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Innovations in decommissioning and their application abroad

A flexible and forward-thinking U.S. regulatory framework has enabled unprecedented innovations in nuclear plant decommissioning, and regulatory considerations will play a key role in transferring these innovations to decommissioning projects abroad.

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Innovation in the U.S. nuclear industry is not exclusive to the advanced reactor community. There has been unprecedented growth in novel approaches to the decommissioning of nuclear power plants and the management of spent nuclear fuel.

In particular, in the United States, third-party specialist decommissioning contractors have been able to take the reins at shutdown nuclear power plants and drive efficiencies in decommissioning and site restoration. The benefits of transferring plants to a decommissioning contractor—manned by a team specialized in nuclear decommissioning, as opposed to a utility specialized in reactor operations—have included shorter decommissioning timelines, the leveraging of experience and efficiencies, lower costs, and better and more reliable outcomes.

The groundwork for these advancements has been as much a story of regulatory flexibility and foresight as technical innovation. Unique parts of the Nuclear Regulatory Commission's regulatory framework, including a flexible process for transferring licenses between companies, a robust mechanism for managing nuclear decommissioning funds, and a U.S. government obligation to cover the costs of managing spent nuclear fuel, provide a mechanism for third parties to develop innovative business models to meet the country's nuclear decommissioning challenges.

As the U.S. decommissioning market becomes increasingly adept at adopting and implementing new third-party decommissioning models, the time is ripe to explore how this model could be exported to the rest of the world. Understanding how the legal framework in the United States drives decommissioning innovation, and how it can best be replicated abroad, will likely be an important aspect of any international decommissioning engagement.

Novel decommissioning models

The Zion nuclear power plant in Illinois lays claim to a major first in nuclear power plant decommissioning. While it was not the first nuclear power plant in the United States to be decommissioned, or the first to be decommissioned largely by a third party (i.e., a decommissioning contractor), it was the first in which the decommissioning was done by a contractor that was also an NRC licensee. ZionSolutions, a subsidiary of EnergySolutions, took possession of the assets of the Zion plant and replaced the utility owner/operator, Exelon, as the NRC licensee. While Exelon still owned the underlying real estate, the entity responsible to the NRC for public health and safety of the shutdown nuclear facility was not a traditional utility or merchant generation owner/operator (simplified herein as "utility"), but the decommissioning contractor itself.

This approach, called the "License Stewardship" model, pioneered by EnergySolutions with Zion in the 2008–2010 time frame, has been generally understood to improve the efficiency of the decommissioning process. As Ken Robuck, president and chief executive officer of EnergySolutions stated in *Nuclear News* (*NN*, Dec. 2017, p. 54), "The license transfer was the first of its kind, and it has allowed us to work directly with the regulator to ensure that we meet all of the standards and limits we are required to meet from a regulatory point of view. Because we are directly involved with both the Nuclear Regulatory Commission and the states, we have firsthand knowledge of the process, and it's not going through a filter."

It was not necessarily easy being a first mover. Nonetheless, the project has been lauded as a major success in the industry. Nothing provides more proof than the remarkable growth seen in the License Stewardship model (and its variants) for decommissioning in recent years. A number of owner/operators have transferred, or have signed agreements to transfer, their plants to third parties for decommissioning.

There is no shortage of opportunities for growth in this field in the future. A num-

Plants Slated for Third-Party Decommissioning in the United States

Plant	Date NRC License Transfer Application Submitted
Zion	2008
La Crosse	2015
Vermont Yankee	2017
Oyster Creek	2018
Pilgrim	2018
Indian Point	Est. 2021
Palisades	Est. 2021–2022

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ber of plants are expected to shut down or begin decommissioning in the near term. The number of entities seeking to enter the market has also grown, including decommissioning and waste management companies, as well as the reactor vendors themselves.

Early success and significant growth potential have provided room for the continued evolution of this general decommissioning model. One of the most significant amendments to the model concerns the management of spent nuclear fuel. Despite periodically renewed interest on Capitol Hill, the Yucca Mountain repository is unlikely to be completed anytime soon. Without the benefit of a geological repository for the final disposal of spent nuclear fuel, nuclear power plant owner/operators have had to find other solutions for the long-term storage of spent fuel. This issue continues to be a major component and expense of decommissioning and post-shutdown plant management.

As a result, instead of simply transferring a plant to a decommissioning contractor to serve as a "steward" for decommissioning, utilities are now seeking to sell the plant and site—reactor, land, spent fuel and all—to a decommissioning contractor or consortium to handle all of the elements of decommissioning. This approach was pioneered with the transfer of the Vermont Yankee plant in 2017 to a decommissioning consortium led by NorthStar. The NRC approved the transfer in October 2018 after a one-and-half-year review. The state of Vermont also accepted this approach, settling with the other parties in March 2018.

The transfer of the land, plant, license, and title to spent fuel is sometimes called the "Acquisition" model (the names are not always consistent). The Acquisition model represents a significant evolution from the License Stewardship approach pioneered at Zion. Most important, it entails a transfer of the title to spent nuclear fuel—and the long-term challenges that go with owning spent fuel—from the utility to the decommissioning contractor team. Under this approach, a decommissioning contractor, and/or other project participants, is responsible for the management of the spent fuel until a long-term solution is found.

The Acquisition model of decommissioning also involves other legal challenges, including increased environmental liability taken on by the decommissioning contractor. The License Stewardship model does not necessarily allow the utility to divest itself of responsibility for mitigating environmental degradation on the plant property. To the contrary, the owner transfers the facility to the decommissioning contractor for the purpose of carrying out decontamination and dismantlement, but the property reverts back to the site owner upon the completion of decommissioning.

Continued innovation in U.S. nuclear decommissioning begets further advancement. In recent years, the NRC received license applications for two consolidated interim storage facilities (CISF). These CISFs would accept spent fuel from nuclear power plant sites across the country, allowing the sites to be fully decommissioned and released. Interim Storage Partners LLC submitted an application for a CISF in Texas on April 26, 2016, and Holtec International submitted an application for a CISF in New Mexico on March 31, 2017. In addition, Congress has occasionally introduced bills to encourage the siting of CISFs to serve as a stopgap until an agreement can be reached on Yucca Mountain.

These CISFs provide decommissioning contractors an opportunity to mitigate the long-term risks of managing spent nuclear fuel because there is a path forward toward consolidated storage. It is therefore not surprising that leading participants in nuclear decommissioning and nuclear waste management are at the forefront of the development of these CISFs, seeking to consolidate and vertically integrate spent nuclear fuel management.

For example, under the Acquisition model pursued by some decommissioning contractors, spent nuclear fuel that is purchased along with a plant to be decommissioned can eventually be moved to a CISF (managed or supported in part by essentially the same contractors), allowing for synergies, more efficient management of spent fuel, and the realization of potential additional gains.

There are areas for continued innovation in the third-party decommissioning model. These include novel ways to manage nuclear decommissioning funds over groups of plants, the establishment of "fleet" models for decommissioning, and leveraging ongoing regulatory changes by the NRC to further drive efficiencies in decommissioning execution. It is safe to say that at no time in recent memory has the decommissioning marketplace seen such dynamism and willingness to implement new ideas.

Drivers of innovation

Why is the U.S. decommissioning market such a fertile ground for innovation? While this is an area that has seen continued technical improvement, no single technical innovation is responsible for a new model of decommissioning. Instead, the drivers are arguably business, legal, and regulatory in nature, because they lay the foundation for new entrants into the field. The key drivers include the following:

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Decommissioning Models in the United States (representative terms)

Traditional Contractor Model	Third-Party License Stewardship Model	Third-Party Plant Acquisition Model
● Owner/operator engages specialized decommissioning contractor (DC) or joint venture ● Owner/operator remains licensee and retains: ■ NRC responsibilities ■ Nuclear decommissioning trust (NDT) funds ■ Nuclear liability ■ Title to spent nuclear fuel	● DC (or affiliate) acquires plant assets and leases site from owner, and takes responsibility for shutdown plant as licensed decommissioning operator ● NRC license transferred to DC ● DC stands in for certain owner responsibilities, including: ■ NRC responsibilities ■ Nuclear liability ■ NDT funding, with risk that funds are inadequate ■ Owner keeps title to spent fuel and underlying real estate ■ Site returned to owner upon completion	● DC (or affiliate) acquires the facility and site, or acquires the owner/licensee ● NRC license transferred to DC ● DC acquires assets and liabilities of owner, including: ■ NRC responsibilities ■ Nuclear liability ■ NDT funding, with risk that funds are inadequate ■ Environmental risks/liabilities (negotiated with plant owner/operator) ■ Title to spent fuel (most recent cases) ■ Plant employees and contractors

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1. A flexible NRC license transfer process.

Something unique to the United States is the complex structure of its energy markets. Instead of having a single, essentially federally managed utility, as is common in many countries, dozens of private utilities and merchant generators operate nuclear plants and electric generating assets across the country. Over the years, as the owners and operators of the U.S. nuclear fleet have split, merged, and changed (particularly after the deregulation of the electricity markets in the late 1990s and early 2000s), the NRC has grown familiar with the license transfer process—that is, the swapping out of owners and/or operators of nuclear power plants with new ones.

Under this process, the plant's license is transferred from one company to another under a specified process governing such transfers, instead of the new licensee having to apply to the NRC for a new license. The process averages around nine months or so. The license transfer requirement originates in the Atomic Energy Act and is implemented in NRC regulations, supported by specific NRC guidance documents. Since deregulation, the NRC has worked through dozens of license transfers.

Armed with this experience, the NRC has proven willing and able to handle license transfers involving decommissioning contractors. With Zion as the initial test case, and Vermont Yankee as a further test case for transferring title to spent nuclear fuel, the agency has been able to review and eventually approve these transactions.

Furthermore, the Atomic Energy Act's granting federal preemption over states as to nuclear safety matters will allow a uniform framework for handling transfers of plants to decommissioning contractors to continue to develop over time. That does not mean that the states are left out. For example, some states have set additional conditions for the completion of decommissioning. States can also involve themselves in NRC proceedings, and in the past have negotiated for other decommissioning-related assurances. However, as the NRC regulates the vast majority of technical and financial issues associated with the transfer of a plant for decommissioning, states are hindered from serving as roadblocks to these arrangements.

2. Segregated nuclear decommissioning trust funds.

Fundamentally, the decommissioning of any facility—nuclear or not—is a cost center for a utility. Work has to be done that does not generate electricity. But there is one important caveat in the case of nuclear power. Because of the large and, at least in the early days of nuclear power, uncertain costs associated with decommissioning a nuclear power station, the NRC has required owner/operators of nuclear power plants to set aside funds over time toward nuclear decommissioning trusts (NDT) that are restricted to certain decommissioning-focused purposes.

These NDTs can get rather sizable (e.g., over $1 billion for Pilgrim), and they are closely monitored by the NRC for sufficiency. Without these NDTs, only large utilities would have the funding positions required to decommission their nuclear plants, severely curtailing the role that new entrants can play in the market. With these NDTs, however, new entrants promising faster, safer, and more efficient mechanisms for decommissioning can take ownership of the plant, and through these NDTs remain financially qualified to handle decommissioning activities. In some cases, the decommissioning contractor can retain excess funds from the NDT after the successful conclusion of decommissioning—a potential bonus for a job well done.

3. DOE obligation to fund spent fuel management.

One of the biggest long-term challenges of owning a shutdown nuclear power plant is the management of spent nuclear fuel. With the Department of Energy's failure to build a repository and collect spent nuclear fuel from the nation's reactor sites, utilities have been forced to expand their spent fuel pools and construct costly dry storage facilities. With progress toward constructing a repository as far off as ever, utilities are essentially forced to manage spent nuclear fuel into the indefinite future (although certain consolidated storage options exist, as discussed).

But with the negatives comes a positive. Because the DOE contracted to accept spent nuclear fuel pursuant to the Nuclear Waste Policy Act in exchange for nuclear operators funding the Nuclear Waste Fund for constructing a final repository, the DOE is now on the hook for its failure to fulfill its contractual and statutory obligations and pick up the spent fuel. As a result, the department pays utilities back (either through a settlement or litigation process) for the vast majority of costs associated with spent fuel management, including dry storage. The DOE's obligation to fund spent fuel management, essentially backed by the full faith and credit of the U.S. government, allows new entrants to take the risk of managing and taking ownership of spent nuclear fuel, assured of a guaranteed funding source.

The development of CISFs in New Mexico and West Texas helps provide a concrete time horizon in which spent fuel can be moved from reactor sites. Fundamentally, however, it is the DOE's general commitment to fund spent fuel management that allows the decommissioning industry to innovate while longer-term solutions to the storage of spent nuclear fuel are worked out. Moreover, it is the DOE's legal obligation to fund spent fuel management and eventually take title to spent nuclear fuel that underpins these private efforts to develop CISFs.

The above is not an exhaustive list. There are other aspects of the U.S. nuclear regulatory framework that facilitate the growth of third-party decommissioning, including protection from nuclear liability under the Price Anderson Act. However, the three items above have played a critical role in the development of innovative nuclear decommissioning models in the United States.

Opportunities abroad

Success and growth in the United States raise the question of opportunities abroad. Indeed, as much as decommissioning is a growth market in the United States, the global nuclear fleet is four times larger than the U.S. fleet, and the phaseout of nuclear power in certain countries (e.g., Germany and Taiwan), combined with the anticipated shutdown schedule for nuclear reactors in Japan, creates significant opportunities for U.S. decommissioning contractors.

The nuclear decommissioning market in Japan is expected to expand to over $30 billion during the next decade. According to one count, approximately half of the Japanese civilian nuclear fleet is permanently shut down. Within the next decade, as many as 10 more reactors could shut down due to economic pressures from costly new regulatory requirements. Decommissioning is rapidly becoming one of the major business opportunities in the nuclear industry in Japan.

At the same time, Japan does not yet have significant experience with decommissioning and recognizes the benefits of leveraging the expertise of U.S. contractors. U.S. companies will therefore have an important role to play in the Japanese reactor decommissioning market.

In Germany, 10 nuclear reactors have been shut down, and the government has announced its plan to shut down its entire fleet. Although German utilities have experience with decommissioning, significant opportunities exist to leverage U.S. expertise gained from many con-

tractors taking different approaches to decommissioning.

Turning back to Asia, although facing domestic opposition, Taiwan's government seems committed to continuing the planned phaseout of its nuclear power sector, which consists of six reactors.

As a first step, opportunities exist for technical collaboration and knowledge transfer. Applying engineering best practices and lessons learned from U.S. decommissioning projects could help Japan, Germany, and other countries bend the cost curve, shorten schedules, and achieve efficiencies, all while maintaining high levels of safety. A consensus has emerged that U.S. decommissioning technical experience, such as in waste minimization, is transferable to other countries, such as Japan.

As this article points out, however, it is not just the technology, but the approach to decommissioning that offers significant cost and efficiency savings. Putting decommissioning experts in the driver's seat aligns the skills and experience of the team with the tasks required—arguably better than if the utility, which is focused on plant operations and power generation, were to manage the decommissioning process. This could be more true abroad than in the United States. As stated during a major decommissioning conference held in Japan, the Japanese have limited experience with decommissioning, and "without experience, cost increases." The fact that many plants may be decommissioned at the same time—in Japan and elsewhere—could challenge the limited resources available, further highlighting the need for outside assistance and new ideas.

In our view, realizing the efficiencies afforded by the third-party decommissioning model requires examining the underlying legal, regulatory, and business framework in each country. In particular, the three areas discussed above are foundational to exporting the third-party decommissioning model abroad: (1) having a regulatory process in place to facilitate license transfers (or transfers of key regulatory responsibilities) for shutdown plants to specialists in decommissioning work, while ensuring both technical and financial qualifications of the new owner/operator; (2) ensuring a dedicated and sufficiently large source of decommissioning funds; and (3) providing a long-term guarantee of spent fuel management costs.

While there are other things that regulators in these countries can do to make the decommissioning process more efficient, such as clarifying decommissioning end-state conditions (something that can also be made clearer here in the United States), the above-listed issues present barriers to third parties from fully leveraging their expertise abroad.

We recognize that these changes may be impossible, or not desirable, to attain in all places. In that case, options may exist to try to replicate some of the benefits of U.S. approaches while maintaining the utility-led model. Financial assurance matters—such as the presence of a trust fund for decommissioning costs—potentially can be organized via contract with the utility. The utility can work jointly with the regulator and decommissioning contractor to identify areas where the contractor can play a larger role in the decommissioning process.

The upshot, though, is that for U.S. innovations in nuclear decommissioning to truly take hold globally, regulatory considerations, as well as other legal and business considerations, are going to be a critical part of any evaluation or negotiation. At a minimum, the nuclear regulator will likely have to become familiar and comfortable with an increased role for decommissioning contractors in the management of shutdown plants. Funding assurance regimes may have to be put in place to facilitate the entrance of third parties. Joint venture arrangements are likely to be a key part of any global engagement strategy. **NN**