Multinational Spent Fuel Disposal: Nonproliferation Challenges and Opportunities

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Abstract: In recent years, we have seen encouraging progress toward siting national nuclear waste repositories. Sweden and Finland have demonstrated workable solutions and selected sites based on overwhelming local support. France, Canada and the UK also have functioning waste management programs at various levels of maturity. For all five, building the requisite public trust has required decades, often after early missteps. However, most countries—including the United States—continue to struggle to permanently dispose of waste produced by nuclear power programs. This is both a waste management issue and a proliferation and security concern as the “back end” decisions that countries make can involve the use of sensitive nuclear technologies such as plutonium separation. While there is currently no back end “market,” enormous opportunities exist for eventual solutions that can enhance safety, proliferation and security goals by leveraging the provision of a spent fuel disposal pathway in return for a commitment not to pursue sensitive fuel capabilities such as enrichment and reprocessing. Fuel assurances are far less valued because the fuel supply market already functions efficiently. There are complicating factors beyond the significant challenges that beset purely national programs. However, we are not without prospects, and one or two successes with multinational cooperation may result in rather rapid and even profound changes. This paper will pay particular attention will paid to developments in Europe – smaller countries have already made important political progress toward this end through organizations such as the European Repository Development Organisation and the European Commission – and how we might apply these lessons to other regions: in particular, Japan, South Korea and Taiwan, which operate large nuclear power programs, have immediate spent fuel storage issues and have proved unable to implement permanent national solutions; and countries/regions with nascent programs or considering nuclear power for the first time, such as Asia and the Middle East, as it is amongst these newcomers that leveraging is likely to be the most effective. This paper will draw from the “NTI-CSIS New Approaches to the Nuclear Fuel Cycle” expert group deliberations and recommendations from the Blue Ribbon Commission on America’s Nuclear Future.

Thirty-one countries plus Taiwan operate nuclear power plants; about half of those have fewer than five plants. Globally, reactors generate about 10,500 metric tons of spent fuel each year and as of the end of 2012, there was more than 270,000 metric tons of spent fuel in storage worldwide. The ten largest nuclear power generators produce about 87% of these totals.

About 90% of spent fuel is in storage ponds, with the balance in dry casks. Spent fuel pools were never designed to be a long-term storage solution, so many sites have had to install high-density racks into pools and/or add dry storage casks on site. Pool storage is limited by the size of the pool and criticality control geometry, and acquisition of dry casks telegraphs a rather long-term commitment to on-site storage, often raising fairness and political issues. For example, in South Korea, where nuclear plants are
close to the surrounding communities, the local community must be consulted before any on-site storage expansion can take place. Storage space shortages are becoming particularly acute in Taiwan, South Korea and Japan.

While most countries with nuclear programs have opted for direct disposal of spent fuel in a permanent repository, political and technical difficulties have prevented any from actually being built – although we are seeing real results in Sweden and Finland and encouraging progress in France and Canada. *Hence there is unmet demand which should equate to opportunity. Multinational spent fuel storage and disposal facilities offer obvious economic and social benefits to countries with nascent or small nuclear power programs and those with limited financial, geographic and/or political resources to pursue national solutions. Cooperative disposal may also increase global security by reducing stocks of spent fuel in countries whose national repository plans are uncertain at best and by consolidating spent fuel from many locations at a few safeguarded facilities with high levels of security. It is true that multinational repositories, as opposed to national repositories, may require more spent fuel shipments over greater distances, increasing cost and security risk. But if managed properly, the relatively modest increases in short-term costs and risks are outweighed by the longer-term costs and risks posed by continued national on-site storage and/or disposal.

The non-existent back end commercial market might present opportunities for leveraging the provision of a spent fuel disposal pathway in return for a commitment not to pursue sensitive fuel capabilities such as enrichment and reprocessing. According to a 2007 US-Russian National Academies workshop, “arrangements that would provide assured return of spent nuclear fuel could provide a much more powerful incentive for countries to rely on international nuclear fuel supply than would assured supply of fresh fuel, because assured take-back could mean that countries would not need to incur the cost and uncertainty of trying to establish their own repositories for spent nuclear fuel or nuclear waste.”

Multinational spent fuel pathways can be divided into three broad categories:

1. **Fuel leasing/take-back**

Fuel leasing/take-back is mainly directed at states with small or emerging nuclear programs and is both a powerful sales incentive and an effective way to strengthen nonproliferation and safety. Take-back is central to Russia’s nuclear reactor deals with Iran, Turkey and Vietnam. The fuel leaser does not necessarily have to dispose of the returned spent fuel; it could be sent (for example through an IAEA-brokered deal) to a third party state or a multinational fuel cycle center located elsewhere. However, the arrangement is far less appealing to the customer when the spent fuel is only being removed for reprocessing and the remaining high level waste will eventually be returned, as is currently the case with the French and British reprocessing programs. While the U.S. Global Threat Reduction Initiative takes back spent fuel from research reactors worldwide to reduce proliferation dangers, the US Congress has thus far shown no interest in replicating this effort for spent fuel from civilian power reactors.

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* In addition, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico has been receiving US defense-generated transuranic waste since March 1999.
Bundled or “cradle-to-grave” services from full service companies or consortia are often mentioned in this context as a promising approach for linking the front and back ends of the fuel cycle but expectations should be tempered. For nuclear newcomers, this service might be attractive, at least at the outset, because it offers the simplicity of a one-stop shop rather than negotiating contracts for each stage of the fuel cycle in what is likely to be an unfamiliar market. However, for more established utilities it is a different story. Conversion, enrichment and fuel fabrication contracts are negotiated separately and on different timetables. Of particular importance in the context, operators are constantly chasing small tweaks to fuel designs that increase reliability and tend to mature in 2-3 year cycles. This means that utilities prefer to have their fuel fabricated at the very last moment before delivery to receive the most efficient fuel possible, so there is not much incentive to get locked into long-term fuel contracts. In addition, many regulated utilities must demonstrate that they have negotiated the best fuel deal possible. Mexico’s power plant, for example, needs to show that it received the cheapest price in order to receive regulatory authority to operate. This is why most utilities contract with several fuel suppliers. On the other side of the equation, bundling may conflict with the supplier’s business model – for example, where a company’s divisions operate largely independently of one another and profitable divisions do not support underperforming divisions. Adding spent fuel disposal may change this dynamic although to what extent is unclear.

2. Interim storage

Provided a longer term disposal strategy is also in place or being pursued, multinational interim storage offers the nonproliferation benefit of enabling spent fuel to be removed from numerous (small) stores to a centralized, well safeguarded location at an earlier date. In addition, shared stores at the same locations may simplify logistics. Such a facility “in no way reduces the necessity of developing final use/disposal options; it provides breathing room, allowing existing and new reactors to operate while permanent solutions are developed.” However, interim storage suffers from many of the same political problems that plague final repositories, such as the difficulty of finding a willing host, and potentially fuels suspicions that any operating interim sites will make the search for a permanent solution less urgent and increases the chances that the facilities will, by design or default, eventually become permanent. Given this, questions have been raised about prioritization: why spend essentially the same amount of time, effort and scarce political capital on a temporary fit? Why not concentrate on the permanent solution? One obvious response to part of this argument is that demonstrating that an interim storage facility can be operated safely will help to build precisely the trust that is necessary for communities, states and federal governments to support a repository. But with the deficit of trust that currently exists in many circumstances, this will not happen quickly or easily.

Ultimately, interim storage and final disposal pathways come with their own sets of technical, economic and political advantages and disadvantages, but neither option should be pursued to the exclusion of the other.

3. Multinational/international repositories
Various scenarios have been advanced for the establishment and operation of multinational repositories. A 1987 preliminary OECD/NEA report weighed two internationalization paths: the creation of a dedicated international repository; and an existing national repository that would accept material on a commercial basis from other states to become an international repository. While the latter was determined to be the more realistic option, the lack of progress on national repositories convinced the authors that a more comprehensive study would be premature.\textsuperscript{v}

The 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management counseled “that, in certain circumstances, safe and efficient management of spent fuel and radioactive waste might be fostered through 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.”\textsuperscript{vi}

In 2004, the IAEA published a study examining scenarios of cooperation for the development of multinational repositories.\textsuperscript{vii} Three broad approaches were identified:

**Cooperation** – a shared repository is developed by a group of partner states. Three variants were outlined:

i. several states with small but developed nuclear programs agree to use a shared repository in an appropriate volunteer host state – economies of scale are the driving force. This succinctly describes the intent of the 1980 Low-Level Radioactive Waste Policy Act (LLRWPA) in the United States and is a potential approach to spent fuel within the European Union.

ii. states with small amounts of radioactive waste cooperate to ensure one of their number acquires the necessary technology and institutional structures. The Ljubljana Initiative comes close to this vision. In late 2003 and early 2004, experts from waste and government agencies in Austria, Bulgaria, Croatia, the Czech Republic, Hungary, Slovakia and Slovenia met in the Slovenian capital to discuss regional HLW disposal solutions.\textsuperscript{viii}

iii. specialized repositories for specific waste types are developed – while commercially driven, waste exchange programs amongst states could be incorporated into this model. Precedent for this type of activity exists. In 1986, Sweden exchanged unused reprocessing contracts for German spent mixed-oxide MOX fuel. Similarly, in August 2000 US Ecology accepted 120 drums of low-level waste containing radium that was flown in from Spain.\textsuperscript{ix}

**Add-on** – a host state offers to expand its existing national repository to accept spent fuel/high level waste from other states. The IAEA’s 2004 report identified the most obvious candidates for this scenario: the host would be a large state with a significant waste inventory (for example, Russia or the United States) and the partners would be either states with small inventories and/or complex geology (for example, Slovenia, Taiwan and Switzerland) or states with only research reactor fuel (for example, Australia, Denmark and Norway). There are some significant obstacles, however. Siting a repository for domestic use has proved hard enough; making the case for accepting waste from other states is more difficult again and may violate the social contract that any future repository is predicated on. The host’s ability to make such an offer is also dependent on a repository that has sufficient space available at the outset or can be expanded later. Less intractable but still important, prospective hosts may have policies
or laws in place (for example, Finland, France and Sweden) preventing acceptance of foreign spent fuel/waste and prospective customers could place requirements on the repository system – Swiss law has just such provisions.

**International/Supranational** – a host state or states cede control of a repository or network of repositories to an international body, possibly with an industrial consortium responsible for construction and operation. This was considered the least likely scenario given the political sensitivity to the transfer of sovereignty requirement. However, taking a broader approach might make this scenario more attractive. The IAEA has concluded: “Willingness to cede land for a full fuel cycle park might be more easily found since this could bring more high-tech activities into a country than is the case for disposal alone.”x This approach need not be limited to nuclear activities, however. Many large, high-tech projects (such as solar energy R&D) could have the same effect.

**Multinational Cooperation in Practice**

In an early demonstration of cooperative waste management, from 1967 to 1982 OECD member countries under the aegis of the Nuclear Energy Agency took part in an experimental low and medium level radioactive waste dumping program in the eastern Atlantic Ocean. From 1974 to 1982, all dumping took place at a single site. The Co-ordinated Research and Environmental Surveillance Programme (CRESP) was established in 1980 to coordinate national programs, share resources and peer review scientific information.xi

Cooperative approaches to low and intermediate-level radioactive waste disposal have been considered more recently. In 2002 Kazatomprom expressed interest in importing both categories of waste which it would temporarily store in abandoned uranium mines until a disposal facility was built in Aktau. Kazatomprom argued that getting cash for burying foreign waste was the only way to deal with Kazakhstan's own massive waste inventories accumulated during Soviet times. The plan proposed that only a small fraction of all waste to be buried would be imported. There was strong opposition to the plan from environmental groups and civil society and it became a non-issue in 2006 with the signing of the Central Asian Nuclear-Weapon Free Zone (CANWFZ), which prohibits import of any foreign radioactive waste into the region. xii Denmark has expressed an interest in cooperative disposal, albeit not as a host. The Danish Government identified six locations in five counties to bury 5,000 cubic meters of low level waste from the Risø National Laboratory. However, the proposed hosts are less than enthusiastic and are more interested in leaving it at the lab or sending it to Germany or Sweden.xiii

In the mid 1990s, the President of the Marshall Islands proposed leasing a contaminated island for nuclear waste disposal and US Fuel and Security, in cooperation with MINATOM, proposed storing spent fuel and excess plutonium on Wake Island and later Palmyra Island.xiv There have also been several false starts in Australia, including an idea in the late 1970s for regional spent fuel storage on Christmas Island (an Australian territory in the Indian Ocean) and, more controversially, the aborted development of a concept by the UK-Canadian-Swiss company Pangea Resources to locate an international repository in western and southern Australia.xv
More intriguingly, in July 2011 the European Council adopted a legally binding and enforceable European Commission proposal encouraging Member States to conclude agreements to collectively meet their radioactive waste disposal needs. Thus, while not mandating the creation of compacts, the European Council is allowing for a just such a system to evolve if states are so inclined, in its efforts to craft binding standards for managing radioactive waste. Other regions (Asia, the Middle East, Africa) will not enjoy the same sense of community, and the existence of an organization such as EURATOM, that exists in the EU, but their interests in finding cooperative spent fuel solutions is the same; indeed, for Japan, South Korea and Taiwan this is a matter of urgency. The United Arab Emirates is also thinking along similar lines. According to Dr John Loy, director of radiation safety at the Federal Authority for Nuclear Regulation: “Options that may be considered for the National Strategy on Nuclear Waste Disposal would be either regional or international repositories operating in different countries.”

Problems of Linkage

Even if the ‘technical’ parts of repository development such as site selection, licensing and construction proceed smoothly, it is a slow process. The biggest challenge remains public acceptance at the local, state/regional and federal levels. Consent-based siting can take decades, which means that any proposal that links the front and back ends of the fuel cycle and offers more than simply committing states to a nonspecific pledge such as ‘developing a spent fuel disposal path’ is inherently speculative and imposes an arbitrary deadline of some sort that is either unenforceable or unacceptable to industry and government. For example, the most powerful negative linkage is between spent fuel disposal and fuel supply; that is, denial of fuel supply unless a spent fuel pathway (repository or interim storage) is operating. But this commits the cardinal sin of threatening the disruption of the fuel market and is thus a non-starter. From a nonproliferation perspective, the provision of multinational storage and/or disposal services would markedly reduce any incentive to reprocess spent fuel and participation could be subject to a ‘no new enrichment’ provision. However, in the absence of any operating storage facilities or repositories, this is a grand bargain that cannot be honored on the supply side and is thus an empty promise.

What can we learn from Sweden and Finland?

Both Sweden and Finland have demonstrated workable waste management solutions and selected sites – Östhammar and Eurajoki, respectively – based on overwhelming local support. The experiences in these countries offer some important lessons, although the extent to which they are transferable to a multinational repository is open to question. Five of the most significant are offered below.

1. Acclimation: Sweden’s Östhammar and Oskarshamn, the two municipalities that competed to host the repository, were ‘acclimated’ to nuclear activity: Östhammar hosts three reactors and a repository for short-lived radioactive waste; Oskarshamn hosts three reactors, an interim spent fuel storage facility (Clab), a Canister Laboratory and the Åspö Hard Rock Laboratory. Similarly, two of the four sites selected for detailed characterization in Finland (Eurajoki and Loviisa) host nuclear plants as well as low/intermediate-level radioactive waste and spent fuel storage facilities. SKB (the Swedish utility consortium managing the repository program) expressed a clear preference for the nation’s nuclear
communities as “potentially ready-made local stakeholders” and part of the appeal for the Finnish municipalities was that a repository would lower the pre-existing risk of “the waste storage pools already familiar to” the local communities.\textsuperscript{xix} Brown field sites and ‘acclimated’ local communities are no guarantee of success, however. For example, in the UK in the mid-1990s, Cumbria County Council rejected Nirex’s plan to construct a Rock Characterization Facility at Longlands Farm near Sellafield to provide proof of concept for an eventual repository for low and intermediate level waste.\textsuperscript{xx}

2. **Community acceptance and competition**: Linked to the point above, SKB asked for volunteers and two Swedish municipalities competed to host the facility. In Finland, four locations were shortlisted. All were crystalline rock and none was determined to be significantly safer than any other.\textsuperscript{xxi} The search was then narrowed in consultation with local communities and the selection of Eurajoki was based largely on community acceptance.\textsuperscript{xxii} In this context, creative approaches to local community interactions and engagement, such as the Dutch Central Organisation for Radioactive Waste’s Highly Radioactive Waste Treatment and Storage Building which is orange and will be repainted in progressively lighter shades until it is white in about 100 years to reflect the reduction in the waste’s heat production, should also be considered.\textsuperscript{xxiii}

3. **Communicating technology issues**: SKB’s decision to stress the importance of engineered barriers in its repository design – the KBS-3 concept – was clearly and effectively articulated. When confrontations between SKB and local communities threatened to derail the geology-based siting process, SKB recalibrated its approach to focus on technology.\textsuperscript{xxiv} Completed in 1995, the Åspö Hard Rock Laboratory is a full-scale experimental facility designed to study changing conditions in different final repositories and provide data to construct repository barriers.\textsuperscript{xxv} By demonstrating different technical solutions, SKB “unshackled” the concept from geology, making it possible to find numerous suitable sites.\textsuperscript{xxvi} Finland adopted SKB’s technical approach.\textsuperscript{xxvii} The contrast with Yucca Mountain is striking. In Nevada, opponents described engineered barriers (such as titanium drip shields) as “ever-more-exotic engineering ‘fixes’” and offered them up as proof that the geological science was flawed.\textsuperscript{xxviii} In fact, the Nuclear Regulatory Commission and DOE had been underscoring the importance of multiple engineered barriers as part of a ‘defense-in-depth’ approach for years but, in order to justify the decision to terminate activities at all other sites and single out Yucca Mountain in 1987, DOE was forced to emphasize the unique suitability of Nevada’s geology.\textsuperscript{xxix} As Elam and Sundqvist have presciently observed: “By concentrating on upholding the Swedish nuclear industry’s ability to demonstratively confirm the attainability of their waste management solution, the KBS Programme has been drawn into valuing mutability, while by prioritizing the actual finalization of a non-negotiable solution, the Yucca Mountain Project has been drawn into over-investing in immutability.”\textsuperscript{xxx}

4. **Incentives**: Not surprisingly, money and jobs are an essential part of the equation. In 2009, the mayors of Östhammar and Oskarshamn agreed to split a £162 million winner’s pot 75/25 with the loser getting the larger percentage and SKB committed to investing in infrastructure, business development and education in both municipalities over the next 15 years.\textsuperscript{xxxi} Similarly, economic and social benefits were identified by Eurajoki Municipality Council member Altti Lucander as one of several key reasons for Eurajoki’s acceptance.\textsuperscript{xxxii} A sense of responsibility and local pride in hosting a cutting edge technology also played an important role.\textsuperscript{xxxiii}
5. A dedicated waste management organization: Verhoef, McCombie and Chapman have observed: “If shared repositories are to become a reality, a dedicated multinational waste management organisation will be required that can work towards the goal on the extended timescales that national disposal programmes have shown to be necessary.” The Blue Ribbon Commission on America’s Nuclear Future made the same recommendation for the United States. In Sweden, the industry consortium SKB is the responsible agency and in Finland it is Posiva Oy. DOE, by comparison, has been hampered by a substantial trust deficit, some of which it inherited from the AEC. SKB and Posiva Oy have carried far less baggage, which is largely a function of historical development and good safety records. Östhammar and Oskarshamn were both assured veto power in the event that they objected and in Finland, municipal veto power can only be changed through an extended legislative process. Neither country experienced a ‘Screw Nevada’ moment.

Learning from the progress national programs have made and the work of regional organizations and the EU and applying these lessons to the specific circumstances of Asia, the Middle East, etc. should be enormously helpful in moving forward. Continuing along the path of delay and indecision that most countries are on right now is irresponsible and ultimately unsustainable.

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iii Stephen Goldberg, Robert Rosner and James Malone, The Back End of the Nuclear Fuel Cycle: An Innovative Storage Concept (Cambridge, MA: American Academy of Arts and Sciences, 2012), p.13, 14, 18. According to the Blue Ribbon Commission on America’s Nuclear Future: “After an initial period of cooling in wet storage (generally at least five years), dry storage (in casks or vaults) is considered to be the safest and hence preferred option available today for extended periods of storage (i.e., multiple decades up to 100 years or possibly more).” It should be noted, however, that the BRC did not advocate using temporary storage as a reason to delay actions and made strong recommendations to move forward with “prompt” initiatives to establish interim centralized storage and repository programs. Report to the Secretary of Energy, 26 January 2012, p.34, http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf
iv The demand for, and economics of, multinational storage have been questioned in the European context. See Chapman, McCombie and Richardson, SAPIERR II – Work Package 3, p.25-29.


xvii "Bornholm mayor Winni Grosbøll explained: “We suggest either leaving the waste in Risø where it has been sitting already for many years, or looking at creating a co-operation deal with neighbouring countries such as Sweden or Germany who are already used to dealing with nuclear material.” Peter Stanners, “Mayors up in arms over radioactive waste,” The Copenhagen Post, 1 May 2012, http://cphpost.dk/news/national/mayors-arms-over-radioactive-waste


Finland’s geology is remarkably uniform which made for simplified site characterization. This is particularly important in terms of promoting public understanding of the process.

Vira, “Winning Citizen Trust,” p.70, 75. In contrast, when Congress amended the Nuclear Waste Policy Act in 1987, the ‘competition’ (in Texas and Washington) was eliminated before DOE completed site characterization. Allison Macfarlane has observed: “Though Congress had asked DOE to simply decide if Yucca Mountain were a reasonable site, by selecting just one site Congress put enormous political pressure on the DOE to find that the site was adequate.” Allison Macfarlane, “Is It Possible To Solve The Nuclear Waste Problem?” Innovations, Fall 2006, p.89. Emphasis added.


Elam and Sundqvist, “Meddling in the KBS Programme and Swedish Success in Nuclear Waste Management,” p.16.


Juhani Vira, Posiva Oy’s Vice President for Research, has proffered an ethical dimension to repository support in municipalities with nuclear power plants, pointing out that some letters to the editor in local Eurajoki and Loviisa newspapers argued that, “having enjoyed the various benefits from the nuclear power plants, the people should now recognize their responsibilities for the wastes as well.” Vira, “Winning Citizen Trust,” p.74; Margot Roosevelt, “U.S. turns to Sweden as model in nuclear waste storage,” The Los Angeles Times, 21 February 2010, accessed 18 July 2010, http://articles.latimes.com/2010/feb/21/nation/la-na-nuclear-waste21-2010feb21


The most important regional organizations are the Association for Regional and International Underground Storage (ARIUS) and the European Repository Development Organization (ERDO) Working Group.