facilities. Subsequent statistical work indicated that a number of the elements of the credo have contributed to success in siting hazardous waste facilities in the United States,¹⁸ and some studies suggest that similar approaches have contributed to success in Canada and Switzerland as well.¹⁹ It should be noted, however, that there have been relatively few real successes in recent years in siting storage or disposal facilities for spent fuel or high-level nuclear wastes; most of the successful experience in recent times, on which the credo was based, is in siting hazardous-waste management facilities, which pose many similarities but also some important differences. In particular, it appears that in the case of geologic repositories for high-level nuclear waste,

providing compensation to nearby communities has a much more problematic impact on public support than it does in the case of hazardous waste facilities.²⁰

We believe, moreover, that the credo as originally developed lacks one element likely to be crucial in siting interim storage facilities for spent fuel—namely, building confidence that the storage really will be temporary, and that permanent solutions will be forthcoming in a reasonable time. In addition, because the first of the “desired outcome” points—gaining broad agreement that not building a facility of some kind is not an acceptable course of action—is so crucial to moving forward with any of the other steps, we discuss this issue first. A modified version of the credo incorporating these points is presented in Table 3.

Achieve Agreement That a Facility is Needed

The crucial first step in finding a site for interim spent fuel storage is gaining broad agreement among affected parties (the “stakeholders” in current U.S. jargon) that such a facility is needed—that the outcome if such a facility were not built would be worse than the outcome of building a facility. In any discussion of a facility that might involve some risk, it is always crucial to include a comparison to the risks and costs of *not* having a facility.²¹ If this “compared to

involvement campaign in the communities under consideration that had been ongoing for several years, and offered a variety of forms of compensation to affected communities. Posiva Oy, for example, will finance a new home for elderly citizens in Eurajoki. In a Gallup poll taken in early 1999, two-thirds of the residents of both Eurajoki and Loviisa, the towns where Finland’s reactors are located, supported having a permanent waste repository in their home community if research demonstrated it was safe. See “Majority of Inhabitants in Loviisa and Eurajoki Approve of Final Disposal of Nuclear Waste,” press release, Posiva Oy (the Finnish nuclear waste management firm), April 30, 1999 (available at the Posiva Oy website, at <http://www.posiva.fi/englanti/default.htm>). The mayor of Loviisa complained about losing out to Eurajoki in the competition to host the repository: see Ariane Sains, “Posiva Ponders Whether to Continue Talks or Sign Exclusive Repository Pact,” *Nuclear Fuel*, May 17, 1999. There were opponents in Eurajoki, who sued to block the project after the town council voted in favor, but they were defeated in court. See Posiva Oy, “Overview on the Siting Process of Final Disposal,” available at the Posiva Oy website. A more detailed description of the various processes followed to inform and involve the public in the repository siting process—and the conclusions drawn concerning which factors were most important to the residents of the candidate communities—can be found in *The Final Disposal Facility for Spent Nuclear Fuel: Environmental Impact Assessment Report* (Helsinki, Finland: Posiva Oy, 1999).

¹⁷ Kunreuther, Fitzgerald, Aarts, “Siting Noxious Facilities: A Test of the Facility Siting Credo,” *op. cit.*

¹⁸ *Ibid.*

¹⁹ Howard Kunreuther, Paul Slovic, and Donald MacGregor, “Risk Perception and Trust: Challenges for Facility Siting,” presented at the “Fairness in Siting Symposium,” *op. cit.*

²⁰ Howard Kunreuther and Doug Easterling, “The Role of Compensation in Siting Hazardous Facilities,” *Journal of Policy Analysis and Management*, Vol. 15, No. 4, pp. 601-622, 1996.

²¹ For an analysis similarly highlighting the central importance of building agreement on the need for a facility as the initial step, see Zeiss and Lefsrud, “Making or Breaking Waste Facility Siting Successes,” *op. cit.*

*Table 2: The Facility Siting Credo***Procedural Steps**

- Institute a broad-based participatory process
- Seek consensus
- Work to develop trust
- Seek acceptable sites through a volunteer process
- Consider competitive siting processes
- Set realistic timetables (“go slowly in order to go fast”)
- Keep multiple options open

Desired Outcomes

- Achieve agreement that a facility is needed, that the status quo without it is unacceptable
- Choose the solution that best addresses the problem
- Guarantee that stringent safety standards will be met
- Fully address all negative aspects of the facility
- Make the host community better off
- Use contingent agreements (specifying what happens if something goes wrong)
- Work for geographic fairness

Table 3: A Modified Facility Siting Credo

- Achieve agreement that a facility is needed, that the status quo without it is unacceptable

Procedural Steps

- Institute a broad-based participatory process
- Seek consensus
- Work to develop trust
- Seek acceptable sites through a volunteer process
- Consider competitive siting processes
- Set realistic timetables (“go slowly in order to go fast”)
- Keep multiple options open

Desired Outcomes

- Choose the storage approaches and sites that best address the problem
- Guarantee that stringent safety standards will be met
- Build confidence that storage will be temporary and permanent solutions forthcoming
- Fully address all negative aspects of the facility
- Make the host community better off
- Use contingent agreements (specifying what happens if something goes wrong)
- Work for geographic fairness

what?” question is not front and center, discussion inevitably tends to focus on the possible negative aspects of a facility, and opposition builds. Indeed, there is substantial evidence that public perceptions include a substantial bias toward the status quo, or aversion to loss—that the desire for a future benefit from some action is less than the fear of comparable hazards from the action.²² This tendency must be overcome through a broad-based discussion of the risks and hazards of *not* providing ade-

quate interim storage facilities for spent fuel.

The public, and particularly residents of potentially affected communities, should not be expected to immediately agree when a government agency or a nuclear company argues that a new spent fuel storage facility is urgently needed. In the U.S. case, the government and the nuclear industry have been seeking to establish a large centralized storage facility for spent nuclear fuel for decades without success—yet no reactors have had to shut down as a result,

²² For a discussion focused on waste siting in particular, see Chris Zeiss, “Community Decision-Making and Impact Management Priorities for Siting Waste Facilities,” *Environmental Impact Assessment Review*, Vol. 11, pp. 231-255, 1991.

as reactor operators have expanded on-site storage through reracking spent fuel in their storage ponds and adding dry casks.²³ In the 1990s, though the industry argued strongly that a large centralized site was needed, and gained majorities of both houses of Congress in support of legislation to establish such a centralized facility, other experts made a compelling case that such a facility was not needed, because on-site dry-cask storage could meet the needs at comparable cost without incurring the costs and risks of transportation to a site that might still prove not to be a suitable location for permanent disposal.²⁴ In Japan, arguments over when a centralized storage facility will be needed, and of what size, depend in substantial part on issues such as whether and when reprocessing will begin at Rokkashomura, how much fuel will be reprocessed there, whether additional fuel will be reprocessed in Europe, and how much re-racking of spent fuel in existing ponds is possible.

In short, the public will suspect, often rightly, that proposals from the nuclear industry or the nuclear agencies of the government are based primarily on the interests of those companies and agencies, and may not have fully considered all factors affecting what the public would consider to be its own interests.

Nevertheless, in most cases, the industry can outline how much spent fuel is generated at particular reactors each year and how much storage space is available, making a strong case for the need for more storage capacity by a particular time. (Even such seemingly simple calculations, however, are complicated by possibilities such as additional re-racking, moving spent fuel from full pools to nearby pools that have more space, and the like.) It should then be possible to explain that if more storage space is not available by that time, the reactor or reactors in question would have to shut down. But to build the credibility of such calculations, it will often be useful to provide analysts who are perceived as fully independent of the nuclear industry the information and resources needed to prepare an independent analysis of the issue.

Complete consensus on the need to establish such a facility is unlikely, especially in the United States. To oppo-

nents of nuclear energy, “choking the industry on its own waste” is precisely the *desired* outcome; to them, the fact that a reactor would have to shut down if more storage is not provided is not a problem but an opportunity to move toward their goals. Such opponents cannot be expected to support the establishment of interim storage facilities. But in communities that have received substantial benefits from nuclear reactors (such as tax revenues and jobs), in many cases it is likely to be possible to generate broad agreement among all but a small minority that premature shut-down of the local reactor would be undesirable, and that the steps needed to prevent such a premature shut-down should be taken.

Procedural Steps

Institute a Broad-Based Participatory Process

As noted already, experience in a wide range of siting processes around the world suggests that a truly democratic process, where a broad range of participants are involved and given full information from the earliest stages, is more often successful than a secretive “decide, announce, defend” approach.

Ideally, a broad-based process should put all potentially affected parties in a position to be fully informed and to have a voice in deciding the outcome. The public should be given the resources needed for effective participation, and should have the opportunity to have independent experts review the recommendations of facility supporters. Processes can be structured that allow the risks, costs, and benefits of different sites (and the assumptions underlying these calculations) to be collected, analyzed, and widely shared. By contrast, processes that secretly seek agreement with only a few parties, such as a local elected official or representatives of one key local industry, create distrust among the excluded parties and undermine their acceptance of the proposed facility.

A broad-based participatory process means much more than having a public meeting where anyone who attends can get up and say a few sentences, followed by an

²³ Nearly a fifth of the U.S. reactor fleet has shut down for other reasons, such as the need for expensive capital repairs that were not economically justified under current market conditions.

²⁴ Allison Macfarlane, “Interim Storage of Spent Fuel in the United States,” *op. cit.*

opportunity, months later, for the public to comment on a several-thousand-page final document analyzing the proposed facility. (This tends to be the approach taken in the U.S. Department of Energy's public consultations under the National Environmental Policy Act.) A genuinely democratic process involves multiple opportunities for sustained dialogue, with citizens given the opportunity to learn about proposals in detail; facility proponents given the opportunity to learn about citizens' concerns, beliefs, and values; and all parties given an opportunity to work together toward approaches that serve the interests of as many parties as possible.

A variety of specific models for such processes have been attempted or proposed in different situations, and optimal approaches are likely to vary depending on political and institutional structures and cultures in particular cases. In Canada, for example, the Environmental Assessment Agency established a broad-based panel to review an approach to nuclear waste management put forward by Atomic Energy of Canada Limited (AECL); after many public hearings and discussions with a broad range of affected parties, the panel made a detailed proposal for a step-by-step democratic, participatory process for deciding on a particular repository approach and site, designed, in the panel's words, "to build public acceptability."²⁵ Another interesting case of a mechanism for public participation in decisions relating to management of nuclear wastes and cleanup—with both positive and negative aspects—are the site-specific citizen advisory boards established by the U.S. Department of Energy (and similar advisory boards established by the U.S. Department of Defense) to provide local advice and input on the cleanup of major sites contaminated by Cold War nuclear activities.²⁶ In general, once particular sites are under consideration for an interim storage facility for spent nuclear fuel, some form of local advisory or control boards are likely to be essential features of a broad-

based participatory process.

By their nature, genuinely democratic processes are messy, uncertain, subject to shifting political winds, and impossible for facility supporters to control. (Such control by one set of participants would negate the purpose of a democratic process.) No guarantee can be offered that the process will succeed in establishing a site the public will accept. For nuclear industry officials seeking to minimize business uncertainties, this approach is not an attractive prospect at first glance. But repeated experience in a number of countries suggests that in fact such processes have higher probabilities of success than traditional, secretive, "decide, announce, defend" approaches. It is essential to build a process for choosing an approach and a site that participants perceive as fair, and that allows all the parties to be heard and to work together.

In the balance between government and private sector responsibility, one potentially important role for government is to establish and oversee such a broad-based participatory process for decisions about interim spent fuel storage. If the entire process is controlled and managed by the private-sector proponents of building a facility, the process is unlikely to be seen as genuinely democratic, fair, and unbiased—perceptions that are crucial to success in building public support.

Seek Consensus

Seeking consensus on the approach to be taken and the site where a facility is to be located requires attempting to address the many different values, concerns, and desires of the various affected parties. Technical analyses by government and industry should be subjected to independent review, and complemented by the "local expertise" of those who live near the proposed facilities. Substantial time may be needed for discussion, and in some cases mediation may be useful.²⁷

²⁵ See *Nuclear Fuel Waste Management and Disposal Concept*, op. cit., especially Chapter 6 and Appendix O. For an overview of and commentary on the Canadian process for identifying an approach and a site for a repository, emphasizing the importance of the extensive public involvement efforts and the decision to move forward slowly (two key elements of the Facility Siting Credo), see Michael E. Kraft, "Policy Design and the Acceptability of Environmental Risks: Nuclear Waste Disposal in Canada and the United States," *Policy Studies Journal*, Vol. 28, No. 1, 2000 (pp. 206-218).

²⁶ See Jennifer Weeks, *Advice—and Consent? The Department of Energy's Site-Specific Advisory Boards*, BCSIA and Science, Technology, and Public Policy Program Discussion Paper 2000-14, Belfer Center for Science and International Affairs, September 2000.

²⁷ Sweden, for example, has established the office of a national "facilitator" for nuclear waste management, whose role includes helping to mediate siting discussions.

In the case of spent nuclear fuel, complete consensus is likely to be impossible to achieve, since, as noted above, nuclear critics are unlikely ever to agree on arrangements for interim spent fuel storage. In Japan's "consensus talks" on the future of nuclear energy, there has been considerable difficulty in reaching consensus, or even defining what precisely is meant by the goal of seeking consensus in an environment where there are a variety of different views of the issues.²⁸ Moreover, a growing literature suggests that in large groups where interests conflict, seeking full consensus may not be the best approach to setting policy.²⁹

Nevertheless, it is important to seek as broad agreement on the path forward as possible. A demonstrated commitment to seek the broadest possible support can help prevent participants from concluding that the process is unfair. Moreover, experiences in the United States and elsewhere (such as the Mescalero Apache case, where one vote rejected a facility and another approved it) make clear that when only a bare majority in a community supports a controversial new facility such as a spent nuclear fuel storage site, there is a substantial chance that political change will lead to a rejection of the facility, or that the overruled minority will mount effective challenges to the establishment of the facility (whether on the barricades or in the courts). The 30,000 riot police required to protect the shipment of nuclear waste to a disposal site in Germany in 1997 are one example of the latter phenomenon.³⁰ Arguably some form of super-majority—two-thirds, or even three-quarters—should be required in local votes on whether to host a spent fuel or nuclear waste facility.³¹ Otherwise, the potential for political reversal, or for minority protest effective enough to stop the project, may just be too great.

Work To Develop Trust

Earning the trust of the potentially affected communities is a crucial element of success in siting facilities such as hazardous or nuclear waste repositories, or spent fuel interim storage facilities. No one is going to let someone they do not trust build such a facility in their backyard.

Unfortunately, in the world of nuclear waste management, trust is in scarce supply. The key government nuclear institutions in the United States, especially the Department of Energy, are deeply distrusted by a broad swath of the public—and for many good reasons, following decades of contamination, cover-ups, and lies during the Cold War. The commercial nuclear industry also faces substantial distrust, particularly over the safety of nuclear facilities. In Japan, trust in government and industry has traditionally been much higher than it has been in recent decades in the United States, but this trust was shaken in the late 1990s by the series of accidents in the nuclear industry culminating in the accident at the JCO plant at Tokai-mura in 1999. Each of these accidents was followed by either misleading initial statements or active cover-ups of key information or both, greatly undermining public confidence in government and industry's ability to achieve high levels of safety and to provide accurate and complete information.

Trust, of course, has to be earned. But it can be difficult to begin earning trust in a community until residents are willing to allow at least some preliminary activities to study a site. A key element of earning trust is gaining a reputation for providing information that is accurate, complete, and timely. In particular, it is important to admit past mistakes, identify specific approaches that have been put in place to prevent them from recurring, and avoid exaggerat-

²⁸ See Susan E. Pickett, *Integrating Technology and Democracy: Nuclear Energy Decision Making in Japan*, Ph.D. dissertation, Tokyo University, Department of Quantum Engineering and Systems Science, 1999.

²⁹ For a useful discussion of the differing circumstances in which consensus processes and majority-rule processes best protect the interests of all parties, see Jane Mansbridge, *Beyond Adversary Democracy* (Chicago: University of Chicago Press, 1983); for an argument that a focus on consensus can lead to less than optimal policy outcomes, see Cary Coglianese, *Rethinking Consensus: Is Agreement a Sound Basis For Regulatory Decisions?*, working paper (Cambridge, MA: John F. Kennedy School of Government, 1999, available at <http://www.ksg.harvard.edu/prg/topics.htm#environmental>).

³⁰ See Mark Hibbs, "Police, Agitators Clash on Eve of Final Lap of Gorleben Trek," *Nucleonics Week*, March 6, 1997.

³¹ In the case of the Private Fuel Storage firm working with the Skull Valley Band of Goshutes in the United States, reportedly two-thirds of the roughly 70 voting members of the tribe signed a document supporting negotiations to host the site. But even that claimed super-majority has been challenged by allegations of bribery and other improper measures to convince members to sign, and opponents within the tribe are challenging the project in court. See Brent Israelsen, "Bribe Allegations Made In Goshute Suit," *Salt Lake Tribune*, August 27, 1999. News stories on the project are available at the Goshutes' website, at <http://www.skullvalleygoshutes.org>.

ed claims and assurances that may not be fulfilled. (The nuclear industry is still suffering from the damage inflicted by the claim of electricity “too cheap to meter.”) In this respect, an important lesson of many siting controversies is that *openness works better than secrecy*. Stakeholders are more likely to accept nuclear facilities if they understand them well. Secret decision-making and negotiations, with exclusion of some affected parties from discussions, only breed suspicion and bitterness. Lack of credible, trusted information leads to exaggerated fears. Moreover, independent peer review can often uncover flaws or opportunities for improvement in the best-laid plans, but such peer review is only possible if complete information is available. Therefore secrecy undercuts safety. Finally, where no credible and detailed information is available from supporters of a facility, opponents are much more likely to be able to convince the public to accept their version of the facts as correct.

Information flow should be a two-way street, with the public receiving information it regards as complete from sources it regards as credible, and also having the opportunity to make its concerns heard early in the decision process and have them taken seriously. Institutions such as citizens advisory boards that provide ongoing input into the siting, design and management of facilities may help build trust and assure communities that well-informed community representatives will be involved in every step of the process.

Building trust when dealing with nuclear spent fuel is inherently difficult. Where trust is lacking, therefore, it makes sense to build additional community confidence through the application of Ronald Reagan’s famous credo: “Trust, but verify.” Steps to involve the community and give it more resources to monitor and enforce commitments—such as funding for the community to hire its own experts to evaluate proposals, construction, and operation of a facility; funding for local monitoring capabilities; citizen advisory boards; and local power to impose penalties or even shut a facility if commitments are not fulfilled or significant accidents occur—can provide “checks and balances” in the management of such facilities.³²

Seek Acceptable Sites Through A Volunteer Process

Rather than imposing a site on a community through decisions made elsewhere, the ideal outcome is for a community to actively volunteer to host a facility such as an interim spent fuel storage site. Such a scenario is unlikely unless other elements of the facility siting credo have been implemented—in particular, building trust in the institutions proposing the facility; ensuring that the facility will be safe; and making clear that there will be substantial benefits to the community from hosting a facility (described below). It is also important to make clear at the outset that volunteering to explore the idea does not represent an irreversible commitment to go forward.

Many countries, including, the United States, Japan, France, Canada, Switzerland, Finland, and Sweden have sought to use such a voluntary process to site nuclear waste or spent fuel storage or disposal sites.³³ As described in chapter 3, for example, the U.S. Nuclear Waste Negotiator convinced several Indian tribes to volunteer for initial studies of serving as hosts for an interim spent fuel storage site. Most decided not to go further, as the process became more and more controversial among the members of the tribe, but the proposals for storage sites hosted by the Mescalero Apache and the Skull Valley Goshutes both had their origins in this process, and the Goshute proposal is still moving forward. In Japan, since formal site investigation can begin only after an invitation from the local community, the siting process is a voluntary one. Since the process of issuing such invitations to begin investigations is informal, however, it is often accompanied by disputes over who has the authority to approve such a facility (see discussion below).

The Finnish case is the only one involving high-level wastes or spent fuel (as opposed to low-level wastes) where such a voluntary process has proceeded all the way to a decision to locate a repository at a particular site—with strong support among the inhabitants in that community. A large fraction of Finland is on granite bedrock suitable for geologic disposal, so a wide range of sites was available to consider. Studies were carried out at several sites over a

³² See Kunreuther, Slovic, and MacGregor, “Risk Perception and Trust: Challenges for Facility Siting,” *op. cit.*

³³ See, for example, Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, *op. cit.*

period of several years, and a publicly available Environmental Impact Assessment was issued in 1999 (prepared by the Finnish nuclear waste management firm, Posiva Oy, but reviewed and approved by the Ministry of Trade and Industry), covering four potential sites.³⁴ A separate safety analysis was also issued in 1999, and the Finnish nuclear regulatory authority formed an international review panel to consider it, which recommended moving ahead with further development of the repository. The volunteer principle is enshrined in Finnish law, as the nuclear waste law mandates that no decision on siting a repository can be made without the approval of the host community. Open forums, small discussion groups, and repeated meetings with elected officials were held in the potential host communities to give them an opportunity to express their concerns; both measures to ensure safety and potential compensation measures were discussed publicly.³⁵ Ultimately some of the communities under consideration opposed hosting the facility, but at least two of them—the two where Finland's existing reactors are located, both of which already had low-level waste repositories—indicated that they would like to host the repository.³⁶ The Finnish government then approved the siting of the repository at one of these two communities, Eurajoki—the community where there was no organized group opposing the project.

Elsewhere in the world, there are many cases in which either no suitable communities volunteered, or local governments volunteered a community for early study stages, but local politicians or voters subsequently rejected pursuing the idea further. In a few cases in Canada, the United

States, and Switzerland, among others, volunteer processes have been used successfully to site facilities for hazardous wastes and low-level nuclear wastes (see discussion under “Make the Host Community Better Off,” below).³⁷

There are also arguments against volunteer processes. Among the most important is the “environmental justice” problem: communities who volunteer to host a nuclear waste or spent fuel facility in return for some form of compensation are likely to be poor communities with few other economic opportunities.³⁸ The volunteer approach, therefore, can be faulted for disproportionately imposing hazardous facilities on disadvantaged communities, which may also disproportionately be made up of racial minorities. (See “Work for Geographic Fairness,” below.)

One key question that must be addressed in a volunteer process is who has the authority to volunteer a community. Elected local or regional councils may volunteer a community for initial studies, but a final decision to move forward and host a facility probably should be made by a binding referendum of local residents, to enhance the legitimacy of the decision.

But even if a local community volunteers, its neighbors and its region may be opposed. As a result, the differing local, regional, and national levels of sovereignty pose a key problem for the volunteer approach. In the current Skull Valley, Utah proposal the Goshutes (who, under U.S. law, have sovereignty on their reservation) want to host the site. The county in which the site would be located has also reached an agreement with the firm attempting to build the site, and the Federal government and its regulators seem

³⁴ *The Final Disposal Facility For Spent Nuclear Fuel*, op. cit.

³⁵ For discussions of the process used, see *The Final Disposal Facility For Spent Nuclear Fuel*, op. cit., and Posiva Oy, “Overview On the Siting Process of Final Disposal,” op. cit.

³⁶ The city council of Eurajoki voted 20-7 to support hosting the facility, while Loviisa's support was expressed by its mayor. As noted above, two-thirds of the residents of both communities supported hosting a repository if research showed that it was safe. See Sains, “Posiva Ponders Whether to Continue Talks or Sign Exclusive Repository Pact,” op. cit.; and Posiva Oy, “Majority of Inhabitants in Loviisa and Eurajoki Approve of Final Disposal of Nuclear Waste,” op. cit.

³⁷ See, for example, the brief discussions in Kunreuther, Slovic, and MacGregor, “Risk Perception and Trust: Challenges for Facility Siting,” op. cit., and sources cited therein.

³⁸ Interestingly enough, this does not appear to have been the case in the successful Finnish case. The communities that volunteered, Eurajoki and Loviisa, while significantly dependent on the nuclear power plants in their communities, were in significantly better shape economically than the communities that tended to oppose the facility, where unemployment ranged as high as 30%. Moreover, a study of who supported and who opposed hosting the repository found that “The supporters of the project tend to be better off people. It is likely that the supporter has good education, a good income, a good occupational position, and quite a lot of knowledge about nuclear waste.” Tapio Litmanen, “Cultural Approach to the Perception of Risk: Analysing Concern About the Siting of a High-Level Nuclear Waste Facility in Finland,” *Waste Management & Research*, Vol. 17, 1999, pp. 212-219.

favorably inclined, but the State of Utah is unalterably opposed to a site in its state—even threatening, as described in Chapter 3, to take over all the roads around the reservation to create a state-owned “moat” that spent fuel could not cross.³⁹ Similarly, in the mid-1980s the community of Oak Ridge, Tennessee considered serving as host for a spent fuel storage facility, but the idea was vetoed by the state. In Japan, the town of Horonobe in Hokkaido officially invited a site investigation for the proposed Underground Research Laboratory for high-level waste. The Governor of Hokkaido, however, opposed hosting such a facility, and as a result it took more than 10 years to negotiate the siting conditions—which now include the use of the facility only for research not involving any actual radioactive waste.

In other cases, neighboring communities rather than regional governments may be the key opponents. Or, rather than a small governmental unit being in favor and larger ones opposed, it may be the reverse: in the case of an international site in Russia, for example, the national government appears to be in favor, but local and regional governments at some of the proposed sites (such as Chelyabinsk Oblast) appear to be opposed.⁴⁰

Thus, in considering voluntary siting processes, the issue of who has the authority to volunteer, and how to engage the other governmental levels involved in the process, has to be addressed with considerable care. In general, it is likely to be essential to address the concerns of *each* government layer whose approval is required—local, state or regional, national—to gain the level of support needed for a stable environment in which to build and operate an interim spent fuel storage facility.

Consider Competitive Siting Processes

In an even more desirable scenario, two or more communities could volunteer and compete against each other to be

chosen for such a site. Such an approach preserves more options and greater flexibility than pursuing only a single site, and reduces the degree to which any one community feels “singularized” as the only one being seriously considered for the storage or disposal facility in question. From the facility proponent’s point of view, competition between communities may reduce the price the host community may be able to charge. In a number of cases around the world, studies have been initiated at multiple communities, with the hope of choosing from among a pool of potential host sites.⁴¹ But because such communities decided against pursuing the idea beyond early study stages, or because the process is still underway, the Finnish case described above is the only one anywhere in the world where a competitive siting process involving storage or disposal of spent fuel or high-level nuclear waste has been implemented through the stage of definitely choosing a site. Competitive siting processes have also been fully implemented in at least a few cases involving facilities such as prisons, however.⁴²

Set Realistic Timetables (“Go Slowly In Order To Go Fast”)

Attempting to rush a siting process—particularly for a facility intended to last decades (in the case of an interim storage facility) or millennia (in the case of a repository)—can seriously undermine the chances of success. It takes time to build trust, and genuinely broad-based participatory processes tend to be time-consuming and unpredictable. At the same time, however, some form of timetable should be set to help structure the process and prevent it from dragging on forever.

Nuclear projects around the world have set and missed many unrealistic deadlines. Repeated failure to meet such deadlines undermines trust, and erodes the credibility of the institutions (both government and private) responsible for managing spent fuel and nuclear waste. In

³⁹ The State of Utah has created a Task Force Opposing High Level Nuclear Waste, whose webpage is available at http://www.eq.state.ut.us/hlw_opp.htm.

⁴⁰ Several regional legislatures have voted to oppose the import of spent fuel. Opponents of the import have quoted the vice-governor of the Chelyabinsk region (home of the Mayak reprocessing facility, a likely site for storage) as being strongly opposed to storing imported spent fuel in the region. See ECODEFENSE!, “Chelyabinsk Authorities Speak Out Against Nuclear Waste Import,” press release, August 9, 2000.

⁴¹ Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, op. cit.

⁴² See, e.g., Howard Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” op. cit.

the United States, for example, setting a 1998 deadline for opening a permanent repository at Yucca Mountain in the 1982 Nuclear Waste Policy Act, as reasonable as it may have seemed at the time, turned out to be a substantial mistake. This timetable proved to be unrealistic, and it led utilities to make plans based on the deadline and then to change them when it came and went. The failure to meet the deadline set off a wave of lawsuits and proposed legislation, and the continuing focus on deadlines for moving forward with the repository fostered complaints that the science to determine whether Yucca Mountain would be a safe repository is being rushed to meet artificial time constraints. Similarly, in Japan, the Rokkasho reprocessing plant that was planned as the destination for most of Japan's spent fuel has been delayed by more than 10 years (though its spent fuel storage pool was completed much sooner). Such delays have generated concern in surrounding areas that the spent fuel could stay at Rokkasho much longer than previously expected. Based on such past experiences, the latest long-term plan for nuclear energy abandons the past practice of setting timetables and targets for the construction of additional nuclear power plants, leaving such decisions to the private sector.

Similarly, efforts to set short deadlines for establishing an interim spent fuel storage site (such as the U.S. Congress's repeated efforts to pass legislation mandating that a site be open within four to five years) are at least as likely to slow progress as to speed it up, since affected communities react negatively to a process perceived as a "rush job." And the virtually inevitable failure to meet such a deadline would then potentially create grounds for another wave of legal actions, legislative debates, and the like. The lesson: the fastest and most effective approach to establishing interim spent fuel storage sites is not to rush, but to set timetables that leave plenty of time for all the necessary steps of the process, and are flexible enough to accommodate delays as the process proceeds.

Keep Multiple Options Open

Another important step in the facility siting credo is to keep multiple options open for as long as possible—not only multiple potential sites, but also multiple approaches to managing the fuel or waste for which a site is being sought. In the case of U.S. spent fuel storage, for example, while the U.S. government was pursuing a permanent repository, the utilities also pursued expanded on-site storage of spent fuel

(both reracking their pools and establishing dry cask stores), attempted to pass legislation mandating a centralized government-run storage site, and simultaneously pursued negotiations to establish centralized privately-run storage sites. In Japan's case, as the government and utilities pursue a centralized interim storage site, it may also be worth considering adding additional at-reactor storage (as has been done at Fukushima), so that delays in a centralized site and at Rokkasho-mura do not force the utilities into accepting additional contracts for reprocessing in Europe.

Desired Outcomes

Choose the Solution that Best Addresses the Problem

To gain approval of a particular spent fuel storage site, it is crucial to make the case that the site in question will provide long-term safety, and that the specific proposed facility is well designed to provide safety, flexibility to respond to changing circumstances (including whatever problems may arise), and sufficient capacity to store all the spent fuel in question.

In the case of interim storage of spent fuel, a broad range of potential locations can provide high levels of safety if the facility is appropriately designed. Many more potential sites exist for a facility that is only designed to maintain dry casks safely for a few decades than for permanent disposal of spent fuel or high-level nuclear wastes, where the geology must be suitable over periods of tens or hundreds of thousands of years. If a community is interested in serving as a host site for an interim storage facility, the facility can readily be designed to address local conditions, such as the high seismicity in the area of the proposed Skull Valley storage facility. But if political processes impose such a facility on an unwilling community in an area that is clearly not the best possible choice from a safety point of view (for seismic or other reasons)—as in the case of the U.S. proposed legislation to create a centralized storage facility near Yucca Mountain, an area of high seismicity—this will tend to exacerbate local opposition and protest over the proposed facilities, making clear that these communities were not chosen because they were technically the best choices. Here, there is an essential role for government in establishing agreed screening criteria so that only sites that can provide adequate safety are considered, and in establishing the safety standards that facilities must meet.

Guarantee that Stringent Safety Standards Will Be Met

Guaranteeing that the facility will meet stringent safety standards is among the most fundamental requirements for gaining support for an interim spent fuel storage facility. Particularly when the issue at hand is spent nuclear fuel, which provokes intense fear and dread, no one is going to want such a facility if they believe that having it will put themselves or their children at risk.

Fortunately, as described elsewhere in this report, interim spent fuel storage facilities can be designed to provide high levels of safety for decades—indeed, they can be among the least hazardous of all nuclear energy facilities. But in most cases, before even attempting to find volunteer communities or to discuss what benefits might be offered to a community willing to host such a facility, it will be crucial to make the safety case in detail—and to allow experts perceived as fully independent of those proposing the facility to review it. In a 1993 U.S. study, for example, giving an *independent* agency the authority to inspect the safety of a facility dramatically increased the percentage of those surveyed who would be willing to have a nuclear waste facility in their community. In another survey asking respondents to judge what measures would be very important to gaining support for a nuclear waste repository, strict government safety standards with on-site inspection ranked first, with all of the safety measures suggested in the poll ranking ahead of all of the compensation measures suggested.⁴³ In another U.S. survey relating to transport of radioactive materials, independent certification of safety was one of the most effective measures for increasing respondents' support for transportation through their communities. Other particularly effective steps included establishing a national laboratory to study means to reduce generation of such wastes in the future; giving state government the power to limit transports to the safest times; and ensuring that drivers had extensive safety training.⁴⁴

In the case of Japanese nuclear facilities, nuclear safety agreements incorporating a range of specific commitments are typically negotiated with local and prefectural governments, in addition to the formal licensing process, which includes an independent review of safety by government authorities. In the case of proposed interim spent fuel storage facilities in the United States, such as the currently proposed Skull Valley and Owl Creek facilities, proponents must prepare extensive safety analyses for submission to the Nuclear Regulatory Commission, analyzing how the proposed facility would meet all regulatory requirements. These documents are made available for public review (though not in a very convenient manner). The NRC then prepares a draft environmental impact statement analyzing the likely impact of the proposed facility, which is published for public comment and hearings, and a Safety Evaluation Report analyzing the safety of the proposed facility in detail. Thus, detailed and public safety analyses by both advocates of a facility and an independent government regulatory body are required, and a potential host community has multiple opportunities to intervene in the licensing process to express concerns about the safety analyses.⁴⁵ Nevertheless, such analyses are often criticized for failing to take into account all the factors that a local community or state may find important.

Another important step to build local confidence in the safety of a proposed facility is to increase the local community's ability to understand, monitor, and control safety. In Japan, for example, some nuclear safety agreements include provisions for financing independent local radiation monitoring, giving the community at least a modest measure of independent capability to monitor safety of the nuclear facilities. Similarly, the U.S. Department of Energy has helped finance a substantial infrastructure of local and state government experts on issues associated with transport of spent fuel and other nuclear materials—a network of experts that often criticizes DOE's efforts, but also often

⁴³ Both studies are reported in *ibid.*

⁴⁴ Hank C. Jenkins-Smith, Amy Fromer, and Carol L. Silva, *Transporting Radioactive Materials: Risks, Issues and Public Perspectives*, (Albuquerque, NM: University of New Mexico Institute for Public Policy, 1996), pp. 24-30.

⁴⁵ The NRC's Safety Evaluation Report for the Skull Valley facility can be found at <http://www.nrc.gov/NRC/NMSS/SFPO/SER/PFS/ser.html>; the NRC's draft Environmental Impact Statement for the facility is available at <http://www.nrc.gov/NRC/NUREGS/SR1714/index.html>.

succeeds in negotiating improved arrangements for proposed transports.⁴⁶ Federal law requires steps to provide local communities with appropriate emergency monitoring and management capabilities. Ultimately, such local monitoring and analysis capabilities are much more satisfying to local communities if the community also has the power to take some appropriate action—such as requiring that operations at the facility be halted, or the entire facility closed—if monitoring should reveal some significant safety problem. (Such arrangements are discussed under “Use Contingent Agreements,” below.)

Fully Address All Negative Aspects of the Facility

Inevitably, even an extremely safe facility will have some negative aspects, and a crucial part of building trust and support with potentially affected communities is to address these negative aspects forthrightly and completely. For example, if a large amount of spent fuel is going to be stored at a particular location, some may fear that location will come to be associated in the public mind with “nuclear waste,” and that this could affect local industries such as tourism, farming and fishing, as well as real estate values and efforts to attract new firms to the area.

In one typical remark emphasizing this point, Governor Jim Gehringer of Wyoming, commenting on the proposal to site a privately owned and managed centralized spent fuel storage facility in his state, said: “I worked with nuclear weapons for a long time. You can effectively handle nuclear materials and spent [fuel] storage. That’s not the point. The point is what do we want to be known for? Wyoming does not want to be known as a nuclear waste repository, pure and simple.”⁴⁷ The nuclear industry, of course, is quick to point out that spent fuel storage facilities need not have such effects; the Swedish CLAB facility, for example, is sited near one of Sweden’s popular Baltic Sea

resorts, while the dry cask storage facility at Virginia’s Surrey Nuclear Power Station is located near the popular Williamsburg colonial heritage site, and neither appears to have had any significant negative impact on tourism for those regions.

Ultimately, all the issues that potential volunteer communities regard as important must be addressed if siting is to be successful. In general, issues based on negative impacts on perception of the community are best addressed both through education and publicity campaigns designed to ameliorate such negative attitudes, and through providing various forms of compensation to the affected communities, discussed below.

Make the Host Community Better Off

Communities are not likely to accept a facility for storing or managing spent nuclear fuel or nuclear waste unless they believe they will be better off overall with the facility than without it. Making the host community better off involves mitigating the risks and costs of hosting a facility as much as possible, and providing benefits of various kinds that compensate for any remaining disadvantages of hosting a facility. Instinctively, many nuclear experts with an engineering or economics training tend to view siting as a simple matter of letting the free market operate: offer money for hosting the facility, and whichever community with an appropriate site will take the facility for the least money gets to have it. (A specific implementation of this approach, in which the siting authority posts offers of slowly increasing amounts of money for hosting a facility until some community agrees to do so, is known as a “reverse Dutch auction.”⁴⁸)

Experience indicates, however, that the issue of compensating potentially affected communities is much more complex and problematic than this simple model would make it seem. While often portrayed as the “answer” to the

⁴⁶ See, for example, the website of the High Level Radioactive Waste Committee of the Western Interstate Energy Board (a group of the state governments of Western states in the United States), at <http://www.westgov.org/wieb/hlw1.html>.

⁴⁷ Quoted in Robert W. Black, “Nuclear Storage Facility Could Create 3,000 Jobs, Study Shows,” *Associated Press*, January 19, 1999.

⁴⁸ For a discussion of applying this approach to siting a nuclear waste repository in the United States, see Herbert Inhaber, “Can an Economic Approach Solve the High-Level Nuclear Waste Problem?” *Risk: Health, Safety & Environment* Vol 2 (Fall 1991), available at <http://www.fplc.edu/risk/vol2/fall/inhaber.htm>. Inhaber elaborates the argument further in his book *Slaying the NIMBY Dragon* (Las Vegas, NV: Nevada Policy Research Institute, 1997). For a slightly different approach involving sealed bids, see Howard Kunreuther and Paul Kleindorfer, “A Sealed-Bid Auction Mechanism for Siting Noxious Facilities,” *American Economics Review: Papers and Proceedings*, Vol. 76 (1986).

not-in-my-backyard (NIMBY) problem, voluntary approaches with compensation have produced relatively few successes to date.⁴⁹

It is possible, as proponents of compensation-based approaches argue, that this is primarily because of flawed implementation in the efforts to use such approaches so far. In the case of nuclear waste disposal facilities, for example, a remarkable number of processes in different countries have offered communities initial study and planning grants without describing even the rough types and magnitudes of compensation that might ultimately be available if the community agreed to host a facility. This approach inevitably creates a situation in which communities have no real idea of what benefits might be available, even as they gain a better and better understanding of the potential negative aspects of hosting a facility. Moreover, in some cases the institutions charged with negotiating arrangements with local communities had no authority to commit that specific benefits would be provided, because the government or industry had not committed to pay the cost, making effective negotiation and trust-building with the community nearly impossible. The author of a survey of these episodes concludes that key lessons are that “packages describing generalized areas of negotiable benefits must be clearly laid out at the very start of a process,” and that “there should be a clear commitment from the very beginning that all negotiated benefits packages will be honoured by central government and/or other relevant funding bodies.”⁵⁰

Moreover, considerable polling data suggests that monetary compensation can be ineffective or even counterproductive in increasing public support for hosting a facility for storage or disposal of nuclear waste or spent nuclear fuel, even if it is effective for less controversial facilities such as prisons or factories.⁵¹ In several studies, the percentage of those questioned who were willing to support a nuclear waste facility in their community did not increase signifi-

cantly when the prospect of compensation was raised, even if the compensation amounted to thousands of dollars per year per family. Moreover, in some surveys, the percentage of respondents willing to support a nuclear waste facility actually *declined* when the idea of compensation was raised—perhaps by provoking potentially affected individuals to believe that if they were being offered money to accept a facility, the facility must pose a more serious hazard than they realized at first. In a number of cases, opponents of facilities have seized on offers of compensation as “bribes” intended to buy off community opposition, and hence an additional argument *against* hosting the facility. The authors of a survey of these results recommend:

- giving first priority to mitigation measures to ensure safety and local control, with compensation measures taking second place;
- establishing a process that can help “convince local residents that a facility is needed from a societal perspective and the siting procedure is fair.” They suggest, toward this end:
 - establishing a Public Siting Authority that would specify technical criteria that sites would have to meet to be considered, and safety standards for proposed facilities; and
 - carrying out a fully voluntary siting process, with negotiated compensation packages, so that “no community is forced into accepting a facility against its wishes.”⁵²

Similarly, the author of a survey of compensation approaches for siting of spent fuel and nuclear waste facilities worldwide, concluded that:

It is probably best to concentrate on demonstrating the fairness of the process, itself no easy task, and the safety of the concept, assum-

⁴⁹ See, for example, Joanne Linnerooth-Bayer and Kevin B. Fitzgerald, “Conflicting Views on Fair Siting Processes: Evidence from Austria and the U.S.,” in *Fairness in Siting Symposium*, op. cit. Pointing to experience with hazardous waste siting in the United States, Linnerooth-Bayer and Fitzgerald argue that “The market approach to siting noxious facilities has had little success...With few exceptions, these approaches have failed to reach agreement on compensating the host community.” For a modestly more optimistic account taking its success stories from a broader range of types of facilities, see Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” op. cit.

⁵⁰ Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, op. cit.

⁵¹ See Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” op. cit.

⁵² *Ibid.*

ing that is possible, and hoping that the community will, in time, feel that such measures are actually a bonus, rather than compensation for some perceived loss. It is, however, also fair to say that most communities do, understandably, feel that they “deserve” some form of compensation for being prepared to take on a facility that no one else wants. This has been recognized by NAGRA in Switzerland, for example, where communities will be specifically recompensed for “services rendered in the public interest.”⁵³

The number of types of compensation that have been considered is almost as large as the number of locations where efforts have been made to site otherwise unwanted facilities. In the case of spent fuel or nuclear waste facilities, respondents in some surveys indicated that types of compensation that directly addressed the issues raised by the facility—such as a fund to compensate for any decline in property values resulting from the facility, or a fund to pay future medical costs of anyone harmed by the facility—were viewed as more legitimate, and more likely to be important in building support for a facility, than simple cash payments.⁵⁴ Five categories of compensation measures other than cash payments have been identified:⁵⁵

- *In-kind awards*, intended to directly offset costs of the facility, such as paying for improved roads and other infrastructure that would be needed during the construction and operation of the facility, improved emergency services and planning. These types of measures are very

common in nuclear facility siting in the United States, Japan, and elsewhere.

- *Contingency funds* set aside to cover any losses that might occur in the future as a result of the facility’s presence, such as in the event of an accident. A specific form of this approach would be to take out an insurance policy to cover all such losses; the willingness of a commercial insurer to sell such a policy, indicating that the insurer’s experts had analyzed the safety of the facility and concluded that such a policy would not pose an unreasonable liability to the insurer, might itself be important in building trust with a local community.⁵⁶
- *Property value guarantees* protect community residents from any decline in the value of their property, by pledging to compensate residents who sell their properties for any decline in value (compared to properties in other similar communities) attributable to the presence of the facility.
- *Benefit assurances* involve guarantees that local residents will receive employment, either directly at the facility or indirectly.
- *Goodwill measures* are effectively charitable contributions made by the company or other organization that manages the facility to projects that are important to local residents, from schools to hospitals, made to maintain a positive image for the facility and its managers within the community.

⁵³ Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, op. cit. NAGRA is the Swiss nuclear waste management institution.

⁵⁴ Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” op. cit.

⁵⁵ Ibid, citing Robin Gregory, Howard Kunreuther, Douglas Easterling, and Ken Richards, “Incentive Policies to Site Hazardous Facilities,” *Risk Analysis*, Vol. 11 (1991), pp. 667-675.

⁵⁶ Kunreuther, Slovic, and MacGregor, “Risk Perception and Trust: Challenges for Facility Siting,” op. cit. The Private Fuel Storage consortium that proposes to build a storage facility in Utah, for example, has pledged to carry off-site liability insurance to cover the cost of any off-site damages, including cleanup costs, in the unlikely event that an accident at the facility caused damage off-site, as well as property insurance to cover the costs of any accidents requiring cleanup within the site. This is in addition to the liability insurance that each utility is required to have under the Price-Andersen Act, and the \$9 billion fund established under that act, which cover liability for any accidents at the reactors or during transportation to the storage facility. See Private Fuel Storage, “FAQs: Financial Accountability,” at <http://www.privatefuelstorage.com/faqs/faq-accountability.html#1>.

Other types of compensation in addition to cash payments that have been considered in past cases include:

- *Investments in other economic development projects* for the affected community or region. In Japan, for example, the decision to build the large nuclear facilities at Rokkasho-mura was originally intended in part to provide jobs to compensate for the failure of a broader economic development project for that region (the Mutsu-Ogawara Project). Therefore, negotiations with the Aomori government over nuclear facilities have often been linked to discussions of funding for additional local development plans, including the construction of a fast rail-line to Aomori prefecture. Aomori Prefecture has also volunteered to be a potential site for the International Tokamak Experimental Reactor (ITER) project. In the United States, when potential locations for a nuclear waste repository were being considered, states were also competing for a multi-billion-dollar physics project known as the Superconducting Supercollider. Then-Representative Phil Sharp, a key player on the relevant congressional committee, mentioned publicly that some participants had suggested linking the two: “if you take the repository, you get the supercollider”—though it was “highly unlikely” that such a deal could be worked out.⁵⁷ Such linkages are generally problematic, as the advocates of the desired facility often do not want to see the fate and location of their project linked with the undesired facilities, and commitments to such additional investments may go unfulfilled when the desired projects are canceled or delayed for unrelated reasons (as occurred with both the planned investments in Aomori prefecture in Japan and the supercollider in the United States). Nevertheless, other activities

that would create local jobs and revenue are often high on communities’ lists of things they would like to negotiate.

- *Investments in local infrastructure* could include such items as building major new roads. In the United States, the negotiator tasked with finding a site for a centralized spent fuel storage facility in the early 1990s listed as possibilities for negotiation “highways, railroads, waterways, airports . . . environmental improvements . . . public school assistance programmes . . . higher education programmes . . . [and] general economic development programmes,” as well as “any other type of assurance, equity, or assistance desired.”⁵⁸ Here, too, care must be taken to ensure that commitments in these areas, if made, are followed through.

A wide variety of cash payments to communities and individuals have been considered for siting such facilities, ranging from modest grants for initial studies and public discussions to large sums associated with hosting the actual construction and operation of a facility. As discussed in Chapter 3, in Japan communities receive “Kofi-kin” payments (funded from a surcharge on electricity bills) to encourage them to consider hosting nuclear power plants, and this practice may be extended to hosting spent fuel storage facilities as well. Once a facility was under construction and then in operation, there would generally be substantial additional payments in the form of taxes (or, as is sometimes the case with tax exempt government facilities in the United States, “payments equal to taxes”) or other cash payments to the community or to individuals within it (including, for example, tax rebates to all those who live within a defined area, payments into a fund controlled by the local or regional government, and the like). In the U.S. monitored retrievable storage case, for example, it was expected that there would be substantial payments to the local community, and similarly in Japan, it is expected that

⁵⁷ Quoted in Inhaber, “Can an Economic Approach Solve the High-Level Nuclear Waste Problem?” op. cit.

⁵⁸ These and other items in the negotiator’s list are quoted in Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, op. cit

a negotiated agreement for a centralized storage site would ultimately include substantial payments of taxes or other types to support the local community. In the current U.S. Private Fuel Storage case, while the terms of the agreement with the Goshute Indians have not been revealed, it is believed to include substantial payments to the Goshutes, and Private Fuel Storage has recently also reached an agreement with the county of Tooele, Utah, where the Goshute reservation is located, under which the facility will pay the county \$500,000 per year in lieu of taxes, in addition to \$3,250 per year for each of up to 4,000 canisters to be stored at the site.⁵⁹

A key issue for any of these compensation approaches is ensuring that *all* of the affected parties benefit. Situations in which only a select group benefits, in addition to being inherently unfair, can undermine long-term support for the facility. In both the Mescalero and Goshute cases in the United States, for example, critics have charged the tribal leadership with directing funds only to supporters of the facility, withholding them from opponents. In a somewhat different situation in Japan, because fishermen and farmers might be most affected by the association of a particular area with “nuclear” facilities (potentially reducing the prices for their products), they often receive particularly generous compensation, and in some communities it is perceived that they have become wealthy while everyone else remains less well off.⁶⁰

Use Contingent Agreements

Another important element of the facility siting credo is the use of “contingent agreements”—agreements with the local

community that specify what will be done if something goes wrong, and in particular what control the local community will have over such a situation.

In the U.S. case, for example, the 1987 amendments to the Nuclear Waste Policy Act that authorized a centralized interim storage facility called for providing funding for a local environment, safety, and health review board, whose members would be drawn from local government and communities, and which would have authority over the operating criteria and standards for the facility, plant operating procedures, and policies on hiring local residents, and also would have the power to close the facility if needed.⁶¹ The community of Oak Ridge, when it expressed interest in hosting a centralized interim storage site, demanded such shut-down authority as a condition.⁶² Polling data suggests that such approaches may be a very important factor in gaining support for siting a spent fuel storage facility or a nuclear waste repository: in one U.S. survey, two-thirds of those polled said that giving a local committee power to shut down the facility would be “very important” in gaining support, and in another survey, offering local officials the power to shut down the facility if problems were detected dramatically increased the percentage of those polled who said they would support such a facility in their community.⁶³

In Japan, the nuclear safety agreement between the local community and the nuclear entities often include a clause offering local shut-down power. For example, the most recently signed Safety Agreement between Aomori Prefecture/Rokkasho Village and JNFL for a spent fuel storage facility includes a clause saying that Rokkasho Village or the Aomori government can ask for operations to be

⁵⁹ The total revenue to the county if all 4,000 canisters are in fact set up at the site would be \$13.5 million per year—a substantial sum for a county with a population of only 33,000 people. Amounts stipulated in the agreement are from Private Fuel Storage’s newsletter: “PFS, Tooele County in Historic Agreement,” *Inside Look*, Summer 2000, available at <http://www.privatefuelstorage.com>; population data is from <http://www.capitolimpact.com/gw/utcty/ut49045.html>. This maximum revenue comes to over \$500 per person per year, in addition to whatever is paid to the Goshutes, who are the principal hosts for the facility.

⁶⁰ Interviews with Japanese nuclear officials, 2000.

⁶¹ These measures are highlighted in Richardson, *A Review of Benefits Offered to Volunteer Communities for Siting Nuclear Waste Facilities*, op. cit.

⁶² See Weeks, *Advice—and Consent?*, op. cit., note 107.

⁶³ Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” op. cit. Interestingly enough, offering local officials the authority to approve the design of a facility actually *reduced* the percentage of those polled who were willing to support a facility in their community—perhaps because of a belief that local officials did not have the expertise required to do such a design review properly.

suspended if they find this is necessary to protect the safety of the local public.⁶⁴

Of course, the greater the local power over the facility, the greater the uncertainty faced by the owners and managers of the facility over what actions local government might take in the future. Contingent agreements can help reduce this uncertainty by specifying ahead of time the circumstances in which a local board would have the authority to shut down the facility, temporarily suspend operations, or impose some other penalty.

Work For Geographic Fairness

The final element of the original facility siting credo is to work for geographic fairness. Unfortunately, the participants in siting processes often have widely different perceptions of what is “fair.” Some analysts argue that it is fair to store spent fuel at the reactor sites, since those sites are the ones that have received the benefits of the taxes paid by those reactors. Others argue that this is unfair, since these communities agreed only to host reactors, not to the additional burden of storing spent fuel as well. Many analysts argue, as this report has above, that the fairest approach to siting is to rely on communities to volunteer to host a facility, in return for some negotiated set of benefits—so that the community feels in the end better off with the facility than without it.

Others argue that this volunteer approach is unfair and contrary to the concept of “environmental justice,” because volunteer communities are likely to be disadvantaged communities who see few other options for economic development (and possibly also racial minorities in countries where this is a substantial issue). As a result, these disadvantaged communities would bear a disproportionate

share of the burden of environmentally hazardous facilities that benefit all of society. In at least some areas of the world, with particularly hierarchical political and cultural systems, a process in which government experts determine the “best” site from a technical point of view, and the government simply mandates that this will be the site, is considered more fair than a volunteer process that might unduly impose on the poorest communities.⁶⁵ For spent fuel storage, however, where a wide range of sites can potentially provide high levels of safety it would be effectively impossible to justify a claim that one particular location was the “best” place for such a facility on technical grounds.

This “environmental justice” concern is an important and complex issue, and is not easily resolved. It has already been the bane of some nuclear enterprises: in the United States, for example, a proposed enrichment facility in Louisiana that the local community wanted was not given a license in substantial part because it was judged a disproportionate burden on a largely poor and black community.⁶⁶ There are arguments on many sides of the problem, and no single approach is suitable to every situation. It seems clear that it would be unfair to site the preponderance of hazardous facilities that benefit society at large in poor, minority communities. On the other hand, if a community wants to volunteer to host such a facility, and feels it would be better off with the facility and the benefits that go with it than without it, is it really more “fair” to deny that community the opportunity it seeks, or does that represent paternalism? Would it really be better to impose the facility instead on a more affluent community, so that both the disadvantaged community and the affluent community felt worse off than if the disadvantaged community had been allowed to receive the benefits it sought?

⁶⁴ “Agreement on Assuring Safety and Environmental Preservation Regarding Surrounding Areas of Rokkasho Reprocessing Facility’s Spent Fuel Storage Facilities,” October 12, 2000 (in Japanese), <http://www.jnfl.co.jp/anzen/anzkty03.html>. Article 13 of the agreement specifies that “When incidents are reported or inspections are conducted under Article 11, (Aomori prefecture and Rokkasho village) will request (JNFL) to take appropriate measures, including suspension of operation of the plant...and (JNFL) must discuss with (Aomori and Rokkasho) before restarting the facility.”

⁶⁵ Some polling data suggests that this is the case in Austria, for example. Linnerooth-Bayer and Fitzgerald, “Conflicting Views on Fair Siting Processes: Evidence from Austria and the United States,” *op. cit.*

⁶⁶ The Nuclear Regulatory Commission’s Atomic Safety and Licensing Board ruled against the proposal on environmental justice grounds, but was overturned by the full Commission; but the substantial delays in the licensing process resulting from this and other issues, combined with oversupply and declining prices in the enrichment market, ultimately led the proposers of the facility to abandon their effort, seven years after it began. See, for example, Jones, Walker, Waechter, Poitevent, Carreer & Denegre L.L.P., Stan Millan, “Environmental Justice Haunts Homer Nuclear Site,” *Louisiana Environmental Compliance Update*, September, 1998.

With respect to storage of spent nuclear fuel, these “fairness” arguments have played out in a variety of ways in the United States and Japan over the years. In Japan, nuclear reactors are typically located in rural areas and provide electricity predominantly to the cities. As described in Chapter 3, the rural communities are increasingly concerned that they are bearing a disproportionate share of the burden or providing the electricity the nation needs, and that the cities should do more. There is also concern in some areas over not having one aspect of spent fuel management after another piled on the same location. The governor of Aomori, in particular, in return for his support for the various nuclear activities at Rokkasho-mura, has insisted that Aomori *not* be the site for the eventual disposal of high-level nuclear wastes: if reprocessing is to be done at Aomori, the waste generated must go elsewhere for disposal.

Similarly, in the United States, the Nuclear Waste Policy Act originally called for two repositories—one in the West, and one in the East, to balance the burden of nuclear waste disposal. Despite the technical advantages of having any centralized storage site be at the repository site, the Act specified that an interim storage facility would *not* be located in a state being considered for a permanent repository—and when repository studies were limited to Yucca Mountain, Nevada, the law made clear that Nevada would *not* be the site for an interim storage facility as well, on grounds of fairness and distributing the burden. Since then, however, with the failure to establish sites elsewhere, majorities of both houses of Congress have attempted to require that Nevada accept an interim site as well as the permanent repository, only to face a Presidential veto. The ferocity of the opposition in Nevada to the idea of an interim storage facility there comes less from concern about the safety of such a facility than from the feeling of Nevada being unfairly singled out to bear a double burden of both the permanent and the interim site.

Ultimately, a key element of addressing the fairness concern will be in designing a *process* that is perceived as fair by the key participants, and that allows all the elements of geographic fairness to be discussed and addressed.

Build Confidence that Storage Really Will Be Temporary

Experience in both the United States and Japan (as well as in other countries) suggests that to gain support for interim spent fuel storage facilities, it will be absolutely crucial to convince potential host communities that “interim” storage really will be temporary, and that these sites will not become *de facto* permanent dumps. Building such confidence will require a clear link to continued progress toward more permanent solutions (e.g., a geologic repository, or a reprocessing plant and a geologic repository for its wastes).

In virtually every case where there has been substantial controversy over a spent fuel storage facility in either Japan or the United States, the fear that it will become a permanent dumping ground has been a central issue.⁶⁷ It was to address this issue, for example, that the 1987 amendments to the Nuclear Waste Policy Act specified, somewhat paradoxically, that an interim storage facility could not be built until a license had been issued to build a repository at a particular site (a situation in which the interim storage facility would be less needed—but also much less likely to become a permanent facility). The Minnesota controversy over Northern States Power’s dry cask storage was focused heavily on concern that it would become a permanent dump, and the law passed in that state ultimately limited the amount of spent fuel storage that could be established before a repository became available. Opposition to the proposed Private Fuel Storage facility in Utah is also heavily focused on the possibility of the facility becoming effectively permanent.

Similarly, in Japan, the local community around the Fukushima site where additional storage has been built near the reactors is heavily focused on ensuring that this storage will only be temporary, and the governor of Aomori prefecture has insisted both on continued progress toward completion and operation of the reprocessing plant before allowing more spent fuel to be stored there (to ensure that spent fuel will not be stored there indefinitely), and on progress in planning for disposal of high-level waste at a site outside Aomori prefecture (to ensure that the storage

⁶⁷ The success in building host community support for a permanent repository in Finland provides a counter-example. In this case, it appears that the community was convinced by proponents’ assurances that the permanent facility would be safe indefinitely.

facilities for such waste associated with the Rokkasho-mura plant will not hold the waste indefinitely).

The strong emphasis that host communities place on the “temporary” aspect of spent fuel storage is surprising in some respects. For most residents of a community, the timescale that is perhaps most relevant is the time it takes to raise their children and keep them safe. For elected officials, the most relevant timescale is the length of the remainder of their likely term in office. In both cases, a storage period of 30-50 years might seem effectively equivalent to storage that would last forever. Yet there is nonetheless very clear evidence that limiting storage to such a period is a key concern of host communities and their elected representatives. This suggests that at some level, rather than considering only their own immediate interests, community residents are considering a broader long-term view. In particular, this distinction between temporary and permanent may relate to perceptions of safety: while it may be relatively straightforward to engineer a system about which one can credibly make assurances that it will be safe for forty years—and the community can reasonably expect that the institutions that make these assurances will continue to exist and to provide appropriate monitoring and support over that time—there is a widespread perception that it is difficult or impossible to make comparably credible assurances of safety over periods stretching out thousands of years into the future. Polling data suggests that if residents believe that a facility will pose *either* a near-term health threat *or* a threat to future generations, a majority will oppose hosting such a facility regardless of the compensation offered.⁶⁸

Given the history of delays and failure to meet deadlines in the management of spent fuel and nuclear wastes worldwide, building confidence that temporary storage facilities really will be temporary will not be easy to do. It is likely to require both (a) enough continuing funding for and progress toward a permanent solution to create a perception that the permanent solution will in fact become available in a timely way; and (b) some contractual or insti-

tutional mechanisms to build confidence that the fuel will be removed from the storage site in a timely way.

Continued progress toward permanent solutions. As described above, providing adequate interim storage capacity capable of lasting for decades (particularly if the fuel is removed from reactor sites to a centralized facility) could reduce the political pressure for progress on permanent solutions, and could also use up some of the funding available for work on permanent solutions. It will be important, in providing interim storage, to create a link to the permanent solution, so that interim storage does not undermine progress toward permanent approaches. Linkages that have been or could be considered include:

- new laws linking particular interim storage milestones (e.g., construction of a facility, acceptance of particular amounts of spent fuel) to the accomplishment of particular permanent solution milestones (e.g., granting of licenses, construction of a facility, opening of a facility);
- reaching agreement on *both* the permanent site and approach, *and* the interim storage site and approach as part of one overall agreement incorporated in legislation, with each contingent on the other; or
- funding arrangements to ensure that financing for interim storage facilities is provided from *additional* funds, beyond those needed to finance permanent solutions, or even arrangements in which revenue from the interim storage facilities contributed to financing work on permanent solutions.⁶⁹

In addition, it will likely be essential to carry out a substantial public education campaign making clear the reasons why interim storage is *not* a substitute for a permanent solution, and reiterating the commitment to move forward with permanent solutions. As part of such a campaign, it will be important to clarify the technical difference

⁶⁸ Kunreuther and Easterling, “The Role of Compensation in Siting Hazardous Facilities,” *op. cit.*

⁶⁹ In the United States, for example, there has been some controversy over DOE’s proposal to fund the costs of at-reactor interim storage until a repository becomes available from the Nuclear Waste Fund, as there is concern over whether money in the fund will be adequate to fund both the permanent repository *and* interim storage. DOE has reached an agreement with one utility that effectively funds interim storage with money that would otherwise have gone to the waste fund—the

between permanent solutions and interim storage; as simple, above-ground facilities, interim-storage facilities are simply not designed to be capable of lasting for centuries or millennia, as deep underground permanent disposal sites are. In Japan, as in some other countries pursuing closed fuel cycles, it is believed that describing spent fuel as a recyclable resource for the future, rather than as a waste for disposal, can help build public support.

Building confidence the fuel will be removed. Mechanisms to give host communities confidence that fuel will be removed in a timely way could include:

- licenses or contracts allowing only a fixed period of storage (e.g., 20-40 years), with any extension requiring a new approval by the host community and/or national regulators;
- contracts or other legal arrangements that include compensating payments of various kinds if agreed time for fuel removal is exceeded; or
- arrangements putting certain assets of the organization that owns and manages the storage facility in escrow until the fuel is removed, creating an incentive to remove the fuel in a timely fashion.

In the United States, for example, as described in Chapter 3, the Private Spent Fuel Storage proposal for storage on Goshute Indian land in the United States envisions a 25-year storage contract, with only one 25-year extension option—so that after 50 years, the fuel would have to leave unless some new agreement acceptable to all parties were negotiated. Of course, a new contract could be negotiated at the end of that time, if the local community agreed, but the willingness to enter into such a fixed-term contract is intended to build confidence that the fuel really will be removed and shipped to a geologic repository at the end of

the contracted time. Similarly, after an extended negotiation, DOE reached agreement with the state of Idaho under which Idaho agreed to allow continued shipment of naval spent fuel to the Idaho National Engineering and Environmental Laboratory (INEEL), and in return DOE agreed that all spent fuel would be removed from Idaho by 2035, or DOE would pay the state \$60,000 per day.⁷⁰

Unfortunately, all of the commitments and mechanisms for providing assurance to communities that they will not be permanent dumping grounds tend at the same time to restrict the flexibility that is one of the prime advantages of interim storage. It is important to avoid having this process lead again to programs becoming locked in to single solutions far in the future that may or not be successful or appropriate when the time comes. If there is one lesson that the nuclear industries of the United States, Japan, and the rest of the world have learned from the past several decades, it is that the situation 20-40 years from now will almost certainly be different from any prediction made today, and it is therefore essential to retain sufficient flexibility to adapt policies and approaches as circumstances change.

Looking Toward the Future

Because of their different political cultures and institutional frameworks, and their different sets of past decisions and experiences with management of spent nuclear fuel and nuclear wastes, future prospects for managing these key spent fuel storage issues and approaches to siting are somewhat different in the United States and Japan.

In the United States, there has been considerable success in establishing dry cask storage at reactor sites, and it makes sense to continue to pursue this route. Nevertheless, it would be desirable to establish at least some limited centralized storage capacity, whether under government or

utility will continue to pay the costs of at-reactor interim storage, but will then be able to reduce its contributions to the Nuclear Waste Fund by a comparable amount. DOE and the nuclear industry's trade group have both asserted that this approach will not undermine the permanent repository, as there will be sufficient funding for both. But eight utilities have sued to block the agreement, arguing that there will *not* be enough money for both, and that their payments to the waste fund will therefore have to be increased if this approach is pursued. Elaine Hiruo, "Eight Utilities Ask 11th Circuit to Block DOE-PECO Agreement; More May Join Action," *Nuclear Fuel*, December 11, 2000; and Elaine Hiruo, "PECO-DOE Agreement Doesn't Hurt Industry or Deplete Fund, NEI Says," *Nuclear Fuel*, August 7, 2000.

⁷⁰ David Kramer, "DOE Warns Idaho Deal is One of a Kind," *Inside Energy (with Federal Lands)*, October 23, 1995.

private auspices, to address situations where continued storage at reactor sites poses an undue cost.

Japan is hoping to succeed where the United States has so far failed, in establishing a large centralized facility for interim storage of spent nuclear fuel. As in the United States, the primary emphasis of the plan is on dry cask storage. The mayor of the village of Mutsu in Aomori Prefecture has volunteered that community for initial investigations of whether it would be a suitable location for a storage facility. This process is still in its early stages.

In both countries, the modified Facility Siting Credo discussed in this chapter offers key guidance for increasing

the chances of success in gaining public support for siting new interim storage facilities. Of course, the credo is not a step-by-step cookbook, but a general set of principles: it will not be possible to implement every aspect of the credo in every specific case. But it our belief that making use of the credo to move toward a trust-building process based on the principles of transparency, democracy, and fairness, intended to achieve a safe, flexible, and clearly temporary facility that will make the host community better off than before, can greatly increase the chances of success as discussions move forward at Mutsu and elsewhere in the future.

6. Conclusions and Recommendations

Conclusions

General

Technology is available to manage spent nuclear fuel safely and securely until permanent management options are implemented.

The diverse technologies now available for storing spent nuclear fuel—from wet pools to dry casks—offer safe, secure, and cost-effective options for storing the spent fuel generated by the world’s power reactors for decades, or for much shorter periods of time, as circumstances warrant. These interim storage possibilities will allow time for permanent options for management and disposal of spent fuel and nuclear wastes to be prepared and implemented with the care they require. Interim storage of spent fuel can also allow time for spent fuel management technology to improve, and for the economic, environmental, and security advantages of different approaches to permanent management of spent fuel and nuclear wastes to become clearer.

There is an urgent need to provide increased interim storage capacity in the United States, Japan, and around the world. Failure to meet this challenge could have serious economic, environmental, and energy-security consequences.

The spent fuel cooling ponds at nuclear reactors in many countries around the world are filling up. Delays in both reprocessing and geologic disposal programs have left reactor operators with far more spent fuel to manage than had

been expected when the nuclear plants were built. If additional storage capacity does not become available—whether at the reactors or elsewhere—reactors could be forced to shut down well before the end of their licensed lifetimes. Such a failure to provide adequate capacity to store spent fuel could result in billions of dollars in economic losses, reduced diversity in electricity supply, and more consumption of fossil fuel, emitting additional pollutants and greenhouse gases. Moreover, if the addition of interim storage capacity is not managed appropriately, increasing quantities of spent fuel could end up being stored in less than optimal conditions, reducing safety. Thus, providing additional spent fuel storage is important not just to the interests of the nuclear industry, but to the interests of society as a whole.

Interim storage is a key element of the fuel cycle—regardless of whether the planned permanent option is reprocessing or direct disposal.

Interim storage of spent nuclear fuel is *not* simply a matter of postponing decisions. It is a central element of an optimized nuclear fuel cycle—whether that fuel cycle approach will ultimately involve direct disposal or reprocessing of the spent fuel. While there continue to be strong differences of opinion over whether spent fuel should be regarded as a waste or a resource—and there is some merit in each view—a consensus is emerging that interim storage of spent fuel is an important strategic option for fuel management, which can be pursued by supporters of both open and closed fuel cycles.

Interim storage is a complement, not an alternative, to moving forward expeditiously with permanent approaches to managing spent fuel and nuclear waste.

Interim storage, by its nature, is a temporary solution, designed to be safe and secure during a defined period when humans and their institutions are monitoring it. It is not a substitute for a permanent approach to the nuclear waste problem designed to provide safety for hundreds of thousands of years. Interim storage approaches should be carefully designed to avoid undermining funding and political support for continued progress toward acceptable permanent solutions for spent fuel management and radioactive waste disposal. Regardless of how much interim storage is provided, facilities for permanent disposal of nuclear wastes will be needed, whether those facilities are intended to hold spent fuel, wastes from reprocessing spent fuel, or both, and interim storage approaches should not be allowed to undermine efforts to develop such facilities. Interim storage should not become a mechanism for this generation to simply leave problems to the next; hence, it is important to make continued progress toward permanent solutions (and a set-aside of sufficient funding to implement them) a part of any interim storage strategy. Indeed, continued visible progress toward the establishment of such permanent waste facilities—providing some confidence that “interim” facilities will not become “permanent”—is likely to be essential to gaining political acceptance for the establishment of adequate interim storage capacity.

Flexibility is crucial to safe, secure, and acceptable management of spent nuclear fuel—and interim storage is crucial to providing such flexibility.

The history of the nuclear age is filled with cases in which billions of dollars were wasted on projects that seemed to make sense when first started, and to which countries became “locked in,” but which were no longer what was needed years later. The economics of different energy approaches (and projections of what the costs of those approaches will be in the future) change; government policies, political attitudes, and perceptions shift; rules and regulations that set the basic framework for decisions are modified; market structures are transformed; particular projects fail or are abandoned; and technology advances. Because nuclear energy involves very large capital investments that are paid off over decades, and because it is embedded with-

in a web of regulation, political commitments, and government oversight that often adapts only slowly to new circumstances, the nuclear industry has had considerable difficulty maintaining the flexibility to adapt to these changing circumstances. Flexibility, where it can be achieved, is critical to the future of nuclear energy.

Interim storage of spent fuel, which keeps all options open, offers such flexibility in managing the nuclear fuel cycle, and is thus a key element of a fuel cycle optimized for cost, safety, and security. Providing adequate interim storage capacity makes it possible to adapt approaches to permanent management as circumstances change, and to choose the optimum rate at which such approaches should be implemented. Whatever one’s view of the future of the nuclear fuel cycle, for example, it does not make sense to incur the costs and risks of reprocessing spent nuclear fuel before the plutonium recovered by reprocessing is needed or wanted, just because there is no room to store the spent fuel. Similarly, it does not make sense to rush spent fuel into a repository before all the necessary studies are completed just because there is no other place to put it. The approaches to interim storage itself should also emphasize flexibility, avoiding being entirely reliant on any single approach or facility where practicable.

A period of perhaps 30-50 years of storage is an appropriate initial figure for planning facilities, but in many cases it may be possible and desirable to implement permanent solutions sooner.

The period over which interim storage facilities are designed to operate should be long enough to offer maximum flexibility, but short enough not to be seen as making them effectively permanent. Thirty to fifty years—the planned operating lifetime of the most recent reactors—in our judgment, is a reasonable planning figure for the lifetime of such facilities. This would require extending the licenses of dry cask storage facilities, which, in the United States, are licensed only for 20 years. It may often, however, be desirable to implement permanent solutions before the 30-50 year period is complete, for example if a suitable permanent repository becomes available, or a decision is taken that the plutonium in the spent fuel is now needed as fuel. In the future, it may in some circumstances be desirable to consider even longer periods of interim storage. In France, for example, storage periods of as much as 100 years are being examined.

Approaches to the back end of the nuclear fuel cycle should be chosen on their economic, environmental, security, and energy security merits, not on the basis of ideology, sunk costs, or inertia.

In the past, too many decisions have been dictated by momentum of past plans and contracts, or ideological judgments for or against reprocessing. Instead, decisions should be made based on in-depth consideration of which approaches offer the best combination of advantages and disadvantages, for each type of fuel at each particular time. The decisions that result from such analyses may change over time as circumstances change. Just as the United States continues to carry out various types of processing on some types of fuel to prepare them for disposal (from reprocessing to “melt and dilute” processing of aluminum-clad fuels), while placing its primary emphasis on direct disposal, Japan should consider adopting a flexible approach including direct disposal as a possibility for some types of fuel (including, for example, fuels with very low plutonium content that are not attractive to reprocess, such as those from the Japan Atomic Research Institute’s reactors).

The most difficult and complex issues facing interim storage are not technological but political, legal, and institutional. Transparency is key in resolving them.

Interim storage of spent nuclear fuel is technically straightforward. The key problems that have made it difficult to provide adequate interim storage capacity for spent nuclear fuel arise from the difficulties of gaining political acceptance for such arrangements by the potentially affected publics, and from the complex web of legal and institutional constraints related to management of spent fuel and nuclear wastes. These constraints vary from one country to the next—but in every circumstance, ensuring a transparent process that allows a well-informed public to feel that its concerns have been fully addressed will be essential to success.

Safety, Economics, Security, and Technology

If appropriately managed and regulated, interim storage of spent nuclear fuel is very safe.

By its nature, storage is a process with very little going on, and very little that could go wrong that could result in radiation being released. While storage (particularly wet pool storage) does require good design and management to ensure safety—as well as effective, independent regula-

tion—where these are in place interim storage is perhaps the safest part of the entire nuclear fuel cycle. The U.S. Nuclear Regulatory Commission has concluded that dry cask storage of spent fuel would be safe for 100 years.

Interim storage of spent nuclear fuel is cost effective.

The cost of storing spent fuel for 40 years is substantially less than a tenth of a cent (or a tenth of a yen) per kilowatt-hour of electricity generated. In the case of dry cask storage, once the initial capital cost of the casks is paid, the costs of maintaining the fuel in storage are very low. Although interim storage does involve a cost, it allows the higher costs of permanent solutions to be paid at a later date and therefore discounted somewhat, so that the overall fuel cycle contribution to electricity costs need not increase.

If appropriately safeguarded, interim storage of spent nuclear fuel is secure and proliferation-resistant.

Although spent nuclear fuel contains weapons-usable plutonium, the plutonium is bound up in massive, highly radioactive spent fuel assemblies. As a result, it would be difficult to steal and recover the plutonium for use in weapons. Hence, spent fuel poses only modest proliferation risks. Stored spent fuel in either pools or dry casks can easily be secured, accounted for, and made subject to international safeguards, with relatively low costs, intrusiveness, and uncertainty.

Several technologies for interim storage are safe and acceptable—but for many applications, dry cask storage may best meet the needs.

There is a variety of technological options for storage of spent nuclear fuel, including pool storage and several types of dry storage. Each of the available approaches has been shown through experience to be safe. Each of these approaches has its advantages and disadvantages, and each is likely to find market niches where it is most appropriate. Wet spent fuel pools pose somewhat greater operating complexities and costs than dry storage approaches, but pools have been the technology of choice for a wide range of spent fuel storage applications. Dry storage technologies, especially dry casks, have been increasingly widely used in recent years. The combination of simplicity, modularity, and low operational costs and risks offered by dry cask storage systems make them highly attractive for many storage applications.

Transportation of spent nuclear fuel involves additional costs and risks, but can be safe and secure if managed and regulated appropriately.

Spent fuel transportation around the world has an excellent safety record, and the approaches being used are continually improving. Whenever fuel has to be transported over long distances, there are additional expenses and greater safety and sabotage risks than there would if the fuel just remained stored at a secure location. Transportation is inherently simpler within Japan, where nuclear material is transported by sea to facilities on the coasts, than in the United States, where it sometimes has to cross thousands of kilometers by road or rail.

Political, Legal, and Institutional Factors

In both the United States and Japan, the politics and legal constraints surrounding interim storage of spent fuel are complex, and options for the future are substantially constrained by the legacies of past decisions.

The U.S. government and the U.S. nuclear industry have been attempting to find a site for a large centralized interim storage facility for spent nuclear fuel for decades without success (though two proposals are still in development). This effort has been substantially shaped and constrained by factors such as the initial decisions to provide only a modest amount of storage space at reactor pools; Congress' decision to limit studies of potential geologic repository sites only to Nevada's Yucca Mountain, and to require that any centralized storage facility be in another state; the government's commitment to accept the utilities' spent fuel by January 1998, and the delays in the repository program that made it impossible to meet that deadline; and the legacy of public distrust of both government nuclear agencies and the nuclear industry. At the same time, however, efforts to establish additional dry cask storage at reactor sites have been far more successful, with many facilities established, many more planned, and only a few having raised substantial controversy. Any future decisions on interim storage approaches will have to take these past decisions into account, as these experiences substantially shape political reactions to proposals for management of spent fuel.

In Japan, efforts to expand interim storage capacity for spent fuel are more recent, but have similarly been shaped and constrained by Japan's past decisions—including

ing the commitment to a closed fuel cycle with reprocessing of all spent fuel; the related commitment to remove all spent fuel from reactor sites for reprocessing; delays in the reprocessing program; and the complex web of political, legal, and institutional commitments related to construction of the reprocessing facility at Rokkasho-mura. In Japan too, the increased distrust following recent accidents, particularly the criticality accident at Tokai-mura in 1999, is likely to make developing a process that will lead to public support for building a spent fuel storage facility more difficult. In Japan, the current focus is on developing a large centralized facility, not on the at-reactor storage approach that has so far been more successful in the U.S. political context.

In both the United States and Japan, there is significant local concern over hosting spent fuel storage facilities.

Many communities simply do not want to be host to a facility for storing spent nuclear fuel, for a wide range of reasons. In particular, many communities are concerned about spent fuel storage facilities becoming de facto permanent repository sites. Local opposition has prevented many past proposed interim storage facilities and other nuclear facilities from being successfully established. Such objections pose the largest obstacle to building adequate storage capacity for spent nuclear fuel.

An approach emphasizing transparency, democracy, and fairness can help overcome the obstacles to gaining acceptance for siting interim storage facilities.

In the past, nuclear decisions have often been made in secret, announced, and then imposed on affected communities over their objections—the so-called “decide, announce, defend” approach. This approach has proved in most cases to generate local opposition rather than support, and has contributed to a number of the recent failures to gain approval for siting nuclear and other facilities. Secrecy surrounding key decisions, in particular, while often justified by the desire to avoid exposing proposals to criticism prematurely, tends to breed mistrust and opposition. Communities want transparent access to all the important information they need about the proposed facility and the process of decision; a democratic process that will allow them to ensure that their concerns are fully addressed; and a process for choosing a site that is fair in its allocation of the burdens and benefits from nuclear energy

and storage of spent fuel, and does not single out any one particular community against its will.

The process for siting interim spent fuel storage facilities must give the host community high confidence that safety will be assured, that all potential negative impacts of the facility will be addressed, and that the host community will be better off, overall, once the facility is built.

Ensuring that stringent safety standards will be reliably met is absolutely essential to building public support for interim storage facilities for spent nuclear fuel. No community will accept a storage facility it does not believe is safe. Strong and fully independent safety regulation, and opportunities for experts from the community itself to confirm that safety is being maintained, are likely to be very important in building local confidence that safety commitments are being met. Other potential negative impacts of a facility, such as traffic and impacts on the value of local property and products, must also be effectively addressed.

Ultimately, communities are not likely to support the establishment of spent fuel storage facilities in their vicinities unless there is some benefit to them (and to the nation as a whole) in doing so. Thus, fair compensation to communities for the service to society of hosting interim storage facilities is very important. It should not be assumed, however, that simply offering compensation is enough to build support for such facilities—indeed, the evidence suggests that unless handled with considerable care, such offers of compensation have modest benefit or can even backfire.

Building confidence that permanent management options are progressing, and that interim storage facilities will not become permanent “dumps,” is essential to building public support for establishing interim storage facilities.

In both the United States and Japan, communities near spent fuel management facilities have placed very high priority on ensuring that facilities built to be temporary will in fact be temporary—that ultimately, there will be some more permanent solution for managing the spent nuclear fuel. Building confidence that permanent solutions are progressing and will be available in a reasonable period of time is likely to be a central part of gaining public support for interim spent fuel storage facilities. A variety of approaches to legally, financially, and institutionally linking interim

storage to continued progress toward permanent solutions can be envisioned, and may be useful in building public confidence. At the same time, however, it is important not to repeat past mistakes by setting deadlines that cannot be met or committing too firmly to implementing particular approaches decades in the future that may turn out not to be appropriate when the time comes; such mistakes would undermine the flexibility that is one of the key advantages of interim storage of spent nuclear fuel.

The “Facility Siting Credo” offers useful guidance for efforts to implement interim storage approaches that can gain public support.

The “Facility Siting Credo,” with the slight modifications described in this report, can provide a useful framework for building support for siting facilities for interim storage of spent nuclear fuel. The modified credo includes the following goals: achieve agreement that a facility is needed, that the status quo without it is unacceptable; institute a broad-based participatory process; seek consensus; work to develop trust; seek acceptable sites through a volunteer process; consider competitive siting processes; set realistic timetables (“go slowly in order to go fast”); keep multiple options open; choose the storage approaches and sites that best address the problem; guarantee that stringent safety standards will be met; build confidence that storage will be temporary and permanent solutions forthcoming; fully address all negative aspects of the facility; make the host community better off; use contingent agreements (specifying what happens if something goes wrong); and work for geographic fairness. Not all of these goals can be achieved in every case, but the credo offers a constructive road-map for a transparent, democratic, and fair process to build support for siting interim storage facilities.

At-reactor, centralized, and multiple-site away-from-reactor approaches to interim storage are all acceptable, and each have advantages and disadvantages requiring a case-by-case approach to choosing the best option.

In the United States, there has been substantially greater success with establishing at-reactor dry cask storage facilities than with building a large centralized facility. There is no immediate need in the United States for a large, centralized facility. Nevertheless, there appear to be good arguments for providing at least some centralized storage

capacity, for example to handle fuel from reactors that are being decommissioned. In Japan, on-site dry cask storage has been built at only one reactor site, and the government and utilities are working to establish a large centralized storage facility. Successful establishment of such a facility would be highly desirable.

Governments and industry share responsibility for ensuring that spent nuclear fuel is managed appropriately, and both have a role to play in interim storage.

In the United States, legislation has given the government a legal obligation to take responsibility for the spent nuclear fuel generated by nuclear utilities. But with no repository yet available, the spent fuel remains at the utility sites, inevitably creating a shared responsibility for its management. Exactly how this burden will be shared is still being negotiated. In Japan, the spent fuel remains the utilities' legal responsibility, but the government has key roles to play in providing effective regulation, and defining national plans and policies. At least in the United States, the government may also have a useful role to play in the future in providing limited spent fuel storage capacity on government sites to deal with special needs, such as those of utilities whose spent fuel ponds might be filled before additional storage capacity becomes available.

The government could also play an important role in demonstrating the safety and effectiveness of various storage technologies, an approach that could help ease local concerns over the safety of spent fuel storage. These measures could be undertaken without interfering with ongoing efforts toward deregulation of the electricity market.

Transportation of spent nuclear fuel can be highly controversial, raising political, legal, and institutional issues that require intensive effort to resolve.

Managing transportation in a way that builds public support, particularly in countries like the United States, where spent fuel has to be transported long distances through many local and state jurisdictions, and where public distrust of nuclear institutions is very high, poses an enormous political and institutional challenge. Resolving it requires implementation of stringent safety procedures; intensive discussion and interaction with the public and with state and local officials to resolve concerns; and careful attention to designing optimal routes.

International Approaches

Proposals for international sites for storage or disposal of spent fuel and nuclear waste pose a complex mix of potential advantages and disadvantages, and face significant obstacles. On balance, it would be highly desirable to establish one or several such facilities over the next two decades.

Each country that has enjoyed the benefits of nuclear energy bears the responsibility for managing the resulting wastes. But this does not preclude the possibility that cooperation among countries could improve efficiency, reduce proliferation risks, and provide other benefits, if managed appropriately. Each proposal related to international storage or disposal of spent fuel and nuclear wastes is unique, poses different issues, and needs to be evaluated carefully on its merits. The obstacles to establishing such an international facility are substantial, and while there has been greatly increased interest in such ideas in recent years, it remains unclear whether these obstacles can be overcome in the near term. If appropriately managed, such sites could contribute both to stemming the spread of nuclear weapons and to the future of civilian nuclear energy.

Advanced countries with large and sophisticated nuclear programs, such as the United States and Japan, should continue to plan on storing and disposing of their spent fuel and nuclear wastes domestically.

Both the United States and Japan have the technical capacity and wealth to manage their own storage facilities and repositories. While we would not rule out the possibility that some limited amount of Japanese spent fuel might be sent to an international site, the primary focus in Japan, as in the United States, should remain on domestic options for managing spent fuel and nuclear wastes. Both countries have a responsibility to manage the wastes resulting from the large quantities of nuclear electricity they have produced, and the issue is too pressing in both countries to delay the search for domestic solutions until an international option may become available.

Establishing one or more international storage facilities could make it possible to remove spent fuel from countries of proliferation concern and enhance

transparency and confidence-building in spent fuel management.

The 1990s witnessed a number of cases in which nuclear material was removed from particular countries to reduce proliferation risks, and more such cases can be expected. An international storage facility would provide a ready site for accepting material in such situations. Moreover, if an international system was established for spent fuel storage, including one or more international sites, the resulting increased international information about and control over spent fuel management could contribute to building confidence and reducing international concerns.

Over the long term, establishing one or more international disposal sites is essential, at least for material from countries with small nuclear programs and geologies poorly suited to permanent disposal.

It will simply not be practical to establish a geologic repository in every country that has a nuclear power reactor or a research reactor. Eventually, some form of international disposal site or sites will be needed. The ultimate trend should be toward consolidating spent fuel in a smaller number of locations worldwide.

Proposals for international sites in Russia pose especially complex issues. Such a facility could make a substantial contribution to international security and would deserve support if several criteria were met—but these will not be easy to meet.

Russia is in the process of debating possible changes to its laws that would allow it to become a host state for spent fuel from other countries. A variety of different specific approaches have been proposed, each raising different issues. Russia's Ministry of Atomic Energy strongly supports entering this potential market, while Russian and international environmentalists are strongly opposed. Such a facility would deserve support *if*:

- Effective arrangements (including independent regulation) were in place to ensure that the entire operation achieved high standards of safety and security;
- A substantial portion of the revenues from the project were used to fund disarmament, non-proliferation, and cleanup projects that were agreed to be urgent, such as securing nuclear

material and eliminating excess plutonium stockpiles;

- The project did not in any way contribute to separation of additional unneeded weapons-usable plutonium, or to Russia's nuclear weapons program; and
- The project had gained the support of those most likely to be affected by it, through a democratic process, including giving them ample opportunity to ensure that their concerns were effectively addressed.

Whether an arrangement that meets these criteria can be put in place in Russia—and what the reaction will be if a proposal advances which meets the first three criteria but not the fourth—remains to be seen.

Recommendations

We recommend that:

- **Interim storage, designed to last for perhaps 30–50 years (though with flexibility to shorten that time to match the progress of permanent solutions) should be pursued as the best near-term approach to managing a large fraction of the world's spent fuel, including much of the spent fuel in the United States and Japan.**
- **Capacity for interim storage of spent fuel should be substantially expanded—in Japan, in the United States, and in the rest of the world.**
- **Approaches to establishing interim spent fuel storage facilities should be based on the principles of flexibility, transparency, democracy, and fairness—making use of the approaches outlined in the modified Facility Siting Credo to the extent possible.**
- **In particular, the degree of secrecy and reliance on hidden negotiations in past siting efforts should be substantially reduced, with all key information about proposed facilities, including potential options for benefits to host communities, made available to those potentially affected.**

- Approaches to establishing interim storage should be designed so as not to undermine progress toward acceptable solutions for spent fuel management and nuclear waste disposal.
- In particular, when spent fuel is placed in interim storage, sufficient funds should be set aside to implement permanent management approaches at a later time, so that a future generation will not be stuck with the bill.
- In both the United States and Japan, the respective responsibilities of government and private industry in managing spent nuclear fuel should be clarified, and the possibility of establishing some limited interim storage capacity at centralized sites to address particularly urgent storage needs should be considered.
- In both the United States and Japan, the policy-making process for management of spent nuclear fuel and nuclear wastes should be improved, making possible an in-depth consideration of all the relevant factors in deciding on the best approach to managing each type of nuclear material, with interim storage of spent nuclear fuel as one central element of a larger back-end strategy.
- In both the United States and Japan, additional steps should be taken to address the concerns of local communities hosting nuclear facilities—both existing facilities and proposed new ones—including efforts to address issues of geographic fairness, community control, and timelines for removing spent fuel and implementing permanent approaches.
- The international community should continue to seek to establish safe and secure international facilities for storage or disposal of spent nuclear fuel, but countries such as the United States and Japan should focus on domestic facilities for the spent nuclear fuel from their own nuclear power plants.

The Project on Socio-technics of Nuclear Energy

The Project on Socio-technics of Nuclear Energy, which concluded in the fall of 2000, was established at the Department of Quantum Engineering and Systems Science at the University of Tokyo in order to deepen the understanding of relationships between nuclear technology and society. Historically, nuclear technology was born out of scientific endeavor and political initiatives. Since then, nuclear technology has been inseparable from its relationship with its social and political contexts. The decline in public support for nuclear technology in recent decades in most developed nations cannot be explained only by technological factors. Deeper understanding of the relationship between nuclear technology and society is essential for improved public policy debate over nuclear technology. The Project on Socio-technics of Nuclear Energy, and its work on this report, was made possible through the generous support of the Japan Atomic Power Company, a Japanese nuclear utility.

http://lyman.q.t.u-tokyo.ac.jp/sociotech/intro_e.html

The Managing the Atom Project

The Managing the Atom Project is a multi-disciplinary research and policy outreach effort focused on selected key issues affecting the future of both nuclear weapons and nuclear energy – especially policy issues where nuclear weapons and nuclear energy intersect, and democratic governance of nuclear decision-making.

Based in the Belfer Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government, Managing the Atom provides its findings and recommendations to policy makers, other analysts, and the news media through publications, briefings, workshops, and other events. Managing the Atom's work on this report was made possible by generous project-specific support from the U.S. Department of Energy (DOE) under Award No. DE-FG26-99FT40281, and the Japan Foundation Center for Global Partnership, as well as general support from the John D. and Catherine T. MacArthur Foundation and the W. Alton Jones Foundation.

<http://www.ksg.harvard.edu/bcsia/atom>

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