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IT IS 6 MINUTES TO MIDNIGHT

*Feature*

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# It's 2050: Do you know where your nuclear waste is?

**Allison Macfarlane**

**Abstract**

In light of Japan's nuclear disaster, a major lesson can be learned related to the back end of the fuel cycle: Planning is necessary for the safe and secure management of spent nuclear fuel and nuclear waste. But the topic of storing waste continues to be subject to last-minute solutions, as the experiences of a number of countries besides Japan show. Countries with nuclear power programs need a medium-term strategy for spent fuel storage prior to the long-term plan for spent fuel or high-level waste disposal. Though difficult, the disposal of high-level nuclear waste is possible, and a clear strategy to develop a repository combines both technical and societal criteria in a phased approach. After Fukushima, it is now imperative to redefine what makes a successful nuclear power program—from cradle to grave. Nuclear waste management must be designed from the beginning; otherwise, the public in many countries will reject nuclear as an energy choice.

**Keywords**

Blue Ribbon Commission, fuel pools, Fukushima, nuclear power, nuclear waste, planning, repository, siting, spent fuel

Though nuclear power produces electricity with little in the way of carbon dioxide emissions, it, like other energy sources, is not without its own set of waste products. And in the case of nuclear power, most of these wastes are radioactive.[1] Some very low level nuclear wastes can be stored and then disposed of in landfill-type settings. Other nuclear waste must remain sequestered for a few hundred years in specially engineered subsurface facilities; this is the case with low level waste, which is composed of low concentrations of long-lived radionuclides and higher concentrations of short-lived ones. Intermediate and high-level waste both require disposal hundreds of meters under the Earth's surface, where they must remain out of harm's way for thousands to hundreds of thousands of years (IAEA, 2009). Intermediate level wastes are not heat-emitting, but contain high concentrations of long-lived radionuclides. High-level wastes, including spent nuclear fuel and wastes from the reprocessing of spent fuel, are both heat-emitting and highly radioactive.

Today, 437 nuclear reactors are in use around the world in 31 countries. In addition, more than 60 countries have

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expressed an interest in acquiring nuclear power for electricity production in the future (IAEA, 2010). Each reactor will produce its own wastes. Yet no repository exists for the disposal of high-level nuclear waste anywhere in the world.[2] Even the topic of storing waste continues to be a minor priority in the planning stages. But this lack of foresight does not come without consequences: Reactor sites can be overburdened with spent fuel without a clear plan for dealing with this material in a timely manner. This is the case right now in South Korea, where the country's utility foresees a crisis in the next 10 years as the storage at all of the country's four nuclear plants fills up. The United Arab Emirates, which broke ground on its first nuclear facility on March 14, 2011 and is set to bring four nuclear reactors online beginning in 2017, has yet to announce storage as a priority. Hans Blix, former head of the International Atomic Energy Agency and current chairman of the UAE's International Advisory Board notes, "The question of a final disposal plan is still open and more attention should be spent on deciding what to do" (DiPaola, 2011).

When it comes to the severity of an accident at a nuclear facility, there may be little difference between those that occur at the front end of the nuclear power production and those at the back end: An accident involving spent nuclear fuel can pose a threat as disastrous as that posed by reactor core meltdowns. In particular, if spent fuel pools are damaged or are not actively cooled, a major crisis could be in sight, especially if the pools are packed with recently discharged spent fuel.

So why, if the danger is comparable to that at the front end, is there so little foresight and planning regarding the back end of the fuel cycle? Certainly for nuclear engineers, there are more rewards for reactor design than waste disposal. The nuclear industry in general has focused on electricity production, and few players in the field of electricity generation writ large put much time and effort into clean-up of their waste products—just think about the coal and natural gas industries and the production of mine wastes, ash ponds, waste water from gas extraction, and, of course, carbon dioxide. Put bluntly, money is made on the front end, not on the back end. But the reality, as South Korea is now realizing, is that a lack of planning for waste streams may cause the front end to collapse, halting the production of nuclear energy. This planning should include a medium-term strategy for spent fuel storage prior to the long-term plan for spent fuel or high-level waste disposal.[3]

Japan's Fukushima Daiichi plant has seven spent fuel pools—one at each reactor and a large, additional, joint pool—as well as dry cask storage for spent fuel on site. Initially, Japan had planned a short period of spent fuel storage at the reactor site prior to reprocessing, but Japan's reprocessing facility has suffered long delays (it was expected to begin operations in 2007, but is still not open), causing spent fuel to build up at reactor sites. In light of the country's nuclear disaster, a major lesson can be learned related to the back end of the fuel cycle: specifically, that careful planning, not ad hoc solutions, is necessary for spent nuclear fuel. A strategy for dealing with nuclear waste is essential to a successful nuclear power program, and it is best enacted *early* in the planning of a nuclear power program.

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## Before the repository

Nuclear fuel is discharged from a light water reactor after about four to six years in the core. Because the fuel is extremely thermally and radioactively hot at discharge, it is necessary to cool it in a pool. Spent fuel pools are about 40 feet deep and are actively cooled with circulated borated water, which helps absorb neutrons and stops the chain reaction that occurs in a reactor. In the United States and other countries, metal racks within the pools hold the fuel in place; today, adjusted racks hold more than four times the originally intended amount.[4] In the US, the re-racking of fuel occurred when the original plan to reprocess spent fuel soon after discharge failed on economic and policy grounds, leaving reactor operators scrambling to find a way to deal with their spent fuel.[5] Now, much more fuel is in the pools than in the reactor core—thus, in the event of a loss-of-coolant accident, such as occurred at Fukushima when the electricity could not be restored, there is a real chance that the spent fuel, if not cooled sufficiently, will release large amounts of radioactivity (Alvarez et al., 2003a, 2003b).

All countries with well-established nuclear programs have found themselves requiring spent fuel storage in addition to spent fuel pools at reactors. Some, like the US, use dry storage designs, such as individual casks or storage vaults that are located at reactor sites; other countries, Germany for one, use away-from-reactor facilities. Sweden has a large underground pool located at a centralized facility, CLAB, to which different reactors send their spent fuel a year after discharge, so spent fuel does not build up at reactor sites. Dry storage tends to be cheaper and can be more secure than wet storage because active circulation of water is not required. At the same time, because dry storage uses passive air cooling, not the active cooling that is available in a pool to keep the fuel cool, these systems can only accept spent fuel a number of years after discharge.[6]

In order to ensure safety, a country with a new nuclear program would be best off including additional spent fuel storage in its waste management plan from the beginning instead of adding it ad hoc, as has been done—and continues to be done—in most countries. By paying attention ahead of time to the back end of the nuclear fuel cycle, money, time, and public trust can be saved by acquiring licenses and siting facilities early, if they are to be at away-from-reactor locations.

## Elements of success

All countries that have traveled down the road of siting a radioactive waste repository have had a very bumpy ride. Only Sweden, Finland, and France have actually come close to getting it right, and only after a number of iterations of the siting process. Sweden—which submitted a license application to build a geologic repository in March 2011—first tried to find potential locations by investigating eight of the most technically suitable sites in the country.[7] The targeted municipalities protested and SKB, the nuclear company charged with site selection and waste management, selected a different approach: asking for volunteers. When no reasonable volunteer communities emerged, SKB went back to the drawing board yet again and approached communities

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that already had nuclear facilities and potentially suitable geology, on the premise that those communities would be more accepting of a repository. This approach worked, and two municipalities—Oskarshamn and Osthammar—competed for the site. Chosen largely on technical grounds—there are few fractures in the rock, therefore little chance of large volumes of water traveling through the repository—Osthammar won the bid in 2009. Oskarshamn, home to a geologic repository laboratory and an underground interim storage facility for spent fuel, CLAB, received 75 percent of the compensation money, while Osthammar received 25 percent. The idea was that the "winner" would receive long-term jobs from repository operations, while the "loser" needed an incentive to compete.

France, Canada, and Germany also have experienced a number of iterations of repository siting, some with more success than others. In the 1970s, Germany selected the Gorleben site for its repository; however, in the late 1990s, with the election of a Red–Green coalition government (the Greens had long opposed Gorleben), a rethinking of repository siting was decreed, and the government established the AkEnd group to re-evaluate the siting process. Their report outlined a detailed siting process starting from scratch, but to date too much political disagreement exists to proceed further.

France has had more success after failing in its first siting attempt in 1990, when a granite site that had been selected drew large protests and the government opted to rethink its approach to nuclear waste disposal entirely. In 2006, the government announced that it needed a geologic repository for high-level waste, identified at least one suitable area, and passed laws requiring a license application to be submitted by 2015 and the site to begin receiving high-level waste by 2025.

Canada recently rethought the siting process for nuclear waste disposal and began a consensus-based participatory process. The Canadian Nuclear Waste Management Organization was established in 2002, after previous attempts to site a repository failed. The siting process began with three years' worth of conversations with the public on the best method to manage spent fuel. The organization is now beginning to solicit volunteer communities to consider a repository, though much of the process remains to be decided, including the amount and type of compensation given to the participating communities.

The United States had been working toward developing a high-level waste repository at Yucca Mountain, Nevada; this fell through in 2010, when the Obama administration decided to reverse this decision, citing political "stalemate" and lack of public consensus about the site. Instead, the Obama administration instituted the Blue Ribbon Commission on America's Nuclear Future to rethink the management of the back end of the nuclear fuel cycle.[8] The US can flaunt one success, though. The Waste Isolation Pilot Project (WIPP), located near Carlsbad in southern New Mexico, is actually the only operating deep geologic repository for intermediate level nuclear waste, receiving waste since 1998. In the case of WIPP, it only accepts transuranic wastes from the nuclear weapons complex. The site is regulated solely by the

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Environmental Protection Agency, and the state of New Mexico has partial oversight of WIPP through its permitting authority established by the Resource Conservation and Recovery Act. The city of Carlsbad is supportive of the site and it appears to be tolerated by the rest of the state.[9]

## Getting it right

Unarguably, the most difficult part of the back end of the fuel cycle is siting the required facilities, especially those associated with spent fuel management and disposal. Siting is not solely a technical problem—it is as much a political and societal issue. And to be successful, it is important to get the technical and the societal and political aspects right.

Certain elements—including an institution to site, manage, and operate waste facilities—need to be in place to have a successful waste management program. In some countries, this agency is entirely a government entity, such as the Korea Radioactive Waste Management Organization. In other countries, the agency is a corporation established by the nuclear industry, such as SKB in Sweden or Posiva Oy in Finland. Another option would be a public–private agency, such as Spain's National Company for Radioactive Waste or Switzerland's National Cooperative for the Disposal of Radioactive Waste.

Funding is one of the most central needs for such an institution to carry out research and development programs; the money would cover siting costs, including compensation packages and resources for local communities to conduct their own analyses of spent fuel and waste transportation, storage, repository construction, operations, security and safeguards, and future liabilities. Funds can be collected in a number of ways, such as putting a levy on electricity charges (as is done in the US) or charging based on the activity or volume of waste (Hearsey et al., 1999). Funds must also be managed—either by a waste management organization or another industry or government agency—in a way that ensures steady and ready access to funds over time. This continued reliable access is necessary for planning into the future for repository operations.

Then, of course, the siting process must be established. This should include decisions on whether to allow a community to veto a site and how long that veto remains operational; the number of sites to be examined in depth prior to site selection and the number of sites that might be required; technical criteria to begin selecting potential sites; non-technical considerations, such as proximity to water resources, population centers, environmentally protected areas, and access to public transportation; the form and amount of compensation to be offered; how the public is invited to participate in the site selection process; and how government at the federal level will be involved.

The above are all considerations in the siting process, but the larger process—how to begin to select sites, whether to seek only volunteers, and so on—must also be determined ahead of time. A short list of technical criteria must be integrated into a process that establishes public consent to go forward, followed by many detailed studies of the site—first on the surface, then at depth. There are distinct advantages

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to characterizing more than one site in detail, as both Sweden and Finland have done. Multiple sites allow the "best" one to be selected, increasing public approval and comfort with the process.

Finally, the site needs to be evaluated against a set of standards established by a government agency in the country. This agency typically is the environmental agency or the nuclear regulatory agency. The type of standards will constrain the method by which a site will be evaluated with regard to its future performance. A number of countries use a combination of methods to evaluate their sites, some acknowledging that the ability to predict processes and events that will occur in a repository decrease rapidly with each year far into the future, so that beyond a few thousand years, little can be said with any accuracy. These countries use what is termed a "safety case," which includes multiple lines of evidence to assure safe repository performance into the future.

## Moving forward

After weathering the Fukushima accident, and given the current constraints on carbon dioxide emissions and potential for growth of nuclear power, redefinition of a successful nuclear power program is now required: It is no longer simply the safe production of electricity but also the safe, secure, and sustainable lifecycle of nuclear power, from the mining of uranium ores to the disposal of spent nuclear fuel. If this cannot be achieved and is not thought out from the beginning, then the public in many countries will reject nuclear as an energy choice.

## Notes

1. Nuclear wastes are classified in various ways, depending on the country or organization doing the classification. The International Atomic Energy Agency (IAEA) notes six general categories of waste produced by civil nuclear power reactors: exempt waste, very short-lived waste, and very low level waste can be stored and then disposed of in landfill-type settings; low level waste, intermediate level waste, and high-level waste require more complex facilities for disposal.
2. Sweden is currently the country closest to realizing a final solution for spent fuel, after having submitted a license application for construction of a geologic repository in March 2011. It plans to open a high-level waste repository sometime after 2025, as do Finland and France.
3. Some countries, such as Sweden, Finland, Canada, and, until recently, the US, plan to dispose of their spent fuel directly in a geologic repository. A few others, such as France, Japan, Russia, and the UK have an interim step. They reprocess their spent fuel, extract the small amount of plutonium produced during irradiation, and use it in new mixed oxide (MOX) fuel. Then they plan to dispose of the high-level wastes from reprocessing in a repository.
4. These racks were originally open-frame designs, but have been replaced by solid, honeycomb-type racks open only at the top and bottom.
5. In the 1970s, a few reprocessing plants either stopped operation or never began operation owing to technical difficulties and economic reasons. By 1976, President Gerald Ford and then President Jimmy Carter indefinitely deferred reprocessing on nonproliferation grounds. President Ronald Reagan reversed this policy, but no reprocessing was established because of unfavorable economics.
6. In the US, all licensed dry cask designs can take spent fuel five years after discharge; newer designs that can accept spent fuel three years after discharge are under development.

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7. Repository sites must be able to contain the radionuclides for thousands of years. Clearly, some sites are more suitable than others—for example, a site that is located in highly fractured rock with rapid groundwater circulation would not be reasonable.
8. I am a member of this Commission. Other members include co-chair Lee Hamilton, former representative from Indiana; co-chair Brent Scowcroft, former national security advisor to President George H. W. Bush; Mark Ayers, president of the Building and Trades Department, AFL-CIO; Vicky Bailey, former Federal Energy Regulatory Commissioner; Albert Carnesale, chancellor emeritus of UCLA; Pete Domenici, former US senator from New Mexico; Susan Eisenhower, president, Eisenhower Group; Chuck Hagel, former US senator from Nebraska; Jonathan Lash, president of the World Resources Institute; Richard Meserve, president of the Carnegie Institution for Science; Ernie Moniz, professor of physics, MIT; Per Peterson, chair, Department of Nuclear Engineering, UC Berkeley; John Rowe, CEO of Exelon Corporation; and Phil Sharp, president of Resources for the Future.
9. Three years after WIPP opened, at least 60 percent of the state's residents supported its operation. See discussion in Jenkins-Smith et al. (2011).

## References

Alvarez R, Beyea J, Janberg K, et al. (2003a) Response by the authors to the NRC review of "Reducing the hazards from stored spent power reactor fuel in the United States." *Science and Global Security* 11: 213–223. Available at: http://www.irss-usa.org/pages/documents/SGS_213-223_response.pdf.

Alvarez R, Beyea J, Janberg K, et al. (2003b) Reducing the hazards from stored spent power reactor fuel in the United States. *Science and Global Security* 11: 1–51. Available at: http://www.irss-usa.org/pages/documents/11_1Alvarez.pdf.

DiPaola A (2011) U.A.E. needs to determine nuclear fuel disposal plan, Blix says. Bloomberg, 8 February. Available at: http://www.bloomberg.com/news/2011-02-08/u-a-e-needs-to-determine-nuclear-fuel-disposal-plan-blix-says.html.

Hearsey CJ, Emmery D, Kunsch P, et al. (1999) The financing of radioactive waste storage and disposal, EURADWASTE '99, 5th European Commission Conference on Radioactive Waste Management and Disposal and Decommissioning, 15–18 November, Luxembourg.

IAEA (2009) *Classification of Radioactive Waste, General Safety Guide*. IAEA Safety Standards Series No. GSG-1. Available at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1419_web.pdf.

IAEA (2010) *International Status and Prospects of Nuclear Power*. Board of Governors General Conference, GOV/INF/2010/12-GC (54)/INF/5, 2 September. Available at: http://www.iaea.org/About/Policy/GC/GC54/GC54InfDocuments/English/gc54inf-5_en.pdf.

Jenkins-Smith H, Silva C, Nowlin M, and deLozier G (2011) Reversing nuclear opposition: Evolving public acceptance of a permanent nuclear waste disposal facility. *Risk Analysis* 31(4): 629–644.

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**Allison Macfarlane** is an associate professor of environmental science and policy at George Mason University, USA, and is an affiliate of the Belfer Center for Science and International Affairs at Harvard University. She was named to the Blue Ribbon Commission on America's Nuclear Future by US Energy Secretary Steven Chu in January 2010, and is the co-editor of *Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste* (MIT Press, 2006, with Rodney Ewing). She is the former chair of the *Bulletin*'s Science and Security Board.

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