Deep Time: The End of an Engagement

BY BAŞAK SARAÇ-LESAVRE

For all its flaws, US nuclear waste policy at least relied on a sense of a moral responsibility toward the present and future. That may now be changing.

Nuclear power plants in the United States have produced approximately 83,000 metric tons of spent nuclear fuel, stored at more than 70 sites in 34 states. Each year, the 96 power plants that remain operational generate another 2,000 metric tons of waste.

In its 1987 amendments to the Nuclear Waste Policy Act, Congress selected Yucca Mountain, in Nevada, to be investigated for suitability as a geological repository for the nation's high-level radioactive waste. If the site proved suitable, the shipment of waste from reactor sites to the repository was to start by 1998. From its inception, however, the Yucca Mountain site faced strong opposition. In 2010, the Obama administration abandoned it.

Current legislation actually bans the Department of Energy from building, owning, and operating interim storage facilities, to prevent them from becoming alternatives to geological disposal.

At that time, and to this day, no alternative sites have been under consideration. National nuclear waste policy has been deadlocked. The federal government has no operational plan for managing the waste, which will remain highly toxic for tens of thousands of years. In the absence of an ongoing geological repository project, the current legislation actually bans the Department of Energy from building, owning, and operating interim storage facilities, to prevent them from becoming alternatives to geological disposal.

With the government in absentia, private-sector firms involved in nuclear energy are increasingly seeking options to manage spent nuclear fuel on their own terms. Their incentive to do so will only grow as an increasing number of reactors enter the decommissioning phase, and nuclear power stations transmute into nothing more than spent nuclear fuel sites.

LICENSE TO OPERATE?

This trend is well illustrated by two license applications for consolidated interim storage facilities now before the Nuclear Regulatory Commission (NRC). Interim Storage Partners (a joint venture between the firms Waste Control Specialists and Orano USA) has applied for a license to store up to 40,000 metric tons of spent nuclear fuel, for 40 years, at a site in Andrews County, Texas. Meanwhile, Holtec International, working with the Eddy-Lea Energy Alliance, a partnership of two New Mexico counties, has applied for a license to store 8,680 metric tons of spent fuel for a 40-year period in New Mexico.

The company plans to request further amendments to the license to store an additional 95,000 metric tons of spent fuel over 20 years—more than the entire current national inventory of waste. In 2021, one or both of these license applications is expected to be approved by
the NRC.

Both proposals require spent nuclear fuel canisters from numerous, geographically dispersed reactor sites to be consolidated at a small number of remote locations. The license applicants argue that the consolidation does not require major technical changes in how the waste is stored. They also argue that, in comparison with continued storage at multiple reactor sites, consolidation reduces overall storage costs, reduces safety and security risks, and facilitates the cleanup of decommissioned reactor sites. But such cost-benefit reasoning and probabilistic risk assessment consolidates all expected "risks" and "benefits" into a single scale of valuation. It cannot account for differing geographic, historical, or cultural contexts and sensibilities. Should this placeless analytical technique automatically trump a host of other values that figure into democratic discussions about siting of this unique form of hazardous waste?

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For those who oppose the proposed facilities, the answer is clearly no. The governors of New Mexico and Texas submitted letters to the NRC opposing the licensing of these facilities, arguing that the transportation and storage of spent nuclear fuel within their borders expose their citizens, communities, first responders, economy, and environment to "unnecessary" risks. Oil and gas producers view the proposed facilities as a threat to their local economic activities, and have submitted a motion to NRC opposing the project. The All Pueblo Council of Governors, representing the 20-member sovereign Pueblo nations of New Mexico and Texas, also opposes the license application. The group points to the lack of federal tribal consultation about transport routes, and the need for resources, training, and infrastructure for tribal emergency preparedness, response, and risk-management capabilities in the event of accidental radiological release during transport.

Opposition to the proposed consolidated interim storage facilities cannot be dismissed as just another *not in my backyard* movement. Dozens of civil society organizations from around the country jointly submitted a letter to NRC asserting: "We do not give our own government license to allow a private industry to further contaminate New Mexicans' home or to expand the massive nuclear burden New Mexicans already bear." Underlining that communities in New Mexico have already been subject to decades of contamination from radioactivity generated by the US nuclear weapons complex, Deb Haaland, then a US representative from New Mexico who is now secretary of the interior, also joined in opposing approval of the sites.
In another letter sent to the NRC, a group of national, state, and local civil society organizations (including the Union of Concerned Scientists, Public Citizen, Natural Resources Defense Council, Sierra Club, Southwest Research and Information Center, Coalition on Waste Valley Nuclear Wastes, and the Nevada Nuclear Waste Task Force)

suggest that spent nuclear fuel should be stored in low-density, hardened, monitored, and retrievable storage facilities at reactor sites. While these groups highlight the risks of moving large volumes of waste across the country, they implicitly raise a principle of geographical and environmental equity and justice: spent nuclear fuel should be stored where it is used.

Such concerns, embodied in the notion of consent of the governed, are central to the legitimacy of democratic decision processes. Decisions that involve the future of communities and the environment should not be settled based on the results of cost-benefit analyses that collapse all values into a single ratio. The consequences of trying to do so have been made clear by the Yucca Mountain story. Congress, relying on majority vote, disregarded the opposition of the state of Nevada, the Western Shoshone Indian Nation, and other concerned stakeholders in the region, while at the same time failing to seriously consider other, equally plausible repository locations. After two decades, billions of dollars spent on characterizing risks, and endless litigation and political dispute, Yucca Mountain was abandoned. Subsequently, the Blue Ribbon Commission on America's Nuclear Future, put in place by the Obama administration, concluded that such choices should rely on a "consent-based" decisionmaking process. According to the commission, the terms of consent are best determined through ongoing negotiations at national, regional, and local scales. Such negotiations involve concerned stakeholder groups whose interests go beyond those of the communities in the immediate vicinity of disposal facilities, and are likely to evolve over time.

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Consolidated interim storage facilities currently under consideration are subject to no such consent-based process. Their approval solely involves public comments on draft environmental impact statements (EIS) produced by the NRC on each individual license application. The NRC decides whether and how to account for (or not account for) the public comments before finalizing the EIS. The process allows for no extended negotiation or deliberation and requires no reasonable definition of consent. To the extent that consolidated interim storage is likely to become the de facto national strategy for managing nuclear waste, the EIS process fundamentally alters how Congress defined, through the Nuclear Waste Policy Act, the roles and responsibilities of government and the citizenry for handling the hazardous legacy of nuclear energy, transferring them to private companies and regulatory procedures intended for entirely different purposes.

NOT YOUR AVERAGE EIS

Three decades after Congress selected Yucca Mountain as the only candidate for a geological disposal site, and a decade after it was taken off the table, no options for long-term management are in play. Indeed, the NRC, in a 2014 analysis addressing the timing of a repository's future availability, developed a "generic environmental impact statement" that considers three possible timeframes within which geologic disposal becomes possible: 60 years, 160 years, and never. Meanwhile, existing approaches for

safe interim storage require that spent radioactive material be stored in dry storage casks (sealed metal cylinders enclosed within a metal or concrete outer shell), and that the casks be replaced at 100-year intervals. No institutional, legal, or regulatory mechanisms are in place to address this possibility. Environmental impact statements for the proposed interim facilities cover only the licensing period of 40 years.

During the formulation of the national nuclear waste policy in the late 1970s and 1980s, both the Department of Energy and government-commissioned expert groups had approached the issue of interim storage facilities with great care and caution. Storage of spent nuclear fuel at interim storage facilities for extended periods was considered undesirable because it risked creating a disincentive for private nuclear utilities to use—or finance—federally built, owned, and operated geological repositories. To assess this risk, in 1977 DOE even sent out surveys asking utilities about their willingness to use federal nuclear waste management services.

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To avoid such a risk, in the original Nuclear Waste Policy Act of 1982, Congress required DOE to contract with private nuclear utilities and start collecting a "nuclear waste fee" to finance the nuclear waste program. This measure was intended to ensure both that utilities would contractually commit to using future federal geological repositories as soon as they became available, and that "those benefiting from nuclear energy" would be "financially responsible for their waste."

The Nuclear Waste Policy Act and standard contracts signed with the nuclear utilities committed the Department of Energy to having an operational geological repository project in place by January 1998. Because Yucca Mountain had not been approved by that time, private nuclear utilities started turning to federal courts, asking DOE to compensate them for the costs of storing their waste in the years since. Each time a court rules for the plaintiffs, they are compensated through the US Treasury's Judgment Fund, and therefore, by taxpayer monies. Furthermore, in 2013, following the abandonment of the Yucca Mountain project, federal courts, at the industry's request, decided to suspend the fee that DOE had been collecting from nuclear utilities. In 2018, DOE estimated its potential liabilities toward private nuclear utilities at no less than $34.1 billion for its failure to complete a long-term repository, including $6.9 billion already paid in settlements and final judgments. American taxpayers are now paying—and will keep doing so for the foreseeable future—private industry to store spent nuclear fuel.

The average age of American reactors now approaches 40 years. Most of them have already had their operating licenses extended for 20 years, and the majority of these extensions will expire in the 2030s. Even with additional 20-year extensions, most of the current US nuclear fleet will have reached its decommissioning stage by the 2050s, if not earlier. Yet even under a very optimistic scenario, a geological repository is unlikely to become operational before most US reactors are shut down. Once consolidated interim storage facilities are operational, and all the operating nuclear power plants are shut down, who will be willing to bear the costs of a geological repository? Who will be willing to exercise the political leadership necessary for a more comprehensive and long-

term policy framework for the governance of nuclear waste? The EIS process for interim storage sites provides no meaningful avenue for democratic decisionmaking about the location of stored waste for periods that could be measured in centuries. Instead, it allows the very long-term responsibilities associated with nuclear waste to be managed by private industrial firms with short-term interests. With no guidance from consent-based democratic process, siting decisions are unlikely to take into account the consequences for a wide range of politically, environmentally, and socioeconomically disempowered stakeholders, today or in the future.

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Moreover, if DOE has to wait until it implements a viable repository program to resume the collection of a nuclear waste fee, and if the nuclear industry is at that point operating few or no reactors, to whom can the federal government turn for financing its future nuclear waste program? Before the suspension of the fee, in its last official fee adequacy evaluation, DOE had concluded that the already collected fees would not be sufficient to cover the overall cost of a nuclear waste program. In the absence of a comprehensive revision of the nuclear waste legislation, whether spent nuclear fuel is stored at reactor sites, in hardened onsite storage, or at consolidated interim storage facilities, it is future taxpayers who will be covering most of the costs of nuclear waste management.

The idea of human intervention into geological time is now familiarly captured by the concept of the Anthropocene. But before that idea became an accepted part of environmental thinking, US nuclear waste policy relied on an engagement with deep time—a commitment to trying to steer a course toward more desirable distant futures. That engagement, though flawed, even presumptuous, came with a sense of moral obligation to present and future generations.

But the evolution of the nuclear waste problem in the United States has brought with it an end of engagement with deep time. In light of this apparent disengagement, do the consolidated, private, away-from-reactor storage facilities constitute a politically and morally desirable way to handle nuclear waste that will remain hazardous for thousands of years? Answering yes to this question is a politically legitimate option, if that answer were explicitly arrived at through politically legitimate means. But right now the question is being answered only by default, and without any meaningful consent-based process that can give citizens a voice in defining what constitutes a desirable and morally defensible way to govern nuclear waste in the present and future—and by extension, to care for the present and future of humans and the planet. Political institutions are backing into a decision, one that future generations could reasonably characterize as marked by a lack of political responsibility and accountability, a toxic political legacy to accompany thousands of tons of toxic waste. Congress and the Biden administration should formulate a political process that can put the decision back where it belongs: with the consent of the governed.

CORRECTION: The original article misstated Interior Secretary Deb Haaland's previous office. She was a New Mexico representative in the US Congress, not a senator.

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Nuclear Waste Storage

A DISCUSSION OF

Deep Time: The End of an Engagement
BY BAŞAK SARAÇ-LESAVRE

READ RESPONSES FROM

- Mary Woollen
- Tom Isaacs
- Rodney C. Ewing
- Per F. Peterson
- Edwin S. Lyman
- Neal Mann, Carl E. Nash

In "Deep Time: The End of an Engagement" (*Issues*, Spring 2021), Başak Saraç-Lesavre describes in succinct and painful detail the flawed US policy for managing nuclear waste. She weaves through a series of missteps, false starts, and dead-ends that have stymied steady progress and helped to engender our present state—which she describes as "deadlocked."

Her description and critique are not meant to showcase political blunders, but to caution that the present stasis is, in effect, a potentially treacherous policy decision. The acceptance of essentially doing nothing and consigning the waste to a decentralized or centralized storage configuration is in fact a decision and a de facto policy. To make the situation worse, this status quo was not reached mindfully, but is the result of mangled planning, political reboots, and the present lack of a viable end-state option.

Although there may be some merit to accepting a truly interim phase of storing nuclear waste prior to an enduring disposal solution, the interim plan must be tied to a final solution. As decreed in the Nuclear Waste Policy Act, and reinforced by the Blue Ribbon Commission on America's Nuclear Future, centralized interim storage was to be the bridge to somewhere. But the bridge is now looking like the destination, and it would be naive not to view it as another disincentive to an already anemic will to live up to the initial intent.

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Saraç-Lesavre seems to believe this current impasse constitutes the end of an earlier era in which shaping decisions and outcomes was once driven by a "moral obligation to present and future generations." She sees the current unfolding scenario as a reversal of a once-prevailing ethos.

I have been involved for the past 20-plus years in just about every sector dealing with nuclear waste disposal. Beginning with the formation of a nongovernmental organization opposed to incineration of waste, I have conducted work on stakeholder engagement with the Blue Ribbon Commission, the Nuclear Regulatory Commission, the Bipartisan Policy Commission, and the Department of Energy, as well as with a private utility, a private nuclear waste disposal company, and an emerging advanced reactor company. From these perspectives and my experience with them, my impression is that the issue of nuclear waste management is continually given consideration, but rarely commitment. Lip service is the native language and nearly everyone speaks it.

For US policymakers—and truly all stakeholders involved with nuclear waste—it will require a steely and coordinated commitment to solve the problem. This has always been the case, but now the problems are becoming more complex, the politics more partisan, and a path that once appeared negotiable is now nearly unnavigable. The reason for this is less about a lack of resolve to comprehend the "deep time" in which we need to consider the implications of nuclear waste, and more about the impediments and cheap workarounds wrought by the short cycles of "political time."

Until we can take the politics out of nuclear waste disposal, it will not be the most sound decisions that prevail, but those with the prevailing wind in their sails.

MARY WOOLLEN

Mary Woollen Consulting

Başak Saraç-Lesavre raises some fundamental and important issues. Spent nuclear fuel (SNF) was created over the past 40-plus years in return for massive amounts of clean nuclear-generated electricity. Are we going to begin to provide a collective answer for managing and disposing of SNF or are we going to shirk our clear moral responsibility and leave a punishing legacy to our children and future generations? More than 50 reactor sites across the United States continue to store SNF on site with no place to send it.

Saraç-Lesavre appears to support the recommendation of important but selective parties whose advice is that "spent nuclear fuel should be stored where it is used." However, while championing consent-based siting, she does not include the views of those communities and states that now house this stranded SNF, nor the views of much of the science community that is working to provide a viable solution. When those nuclear power plants were originally sited, it was with the understanding that the federal government would take responsibility for removing SNF and disposing of it, allowing the sites to be decommissioned and returned to productive use. Siting and opening a

repository for permanent disposal will take many decades even under the most optimistic scenarios; the nation needs to develop one or more interim storage sites that can be licensed, built, and opened for SNF acceptance decades earlier.

Saraç-Lesavre mentions the Obama administration's Blue Ribbon Commission on America's Nuclear Future conclusion that siting a nuclear waste repository or interim storage facility should be consent-based. However, the commission made eight fundamental recommendations while also making it clear that it was not a matter of picking just one or several of them; rather, they were all required to resurrect an integrated US program and strategy that had the best chances for success. Two of the commission's recommendations called for "prompt" actions to develop both a repository for the permanent disposal of SNF (and other high-level radioactive wastes) and centralized interim storage to consolidate SNF in the meantime. The reasoning was detailed and sound, and those recommendations remain highly relevant today.

A healthy, enduring federal repository program is needed and needed promptly. Whether through government, private industry, or a private/public partnership, consent-based centralized interim storage remains needed as well.

TOM ISAACS

Former Lead Advisor, Blue Ribbon Commission on America's Nuclear Future

Başak Saraç-Lesavre's commentary on the interim storage of commercially generated spent nuclear fuel raises a variety of important issues that have yet to be addressed. Here I would like to expand on some of her most salient points.

One of the consistent characteristics of the US strategy for the back-end of the nuclear fuel cycle has been the absence of a systematic understanding of the issues and a failure to develop an encompassing strategy. In the report on a two-year study by an international team of nuclear waste management experts, *Reset of America's Nuclear Waste Management Strategy and Policies*, sponsored by Stanford University and George Washington University, one of the most important findings was that the present US situation is the product of disconnected decisions that are not consistently aligned toward the final goal—permanent geologic disposal. The isolated decision to consolidate spent fuel inventories at just a few sites is another example of this same failed approach. Any decision to go forward with interim storage needs to be part of a broader series of decisions that will guarantee the final disposal of spent fuel in a geologic repository.

Another critical issue is the meaning of "interim" storage, as *interim* may well become *permanent* in the absence of a larger strategy. The present proposal is for interim storage for some 40 years, but it will almost certainly be longer if for no other reason than it will take the United States some 40 to 50 years to site, design, construct, and finally emplace spent nuclear fuel and high-level waste at a geologic repository. The siting of an interim storage facility and the transportation of waste to that facility will be a major undertaking that will take decades. One can hardly imagine that once the waste is

moved, there will be an appetite for another campaign to move the waste again to a geologic repository, particularly as time passes, funding decreases, and administrations change. One must expect that as 34 states move their nuclear waste to just a few locations, such as to Texas and New Mexico, the national political will to solve the nuclear waste problem will evaporate.

The siting of an interim storage facility and the transportation of waste to that facility will be a major undertaking that will take decades.

What is the alternative to interim storage? There is an obvious need is to secure the present sites by moving all the spent fuel into dry storage containers that should then situated below grade or in more secure berms. There may be good reason to move the casks from closed reactor sites to those that are still operating. As reactor sites shut down and are decommissioned, there may be value in retaining pools and waste handling facilities so that spent fuel casks can be opened, examined, and repackaged as needed. As my colleagues and I have reported, even this short list of requirements reveals that the selection between alternatives will be a difficult mix of technical issues that will have to be coordinated with the need to obtain consent for local communities, tribes, and states. Interim storage, by itself, will not solve the United States' nuclear waste problem. In this case, today's solution is certain to become tomorrow's problem.

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Başak Saraç-Lesavre's article addresses the important topic of our moral obligations to future generations, but its focus only on nuclear waste is too narrow. The most important questions for our long-term obligations involve the long-term problems of all wastes generated by all energy technologies.

The focus on nuclear wastes is logical, in the same sense that it's logical to look for lost keys under a streetlight. One of the major advantages of nuclear waste, compared with wastes that other energy technologies produce, is that it's plausible to plan for and implement reasonable approaches to safely manage the waste for decades, centuries, and millennia into the future.

We need to shine a brighter light on the question of the very-long-term environmental and public health consequences of all the wastes produced by energy technologies, whether it be the rare-earth mill tailings in Baogang, China, thousands of coal-ash impoundments worldwide, fracking waste waters reinjected into wells, or most importantly, the thousands of gigatons of carbon dioxide and methane released from our current use of fossil fuels.

It sounds deeply dissatisfying, but our current de facto policy to use interim storage for spent nuclear fuel makes sense. Today's lack of consensus about the permanent disposal of spent fuel is logical, because we do not now know whether it is actually waste, or is a valuable resource that should be recycled in the future to recover additional energy. We cannot predict this today, any more than in the 1970s one could predict whether shale oil could be a resource or should be left in its existing geologic isolation. Certainly with the shale technology of the 1970s, which involved mining, retorting, and generating large volumes of tailings, shale oil was not a resource. But technology has changed, and based upon statistics from the Department of Energy's Energy Information Agency, the advent of shale fracking gets most of the credit for recent reductions in US carbon dioxide emissions from electricity generation.

Regardless of whether existing spent fuel is recycled in the future, there will still be residuals that will require deep geologic disposal. The successful development of the Waste Isolation Pilot Plant in the United States, for the deep geologic disposal of transuranic wastes from US defense programs, provides evidence that geologic disposal can be developed when societal consensus exists that materials really are wastes, and where clear benefits exist in placing these materials into permanent disposal. Today the United States needs to rethink its approach to managing nuclear wastes. Deep geologic disposal will be an essential tool, and development of multiple options, focused on disposal of materials that are unambiguously wastes, makes sense as the path forward.

PER F. PETERSON

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Başak Saraç-Lesavre provides an excellent account of the failed US government effort to implement a long-term solution to manage and dispose of the country's growing backlog of spent nuclear fuel, and makes a compelling case that the prolonged absence of a national nuclear waste strategy has led to a lack of coordination and direction that could lead to inequitable and unjust outcomes. In particular, the development of consolidated interim storage facilities—if made economically attractive for nuclear plant owners—would likely undermine any political consensus for pursuing the challenging goal of siting and licensing a geologic repository.

For this reason and others, the Union of Concerned Scientists does not support consolidated interim storage facilities, and has consistently opposed legislation that would weaken current law by allowing the government to fund such facilities without closely coupling them to demonstrated progress in establishing a geologic repository. However, Saraç-Lesavre references our organization's position in a way that could give

the misleading impression that we support surface storage of spent nuclear fuel at reactor sites for an indefinite period. Although we strongly prefer on-site interim spent fuel storage to consolidated interim storage, provided it is stringently regulated and protected against natural disasters and terrorist attacks, maintaining a network of dispersed surface storage facilities forever is in no way an adequate substitute for a deep underground repository.

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The challenge, of course, is how to revive the defunct repository siting program and execute it in a manner that addresses both environmental justice and intergenerational equity concerns. This is not straightforward. Locating a repository site in a region far from the reactors where spent fuel was generated and the areas where the electricity was consumed may seem unjust to the host community, but it could well be the best approach for minimizing long-term public health risks. In that case, one means of redress for the affected community would be fair compensation. The likely need to provide such compensation must be factored into the total cost of the repository program.

An alternative path is offered by the company Deep Isolation, which has proposed to bury spent fuel at or near reactor sites in moderately deep boreholes. While this concept raises significant technical and safety issues and would require major changes to current law and regulations, it does have the political advantage of obviating the need to find a centralized repository location. Whether it is a more just solution, however, is an open question.

EDWIN S. LYMAN

Director of Nuclear Power Safety

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Başak Saraç-Lesavre’s article on nuclear waste storage offers valuable insights, as do the other two articles on nuclear energy, but none addressed two glaring energy issues.

While not directly related to nuclear power, increasing renewable power will affect the electricity market. Sophisticated market mechanisms balance power output and distribution against demand to ensure fair electricity pricing. The temporal, seasonal, and weather-dependent variations in renewable production, along with the current inability to store large amounts of surplus energy, can upset that market. Backup resources, currently provided mostly by fossil-fuel generation, are critical to electricity marketplace stability.

Excess energy from renewables can force prices to plummet, discouraging investment and exacerbating price uncertainty. A lack of backup forced price spikes in Texas in February 2021 when the industry could not produce or obtain sufficient energy to meet needs driven by an unusual cold spell.

This ties into the three nuclear articles in that they did not acknowledge the advances in energy technology that could solve two issues: what to do with nuclear waste and how to back up renewables. There are at least 50 groups developing new concepts in nuclear fission and fusion energy. Few will survive, but those that do will affect storage of nuclear fuel policy, grid reliability, and uranium mining.

A nuclear power plant concept that one of us developed—the molten uranium thermal breeder reactor (MUTBR)—could reduce nuclear waste, provide backup to renewables, and reduce uranium mining.

There are at least 50 groups developing new concepts in nuclear fission and fusion energy. Few will survive, but those that do will affect storage of nuclear fuel policy, grid reliability, and uranium mining.

The MUTBR is mostly fueled by molten uranium and plutonium metals reduced from nuclear waste. They are its fuel and, as liquids, are pumped through a heat exchanger to give up their energy. It has large fuel tubes to facilitate uranium-238 fission and is a "breed-and-burn" reactor. In operation, it "breeds" enough plutonium from the plentiful isotope of uranium to fully replace the easily fissionable but scarce isotope of uranium (the primary fuel in conventional reactors) and plutonium that has fissioned (burned). The MUTBR may be a way to deal with used nuclear fuel while producing copious amounts of carbon-free power on demand.

The MUTBR could provide flexible backup power in the way hydroelectric dams can do to smooth out changes in production and demand. A dam's reservoir storage capacity facilitates production management. MUTBR can facilitate backup in three ways.

First, it can send excess heat (beyond what is profitable to sell) to thermal reservoirs. Its high operating temperature would enable cheap heat reservoirs using molten sodium chloride salt. That energy can be released to the grid when demand and prices are higher. Second, if this salt heat storage is depleted but electricity demand is high, biofuels could be used to generate heat energy for its electric generators for backup. The generators would be sized to convert substantially more heat to electricity than the maximum available from its reactor. Third, when the thermal salt reservoirs are fully charged and power demand is low, MUTBR's patented control mechanism provides flexibility to reduce its fission rate. This system would also improve safety by automatically throttling fission if there is a system failure.

These features of the MUTBR design could provide an excellent non-carbon-producing complement to renewable resources, filling in when renewable production is low and reducing output when renewables are near maximum output. These economic considerations are basic to having a reliable electric power industry.

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