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Wrestling with the Hydra of Nuclear Waste Storage in the United States

Despite decades of legal and policy action, and billions of dollars expended on a recently scrapped permanent nuclear waste storage facility at Yucca Mountain, the inability to resolve the longstanding issue of waste will seriously threaten a nuclear renaissance in the United States.

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I. Introduction

In ancient Greek mythology the hydra was a serpent-like beast with many heads that guarded the entrance to the Underworld. It had a breath so deadly that even its footprints were reputed to poison men to death. The inability of the United States to yet build and operate a safe permanent geologic repository for spent nuclear fuel rods and high-level nuclear waste could very well be the industry's equivalent of a hydra, lurking beneath the surface, for it is an issue that poses perhaps the most serious threat to continued expansion of the industry.

For those who have not kept up to date on recent events, the Barack Obama Administration asked the Department of Energy (DOE) to establish a Blue Ribbon Commission (BRC) to develop a new approach to nuclear waste disposal in January 2010. A few months later that year, the DOE filed a motion with the Nuclear Regulatory Commission (NRC) to withdraw the pending license application ‘‘with prejudice’’ for

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Yucca Mountain.[1] Then, in *New York v. NRC*,[2] the D.C. Circuit Court of Appeals vacated a 2010 update to the NRC's Waste Confidence Decision in late 2012.[3] Responding to this decision, the NRC has postponed the insurance of at least 19 new reactor licenses and has stated that no new licenses will be issued until the agency can address the issues raised by the D.C. Circuit.[4]

Furthermore, both the 110th and 111th sessions of Congress introduced legislation that would have amended the Atomic Energy Act to create a new federal corporation (the ''United States Nuclear Fuel Management Corporation'') that would ''assume responsibility for the activities, obligations, and use of resources of the federal government with respect to spent nuclear fuel (SNF) management.''[5] The Rand Corporation announced in December 2012 that a new public-private nuclear waste ''Management and Disposition Organization,'' or MDO, should be created along the lines of those proposals.[6]

Most recently, Secretary Chu and the U.S. Department of Energy announced a ''new waste disposal strategy'' on Jan. 10, 2013. This three-tiered approach to the waste issue would see a ''pilot interim store'' beginning operations in 2021 to house spent nuclear fuel from shutdown nuclear power plants; a bigger ''full-scale interim store'' built shortly after that; and an ''underground disposal facility'' completed by 2048.[7] However, even the overly optimistic policy document from the DOE admitted that such a plan faces two serious obstacles: public opposition and new legislation. As the DOE's 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* noted, building any type of storage facility will depend ''on the expressed will of American people.'' Moreover, it needs new Congressional approval and legislation to ''enable progress on implementing this strategy.''

> *What does all of this mean? Simply put, it doesn't look good for the nuclear power industry.*

What does all of this mean? Simply put, this article argues it doesn't look good for the nuclear power industry. Like the hydra, who had multiple heads, the waste dilemma is also multi-headed, for it consists of at least two closely related, though separate, crises. One of these ''heads'' threatens the short- or medium-term future of electric utilities when spent fuel pools at currently operating reactors run out of space. The other ''head'' is the long-term issue of finding a suitable permanent repository. The two are linked, but distinct, and solving one doesn't mean that the other is solvable or solved.[8]

Moreover, as the article explains, all of the five best existing alternatives to Yucca Mountain—extended onsite storage, a centralized interim facility, reprocessing, non-repository options, and building a new repository—come with their unique sets of risks and challenges, perhaps insurmountably so. Consequently, the so-called nuclear renaissance in the United States may stall on the runway before it ever actually lifts off.

II. The Dilemma of Nuclear Waste

To better comprehend the challenges inherent with existing alternatives to Yucca Mountain, it's useful to first provide a few details about nuclear waste itself as well as wet storage, dry storage, and permanent sequestration.

The term ''nuclear waste'' technically includes six categories of waste. The first three—SNF, high-level waste, and transuranic waste—are the most important or radioactive; the remaining three are low-level waste, mixed waste, and uranium mill tailings. SNF refers to fuel rods that have been irradiated in a nuclear reactor, meaning they contain high active and short-lived fission products such as cesium and strontium as

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well as long-lived radionuclides. High-level waste refers to highly radioactive material resulting from the reprocessing of spent nuclear fuel, the chemical processes that break down fuel rods into uranium and plutonium. Transuranic waste refers to any type of waste that has more than 100 nanocuries of alpha-emitting transuranic isotopes with half-lives greater than 20 years per gram of waste, excluding high-level waste.[9]

Typically, a single nuclear reactor will consume an average 32,000 fuel rods over the course of its lifetime, and it will also produce 20 to 30 tons of spent nuclear fuel per year—an average of about 2,200 metric tons annually for the entire U.S. nuclear fleet.[10] Spent nuclear fuel is currently stored at 77 different sites across the country. This total includes 63 sites with licensed operating commercial nuclear power reactors, four DOE-operated sites, nine decommissioned reactors, and a proposed reprocessing plant in Morris, IL.[11] According to the Congressional Research Service, the total amount of commercial SNF was 67,450 metric tons in May 2012.[12] If you include the 2,458 metric tons of DOE spent fuel and high-level waste that is also destined for Yucca Mountain, the total amount of waste requiring storage already equals the 70,000 metric-ton limit for the repository imposed by the Nuclear Waste Policy Act of 1982.[13] According to the BRC, the amount of waste generated by the industry could potentially increase to between 150,000 to over 200,000 metric tons by mid-century.[14]

To handle SNF, scientists and engineers distinguish between two primary types of storage: wet and dry. Wet storage pools involve placing spent fuel assemblies in racks in pools of water made of concrete and lined with stainless steel or epoxy-based paints. The pool is enclosed within a building, and radioactivity in water is kept as low as possible.[15] The pools themselves can become quite deep, with at least three meters of water covering the top of fuel assemblies to provide radiation shielding.[16] Operators often add boron and other neutron absorbing materials to the water to prevent the fuel from starting a chain reaction. About 90 percent of spent fuel globally is currently stored in wet pools.

Risks of geological repositories include groundwater seeping into the repository, corrosion of waste containers, and natural disasters such as earthquakes.

Dry storage of spent fuel can work only for rods that have had sufficient time to cool down to a point when it no longer needs to be kept under water. It differs from wet as it uses gas or air (sometimes enhanced with helium or nitrogen to limit oxidation) instead of water as a coolant, and metal or concrete as a radiation barrier. Fuel must be stored in wet pools for several years before it becomes cool enough for dry storage. Dry storage vaults use metal tubes and cylinders to store fuel and remove heat through air convection and have the building itself act as a radiation shield.[17] Although there are many different cask types, those in the United States typically hold 20–24 pressurized water reactor (PWR) fuel assemblies, sealed in a helium atmosphere inside the cask to prevent corrosion. Decay heat is transferred by helium from the fuel to the outside of the storage cask for cooling.

Permanent geological repositories are intended to store fuel rods currently in dry storage and those in wet storage that might eventually enter dry storage. They must provide protection against every plausible scenario in which radionuclides might reach the biosphere or expose humans to dangerous levels of radiation. These risks include groundwater seeping into the repository, corrosion of waste containers, and natural disasters such as earthquakes. The concern is that radionuclides might escape from containers and contaminate groundwater, which could flow to areas where it might be used as drinking water or for agriculture.

The Nuclear Waste Policy Act of 1982 currently provides that the

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DOE may only select Yucca Mountain as a repository site and that a federal interim storage facility cannot be opened before the repository is licensed. Thus, without congressional action, the only alternatives to Yucca Mountain are (1) extended on-site storage, (2) federal or private interim storage, (3) reprocessing, (4) non-repository options, and (5) building a new repository. As this article argues, however, none of these options look particularly feasible.

A. Extended on-site storage

On-site storage for spent nuclear fuel—essentially the status quo—does have some theoretical benefits, whether it is indefinite or only for a few decades. Maintaining on-site storage requires minimal effort, because no legislative changes are required. Transportation risks are reduced, because the spent fuel would only have to be transported once, to a final geological repository, instead of twice if moved to a centralized interim facility. Also, the fuel will be cooler having been located in a storage pool for an extended period of time.[18] Extended on-site storage provides the federal government with the flexibility and time to assess alternatives for a comprehensive waste management system.[19] Thus, extended on-site storage is beneficial given its simplicity, proven track record, and for allowing the federal government to develop better options.

However, on-site storage is a potential solution only to the short-term problem, not the long-term problem, and even then the risks of extended on-site storage significantly outweigh any perceived benefits given issues of storage capacity, safety, liability, and cost. In terms of capacity, there simply isn't enough space. About half the reactor fleet in the United States is already at or near pool storage capacity, and one GAO study found that 28 reactor sites will have to add dry cask storage space over the next decade to maintain a desired capacity in storage pools.[20]

On-site storage is a potential solution only to the short-term problem, not the long-term problem.

In terms of safety, the lack of a permanent repository requires nuclear operators to expand wet storage pools and to pack spent nuclear fuel more densely within them, raising serious concerns about protection in the event of a Fukushima-like accident, fire, or explosion. Many of the on-site storage pools designed to be temporary are turning into permanent ones, and temporary waste sites are not typically intended to handle contingencies such as earthquakes, tornadoes, and plane crashes, and operate safely only during normal operations.[21]

Complicating matters, various external threats could breach containment structures and cause serious accidents and fires. For example, the National Academy of Sciences (NAS) concluded that a terrorist attack or aircraft crash could drain the storage pool and cause the spent fuel inside to overheat and catch fire.[22] Furthermore, the long-term impacts of a fuel cladding fire could be significantly *worse* than those from Chernobyl, with hundreds of billions of dollars of damage in addition to human deaths and environmental devastation.[23] These storage facilities are not located inside containment buildings and are usually aboveground, making the consequences of an accident more severe. As one peer-reviewed study put it:

> A loss of coolant . . . [at a storage pool] could result in a nuclear accident. A loss of coolant could cause rapid heating, and then the outside shell of the fuel rods could catch fire. The result could be significant dispersal of highly radioactive fission products.[24]

Even the NRC estimated the median consequences of a spent-fuel fire at a pressurized water reactor would result in 54,000 to 143,000 extra cancer deaths, 2,000 to 7,000 square kilometers of agricultural land contaminated, and economic costs due to

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evacuation as high as $566 billion.[25] Another study projected that one single pool fire would cause 24,000 lung cancer deaths and induce economic damages 10 times as large as those caused by Hurricane Katrina.[26]

A fire or explosion need not be the result of deliberate attacks. Existing waste sites are already prone to accidents resulting in safety risks. In 1996, as one example, after fuel had been loaded into a dry storage cask at Point Beach, Wis., hydrogen inside the cask ignited as it was being welded and blew the three-ton lid off. The NRC had to take repeated actions throughout the 1990s to address defective welds on dry casks that led to cracks and quality assurance problems. Helium had leaked into some casks, increasing temperatures and causing accelerated fuel corrosion.

Thirdly, in terms of liability, extended on-site storage exposes the federal government to significant and growing liability to pay claims resulting from DOE's failure to begin accepting waste from commercial utilities under the NWPA. The U.S. government has paid approximately $1 billion to settle a series of claims by utilities that DOE had breached its contracts to accept SNF.[27] Looking to the future, as of July 2012 the Congressional Budget Office found that the federal government's current liability for settlements, final judgments, and entered judgments under appeal stand at $1.8 billion.[28] The DOE's own estimates project that its potential liabilities for waste program delays would total $20.8 billion if disposal began by 2020, which appears unlikely given the delays in the Yucca Mountain licensing process and recent budget cuts.[29]

Lastly, in terms of cost *beyond* liability, is the mere expense of storing spent fuel and high-level waste. Total undiscounted lifecycle costs for 40 years of dry cask storage for 1,000 tons of spent fuel, the amount generated by a typical reactor in roughly 30 years, amount to $120 to $250 million.[30] The costs of expanding onsite storage are, therefore, significant, with each dry cask running about $35,000 to $65,000 per ton[31] and other storage methods running about $80,000 per ton, or $470,000 to $750,000 per site per year.[32] This, of course, only presumes the fuel is being stored for four decades whereas in reality it will eventually need to find a safe storage facility for thousands of years.

Existing waste sites are already prone to accidents resulting in safety risks.

B. Centralized interim facilities

Advocates of interim storage facilities, designed to operate 40 to 60 years utilizing dry cask technology, argue that centralized interim storage facilities are safer and less expensive than on-site storage, and would allow DOE to meet its long-overdue obligations to begin accepting the fuel under the standard contracts it signed with nuclear facilities.[33]

Nonetheless, the option really isn't feasible or worth pursuing, because any interim facility will likely face intense state or local opposition, especially if there is no final repository located or other benefits provided.[34] Affected host states and communities would also raise concerns about safety and security, meaning development would take a considerable amount of time and be very costly. According to the GAO, a federal centralized storage option at two locations would take about 19 years to implement and would cost from $23 billion to $81 billion.[35]

Centralized storage also does not ultimately solve the long-term nuclear waste issue, because it only provides a temporary alternative and does not eliminate the need for a final repository. Furthermore, centralized storage requires nuclear waste to be transported twice—once to the centralized site and once to the repository— if it were not co-located along with a repository.[36]

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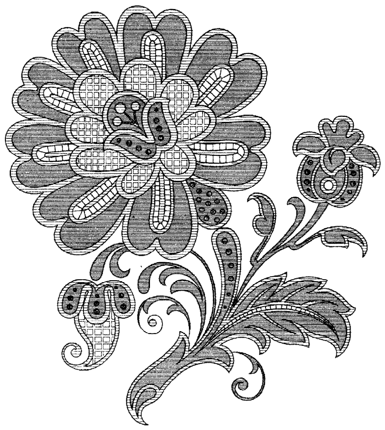
Another challenge confronting centralized interim storage is that DOE currently lacks the legal authority under the NWPA to provide it. The NWPA provisions addressing central storage have either expired or become unavailable because they are contingent on the final repository being licensed. Therefore, in order for DOE to begin working on a federal interim facility, Congress would need to pass legislation eliminating the restrictions in the NWPA and establishing an expedited siting and development process for the facility—unlikely in today's partisan, polarized political environment.

Given the delays in determining whether a federal interim facility should be built, a number of private organizations have sought licenses for interim storage facilities under the Atomic Energy Act, seeing that they are not bound by the rigidity of the Nuclear Waste Policy Act.[37]

However, these private enterprises pose even more uncertainty. In 2006, after a nine-year process, the NRC issued a license for a private storage facility to a partnership between a utility consortium and the Skull Valley Band of the Goshute Indians.[38] The partnership received a 20-year license, renewable for an additional 20 years, for storing up to 44,000 tons of spent fuel pending shipment by DOE to a permanent repository.[39] Since the project would impact public lands, the Department of Interior issued two decisions against it. The Bureau of Indian Affairs disapproved a proposed lease of tribal trust lands for the project, finding that there was too much risk that the waste would remain at the site indefinitely.[40] The Bureau of Land Management also rejected a necessary rights-of-way authority to transport waste to the facility, determining that the railroad line would be incompatible with the nearby wilderness area and that existing roads were inadequate to support transportation to the proposed facility.[41]



C. Spent fuel reprocessing

In the early days of the nuclear era, plutonium was considered a possible ''silver bullet'' solution to the world's energy problems. Continuous burning, breeding and recycling through a collection of reactors were to eliminate the need for uranium mining and enrichment and one day replace fossil fuels altogether. This idea pushed two related research programs in the early 1950s: the development of breeder reactors, and the separation of plutonium from spent fuel by reprocessing.

The first option, reuse at fast-neutron reactors or fast breeders reactors, has a complicated history much too detailed to explore here.[42] In short, because of the link between plutonium and nuclear weapons, the potential application of fast breeders led to concern that nuclear power expansion would usher in an era of uncontrolled weapons proliferation. The U.S. signed the Nuclear Non Proliferation Treaty in 1968 partially to address the issue, but India's unexpected test of a nuclear device in 1974 took the U.S. by surprise and culminated in President Carter's nonproliferation policy, which banned civilian reprocessing of nuclear fuel.[43]

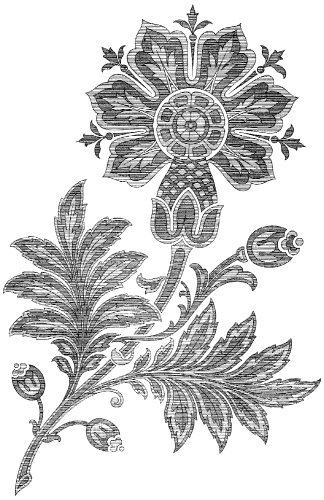
The U.S. federal government did begin efforts on commercial reprocessing of nuclear waste in 1966 at a facility in West Valley, N.Y., but the operation ended in disaster.[44] The plant was repeatedly criticized for lax security measures and for exposing employees to dangerously high doses of radiation, exceeding federal regulations dictated by the Occupational Safety and Health Administration, established in 1970.[45]

As well, the project ran into insurmountable logistical problems. The cost of reprocessing one year's worth of spent fuel was originally estimated to be $15 million but was later reported to be $600 million, the probability of a major earthquake in the area was deemed too great a risk to justify continued operation, and in practice the reprocessing plant was far less efficient than engineers had originally estimated.[46] After reprocessing only 640 tons of spent fuel, while accumulating more than 600,000 gallons of high-level waste, the facility was closed in 1972. It was not until 2002 that the West Valley facility was stabilized to the point that it could be safely decommissioned. However, remaining cleanup was estimated in 2008 to cost an additional $5 billion and take another 40 years.[47]

Newer modes of reprocessing, such as manufacturing mixed oxide fuel (MOX) and the Uranium Extraction Plus (UREX+) technique, face at least four serious challenges: they are expensive, they are relatively inefficient, they produce their own waste, and they still pose a substantial risk to weapons proliferation.

In terms of expense, the DOE estimated in 1999 that it would cost $279 billion over a 118-year period to fully implement a reprocessing and recycling program for the existing inventory of U.S. spent fuel relying on UREX+.[48] The National Academies concurred, and noted in 2008 that ''there is no economic justification for going forward with [a UREX+] program at anything approaching a commercial scale. . . . [UREX+] is [not] at a stage of reliability and understanding that would justify commercial scale construction at this time. Significant technical problems remain to be solved.''[49]

In terms of efficiency, the quality of recycled fuel significantly decreases the more it is reprocessed. A reduction in quality occurs each time fuel is reprocessed and recycled, and as fuel quality degrades, more energy is needed to enrich fuel rods, which makes the fuel even more dangerous, due to greater emission of neutron and gamma radiation that lead to higher overall burn-up rates and drastically less efficient fuel.



Moreover, reactors cannot run on entirely recycled fuel. The industry standard is 30 percent MOX and 70 percent fresh uranium. Plants still need significant supplies of natural uranium that must be mined from depleting stores of diminishing levels of quality ore.[50]

More significantly, spent fuel that has been reprocessed and used again has a higher heat content than spent fuel only used once—meaning it does practically nothing to relieve the industry's burden of waste.[51] Since the major factor that determines the overall storage capacity of a long-term repository is the heat content of the waste, not its volume, reprocessing does not significantly reduce the size of a future repository.[52]

Lastly, in terms of waste, both types of reprocessing create their own waste, including elements such as plutonium-241 and Americium-241 that would still need to be separated and stored in a centralized repository, and reprocessing produces plutonium that can be utilized for nuclear weapons. Worldwide, about half of the plutonium being separated is simply being stockpiled at reprocessing plants. As of 2005, this global stockpile of separated plutonium exceeded 250 tons, or enough to make more than 30,000 nuclear weapons.

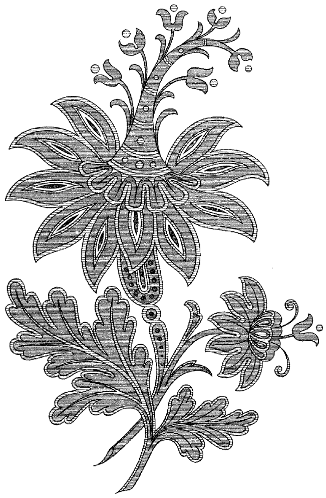
For perhaps these reasons, the DOE's newly released 2013 waste strategy affirms that reprocessing is not a feasible option. As it stated, ''one area of activity ruled out . . . was anything to do with reactor fuel reprocessing and recycling. U.S. policy is against this and can be expected to remain so for the practically foreseeable future.''[53] Similarly, a December 2012 report from the Oak Ridge National Laboratory and Department of Energy's Office of Fuel Cycle Technologies (FCT) in the Office of Nuclear Energy presumed that almost all existing nuclear waste—more than 98 percent by mass—would be sent to a permanent disposal “without the need to ensure retrievability for reuse or research purposes.”[54]

D. Non-repository options

Given the difficulty in siting and establishing a permanent geologic repository for spent nuclear fuel, numerous non-repository proposals have been studied over time. Section 222 of the NWPA provided DOE with the authority to research and investigate these unconventional means for disposal, but most of these alternatives have failed to be considered as viable options due to large technical obstacles, uncertain costs, environmental concern, and public opposition.[55]

For example, during the 1970s and 1980s, the DOE investigated sub-seabed disposal in stable clay sediments, and the 1987 amendments to the NWPA even established an Office of Subseabed Disposal Research within the agency.[56] The office developed a research plan for identifying potential sites and assessed some conceptual storage designs, but the program was terminated in 1996.

International efforts to study sub-seabed disposal were also conducted through the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development.[57] The NEA program evaluated the possibility of placing nuclear waste canisters in ocean sediments with gravity driven-penetrators or in drilled holes.[58] The NEA determined that sub-seabed disposal would probably keep the maximum dose to humans “many orders of magnitude below present standards” and pose “insignificant risk to the deep sea environment.”[59] Despite the NEA’s optimistic findings, sub-seabed disposal is currently prohibited under the 1972 London Dumping Convention.[60]



Another prominent non-repository alternative that has been considered is the disposal of waste in outer space. Space disposal involves placing nuclear waste canisters into a space shuttle and launching the shuttle into space or at the sun.[61] This is a very costly approach given the small capacity for storage in the shuttle, the amount of waste requiring disposal, launch safety, launch costs, and concern over reentry. The Atomic Energy Commission, which studied the issue during the 1970s, ultimately concluded that space disposal “does not seem an attractive alternative to the geological development program.”[62]

E. Building a new repository

A new repository would need to overcome several obstacles before completion. For starters, the current amount of nuclear waste requiring disposal already exceeds Yucca Mountain’s current legislated capacity of 70,000 metric tons. Therefore, more than one permanent repository site will need to be identified, studied, approved, constructed, and operated to handle current waste projections unless Congress amends the NWPA. The project would also be costly. According to the DOE, the estimated life-cycle cost of Yucca Mountain was $96.2 billion to license, construct, operate, and close a repository able to dispose of 122,000 metric tons of commingled commercial and defense waste, and that was only for the first few centuries of storage, not accounting for the entire lifetime of the spent nuclear fuel.[63] Thus, a new site selection effort, without amending the NWPA site selection process, would be time-consuming, costly, and extremely controversial, though it could, in principle, succeed.

III. Conclusions

In short, Yucca Mountain is all but dead, yet none of the five alternatives to it seem desirable or feasible. Extended onsite storage is limited in the volume of waste it can handle, and it is expensive, costing roughly $250 million per 1,000 metric tons. Furthermore, a single serious mishap at an onsite storage facility, whether accidental or intentional, could be 10 times worse than the economic damage inflicted by Hurricane Katrina.

Centralized interim storage does nothing to offset the requirement for a final repository, it would require waste to be moved twice, and facilities would have to confront likely fierce local opposition.

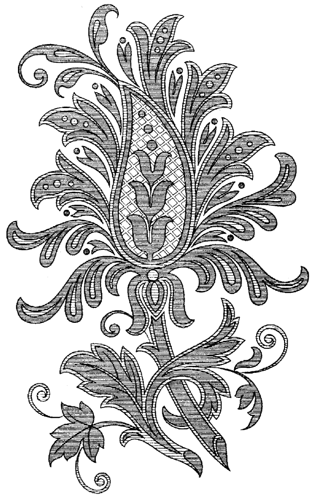
Reprocessing is no panacea, either, because it generates hotter rods that offset any space saved, it is more expensive, it produces its own waste, and it creates materials that can be utilized to manufacture weapons of mass destruction.

Non-repository options are either outlawed, such as sub-seabed disposal, or too dangerous, such as sending waste into space yet risking space shuttle crashes that could disperse highly radioactive debris into the atmosphere.

Building a new permanent geologic repository would suffer all of the same problems as Yucca Mountain, would take at least four decades, and will likely cost at least $100 billion.

Because of these difficulties, which culminate into something we call the country's ''nuclear waste dilemma,'' we believe two uncomfortable conclusions emerge.

First, Congress should explicitly prohibit the relicensing or licensing of reactors without definite plans for waste disposal in place. Such a moratorium would prevent waste from continuing to build up in the United States. It would also possibly force utilities to rethink their approach to the waste disposal issue, perhaps encouraging more private sector participation. A moratorium, in addition, would encourage states relying on nuclear power to seek a cooperative solution to the disposal problem, though the historical record suggests that neither private sector involvement nor state cooperation may be sufficient to change the state of affairs.



Second, the nuclear waste dilemma implies that the Obama Administration has developed a nuclear energy policy that may resemble schizophrenic convulsions more than any coherent strategy. On the one hand, the Obama Administration has stood firm behind expanding the nuclear power industry in the United States. Obama's energy plan includes providing several financial incentives for nuclear power, incorporating nuclear power into a Clean Energy Standard, and continuing with research and development. Even the DOE's 2013 waste strategy document proclaims that ''nuclear power is an integral part of our 'all-of-the-above' energy strategy . . . Nuclear energy is an important contributor to our nation's energy security, and promotes clean-energy jobs.''[64]

This type of federal support has arguably prompted several utilities to reconsider pursuing nuclear units and power plants. Early this year, the NRC issued a license to build and operate two new reactors in Georgia. While the *New York v. NRC* D.C. Circuit decision may impede new licenses from being issued, nuclear power is once again becoming a seemingly popular generation option.

However, the Obama Administration has also taken considerable steps, and may have ultimately terminated, the only current, viable option for nuclear waste disposal: Yucca Mountain. Though it certainly had merit, this decision by the Obama Administration may have set the entire waste disposal project back 40 years and will cost billions of additional dollars. In fairness, the Obama Administration did establish the BRC to identify a new approach for our congressional leaders. Yet the BRC's recommendations set out a very long, slow siting process that will require major amendments to the NWPA.

To conclude, permanent geologic storage of nuclear waste is an issue, given the longevity of that waste, perhaps more serious than that of safety—since meltdowns and accidents tend to be limited to a few select individual reactors such as Three Mile Island, Chernobyl, Davis Besse, and Fukushima, whereas every reactor produces waste.

Waste is also an issue that undercuts many of the proclaimed benefits of nuclear power—that it is clean and environmentally friendly, that it is cheap, and that it can and should be rigorously pursued for the sake of future generations.

In closing, we are reminded of the wise words of the late media scholar Marshall McLuhan who once wrote that ''Only puny secrets need protection. Big ones are protected by public incredulity.'' His statement infers that sometimes the most incriminating secrets are not secrets at all; rather, they hide in plain sight. The more obvious a particular failing may be, sometimes it's so discernible as to be missed entirely.

The nuclear power industry in the United States has an incriminating, longstanding, historically intractable yet obvious ''secret'' that continues to hide in plain sight: storage of nuclear waste. That analysts and lobbyists can proclaim the beginning of a nuclear renaissance in the United States, and indeed throughout the world, when no country but two—Finland and Sweden, where underground disposal sites are in the licensing stage—has even begun to meaningfully address the waste issue should provoke exactly the sort of mass incredulity McLuhan had in mind.

Ultimately, we shouldn't count on nuclear power addressing our energy security and climate change needs until the industry and government are able to resolve their nuclear waste dilemma. Not seeing the hydra's poisonous footsteps does not make them any less deadly.■

Existing waste sites are already prone to accidents resulting in safety risks.

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Endnotes:

1. Motion to Withdraw, *In the Matter of U.S. Department of Energy*, No. 63-001 (Mar. 03, 2010), at http://energy.gov/sites/prod/files/edg/media/DOE_Motion_to_Withdraw.pdf.

2. *New York v. Nuclear Regulatory Comm'n*, 681 F.3d 471 (D.C. Cir. 2012).

3. See footnote 2, at 473.

4. Maryam Ansari, *NRC Stops Issuing Nuclear Reactor Licenses. . .For Now*, FindLaw, Aug. 10, 2012, at http://blogs.findlaw.com/dc_circuit/2012/08/nrc-stops-issuing-nuclear-reactor-licenses-for-now.html?DCMP=NWL-cons_greenpage.

5. Blue Ribbon Commission, Report to the Secretary of Energy 16 (2012) at http://cybercemetery.unt.edu/archive/brc/20120620220235/http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf.

6. RAND Corporation, *Choosing a New Organization for Management and Disposition of Commercial and Defense High-Level Radioactive Materials*, Washington, DC, MG-1230-DOE, 2012.

7. See *New Start for US Nuclear Disposal*, WORLD NUCLEAR NEWS, Jan. 14, 2013, at http://www.world-nuclear-news.org/WR_New_start_for_US_nuclear_disposal_1401131.html; as well as U.S. Dept. of Energy, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (Washington, DC: DOE, Jan. 2013).

8. For instance, planners may be able to get a repository constructed, but that would take decades and if utilities cannot build additional storage onsite, perhaps because of local opposition, their spent fuel pools will run out of space. The converse is also obvious.

9. Richard B. Stewart, *U.S. Nuclear Waste Law and Policy: Fixing a Bankrupt System*, NEW YORK UNIV. ENVIRONMENTAL LAW J. 17 (2008), at 783–825.

10. See footnote 9.

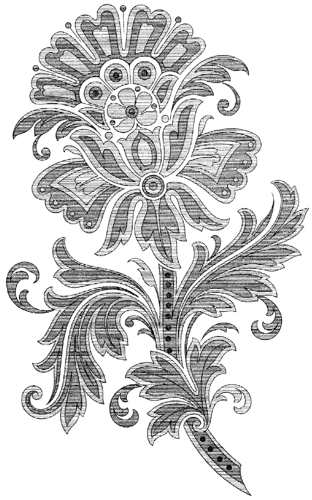
11. John Werner, Cong. Research Serv., R42513, U.S. Spent Nuclear Fuel Storage 17 (2012).

12. See footnote 11, at 5.

13. See footnote 12.

14. BRC Final Report at 14.

15. Matthew Bunn, John P. Holdren, Allison Macfarlane, Susan E. Pickett, Atsuyuki Suzuki, Tatsujiro Suzuki and Jennifer Weeks, *Interim Storage of Spent Nuclear Fuel: A Safe, Flexible, and Cost-Effective Near-Term Approach to Spent Fuel Management* (Cambridge, MA and Tokyo: A Joint Report from the Harvard University Project on Managing the Atom and the University of Tokyo Project on Sociotechnics of Nuclear Energy, June 2001).



16. Allison Macfarlane, *Interim Storage of Spent Fuel in the United States*, ANNUAL REV. OF ENERGY & ENV'T. 26 (2001), at 201–235.

17. Bunn *et al*. 2001.

18. U.S. Gov't Accountability Office, GAO-10-48, Nuclear Waste Management 36 (2009).

19. BRC Final Report at 34.

20. GAO-10-48, *supra* note 258, at 30.

21. Bunn, *et al., supra* note 15.

22. National Academy of Sciences Board on Radioactive Waste Management, *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report* 6 (2005).

23. Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson and Frank N. von Hippel, *Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States*, SCI. & GLOBAL SECURITY 11 (2003), at 1–51.

24. A.E. Farrell, H. Zerriffi and H. Dowlatabadi, *Energy Infrastructure and Security*, ANNUAL REV. OF ENV'T. & RESOURCES 29 (2004), at 454.

25. The Alvarez study produced quite a controversy. The U.S. Nuclear Regulatory Commission responded in *Nuclear Regulatory Commission (NRC) Review of 'Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States*, SCI. & GLOBAL SECURITY 11 (2003), at 203–211, that the study (1) exaggerated the probability of a spent-fuel-pool fire; (2) overestimated the release of 30-year half-life cesium-137; (3) overestimated the damage from the release; and (4) underestimated the costs of moving to dry-storage casks a large fraction of the older spent fuel currently in spent-fuel pools. Alvarez *et al*. responded in Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison MacFarlane, Gordon Thompson and Frank von Hippel, *Response by the Authors to the NRC Review of Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States*, SCI. & GLOBAL SECURITY 11 (2003), at 213–223. They retorted that the NRC's critique in each of those four areas evaporates upon detailed inspection: (1) on probabilities, they restated some of our observations as if we had said the opposite; (2) on cesium-137 releases from a spent-fuel fire, they noted they had adopted the lower end of our uncertainty range by simply assuming that a fire would not spread from recently discharged to older spent fuel; (3) on damage, they asserted that projections of the future population density around U.S. reactors used in a 1997 study done for it were unrealistically high without offering an alternative; and (4) on costs, they argued incorrectly that we have neglected certain costs of removing 80 percent of the spent fuel currently in spent-fuel pools and ignores lower-cost options that we urged it to examine as well.

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30. Macfarlane, *supra* note 16.

31. Jason Hardin, *Tipping the Scales: Why Congress and the President Should Create a Federal Interim Storage Facility for High-Level Radioactive Waste*, J. LAND RESOURCES & ENVIRONMENTAL LAW 19 (1999), at 293–323.

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37. 42 U.S.C. § 2011 *et esq*. (2006), 10 C.F.R. Part 72 (2012).

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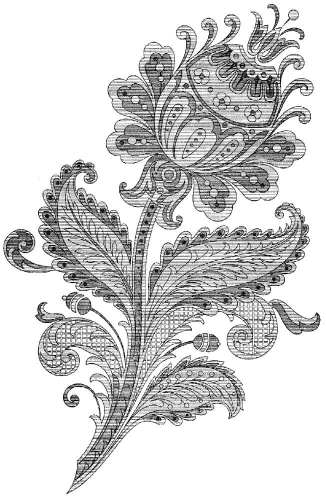

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