white paper

# Second License Renewal: Nuclear Plant Operations Beyond 60 Years

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*Photos on cover and page 5, Areva Inc. Photo on page 3, American Electric Power Co. (AEP). Photo on page 7, DTE Energy Co.*

## Executive Summary

Federal law and regulations governing the safety of U.S. nuclear reactors allow for extensions of the initial 40-year operating license in 20-year increments. The nuclear industry is considering whether extending nuclear plant operation beyond 60 years would be desirable. For those utilities that apply for a second license renewal, the U.S. Nuclear Regulatory Commission, an independent agency, will conduct a safety review.

The first U.S. reactors will reach 60 years of operation after 2029.[1] Many years ahead of that date, companies must begin planning either to continue operating those plants or to develop new sources of electric generation. The NRC already has a regulatory framework to review applications for second license renewals. Before applying, nuclear plant owners and operators must complete extensive research and decide whether to replace large, expensive components. Some large components require several years' lead time to order and, once installed, many more years to recover their investments. These companies need regulatory clarity well in advance of these decisions, especially for reactors approaching the end of their first license renewal period. In addition, before an extension can be granted, the owners must complete extensive research.

Two companies already have announced their intention to seek second license renewals: Dominion Resources Inc. for its twin-reactor Surry Power Station in Virginia and Exelon Corp. for the two reactors at its Peach Bottom Atomic Power Station in Pennsylvania.

Today's nuclear power plants are safe regardless of their age. U.S. nuclear energy facilities are subject to a rigorous program of daily NRC oversight and inspections and undergo continual preventive and corrective maintenance, including equipment replacement. Billions of dollars are spent every year to maintain and upgrade America's nuclear plants to make sure they operate safely and reliably. Plant operators continually upgrade and invest in plant systems and components, such as pumps and valves, as part of a detailed preventive maintenance program. Massive multiton components, like reactor vessel heads and steam generators, are replaced to ensure continuing safety and reliability. In the past three years, the industry has invested approximately $23 billion in capital projects to upgrade and maintain plant systems.

America's evolving electricity marketplace, faced with growing requirements for 24/7 reliability and mandates for lower-carbon electricity production, requires that policymakers and the electric industry place a high premium on preserving existing nuclear generating capacity. This means ensuring workable regulatory requirements for second license renewal and building new reactors to maintain, at a minimum, nuclear energy's current 20 percent share of U.S. electricity supply. Second license renewal makes economic and environmental sense for consumers, the community and companies that operate these facilities. Although nuclear facilities require significant capital investment to ensure safe and reliable performance, they are the largest and most reliable emission–free sources of electricity.

## What the Research Shows

> "**The Union of Concerned Scientists** believes there's nothing inherently unsafe about a nuclear power reactor operating for up to 60 or even up to 80 years."
>
> – David Lochbaum, Union of Concerned Scientists, NRC public meeting, May 8, 2014

[1] As of December 2015, 80 commercial nuclear reactors have had their licenses renewed and 38 reactors have been producing electricity for more than 40 years with a renewed license. An additional 19 license renewals are still under review. Indian Point Energy Center applied for license renewal in 2007 and the application is still under review due to legal challenges. It is continuing to operate under the commission's "timely renewal" policy, as defined in Title 10 of the Code of Federal Regulations (CFR Part 2 Section 109 (10 CFR 2.109)), "Effect of Timely Renewal."

*Workers at AEP's Donald C. Cook Nuclear Plant in Michigan reinstall the piping following replacement of the feedwater heater.*

## No Technical Limitations to Second License Renewal

The U.S. Department of Energy, the NRC and the industry are examining what will be required to maintain safe operations at nuclear plants during a second license renewal term.

The Electric Power Research Institute (EPRI) and DOE have conducted scientific research to understand the technical issues associated with the long-term, safe operations of nuclear power plants. The industry will use this knowledge and apply these insights to second license renewal efforts. This fundamental research includes work on replacing, upgrading and maintaining piping, concrete, metal and other long-lived materials and components. This research has shown there are no generic technical issues that would prevent a well–maintained nuclear power plant from operating safely during a second license renewal period. Programs and actions currently underway include:

- DOE's Light Water Reactor Sustainability Program provides the technical foundation for managing the long-term, safe and economical operation of nuclear power plants as they age. This effort focuses on longer term and higher reward research, and received $35 million in fiscal 2015.

- DOE has entered into a memorandum of understanding with EPRI to cooperate on research related to second license renewal. The NRC conducts research to confirm the results.

- DOE and the NRC have held joint workshops to facilitate discussion among these agencies and the industry, national laboratories, academia and the public in such areas as long-term use of systems, structures and components, materials safety assurance, diagnostic and prognostic technologies, and future technical and research requirements.

- In 2012, the NRC and DOE co-sponsored the "Third International Conference on Nuclear Power Plant Life Management for Long-Term Operations," which provided a forum for discussing international policies and best practices related to safety aspects of second license renewal.

- In 2013, NEI held a forum that discussed the technical, environmental, economic, political and regulatory aspects of second license renewal.

- In October 2014, the NRC and DOE completed a report on aging-related degradation issues over 80 years of nuclear power plant operations.

## Electric Power Research Institute Research

EPRI and DOE are conducting extensive research to investigate how certain materials used in nuclear power plants will respond during an extended period of electricity production. This continues to provide a sound technical basis for second license renewal. This research builds on programs that have already allowed the industry to renew plant licenses and operate them beyond 40 years. Results from this research will be used to enhance aging management programs and to assist in extending electricity production beyond 60 years.

The EPRI Long–Term Operations Program is an industry–funded project to develop the technical information to aid decisions on second license renewal. Results of the research will help industry, policymakers and regulators make informed decisions concerning long-term operations. EPRI's program features broad collaboration in research across multiple countries and entities. The program includes:

- reviewing aging management programs to determine if there are any effects related to plant operation beyond 60 years
- developing a tracking table to identify and prioritize long-term operations issues as the basis for collaborative research and development programs at DOE and EPRI
- examining the concrete of the containment building at the Ginna Nuclear Power Plant in New York to evaluate new approaches for assessing the condition of such structures
- documenting concrete structures at U.S. nuclear power plants that can be used to identify and coordinate research on concrete during long-term operations
- identifying the potential for cable failures as a result of long-term operations and environmental factors.

## Department of Energy Research

DOE's Light Water Reactor Sustainability Program has two strategic goals: to develop the scientific basis for understanding and predicting long-term environmental impacts on materials in nuclear power plants; and to provide data and methods to assess the performance of systems, structures and components essential to sustained nuclear power plant operations. Materials research is organized into five principal areas:

- reactor internals and the reactor pressure vessel
- concrete
- cables
- underground piping
- weld quality

As nuclear power plants seek approval for second license renewals, the way in which these materials perform will be evaluated and their capabilities reassessed to ensure they maintain the ability to perform their intended functions in a safe and reliable manner.

### Reactor Metals

Numerous metal alloys are used in nuclear power plants. Some of these materials, particularly the reactor internals, are exposed to high temperatures, water and neutron fluxes. This can create changes in the metals.

### Concrete

Assessing the long-term stability and performance of concrete structures within a nuclear plant is important because operational data is limited.

*Incoming inspection on a rotor includes a thorough visual check for cracks in the resistance ring.*

### Cables

Cable failure can be caused by long-term exposure to high temperatures. Additionally, buried or underground cables are frequently exposed to groundwater. Plant operators carry out periodic cable inspections to determine when replacement is needed.

### Underground Piping

Maintaining miles of buried and underground piping at a nuclear power plant is essential when evaluating the feasibility of second license renewal. Although many underground pipes are connected to nonsafety systems, some of them serve a direct safety function. Maintaining the integrity and reliability of all of these systems is necessary to extend production at nuclear power plants. EPRI has done extensive research in this area.

### Advanced Welding for Highly Irradiated Materials

Welding is used widely to repair components at power plants. Repaired welds must be resistant to corrosion, irradiation and other potential degradation. EPRI and the Department of Energy are developing a hybrid laser welding system to be able to repair or replace highly irradiated materials.

## Regulatory Framework for License Renewal

The NRC maintains a comprehensive rule book for license renewal. This process is appropriate for evaluation of a second license renewal period and should require only minor updates to guidance documents. The license renewal process considers both safety-related requirements (under 10 CFR Part 54) and environmental impacts (under 10 CFR Part 51). An applicant should be prepared to address the technical aspects of second license renewal and describe the ways they will be managed to ensure public safety. The applicant also must evaluate the potential impact on the environment if a nuclear power plant operates for another 20 years. A renewed license does not guarantee the right to continue operations; nuclear plant operators must continue to meet NRC safety requirements.

Each nuclear facility must operate, inspect and maintain its equipment and components according to plant-specific procedures, which are guided by the NRC and each plant's operating license. All plant equipment necessary for safe operation and shutdown is managed through regulatory programs.

Active equipment and components—such as pumps, valves and instruments—that are replaced regularly are managed under the NRC's so-called "maintenance rule" (10 CFR 50.65). These components are closely monitored to confirm that they can

perform their intended function when required and are repaired or replaced as part of the industry's commitment to preventive maintenance. The nuclear industry has collected vast quantities of reliability and performance data for these components and uses this information—along with active performance monitoring—to predict when replacement or repair of each component is needed.

The other category of equipment is long-lived components that are inactive. These components, such as the reactor containment building, reactor vessel, concrete, reactor coolant system piping and electrical cables, typically are not replaced. For nuclear plants that will be operating beyond the original 40-year license, this equipment is managed under the requirements of the NRC's 10 CFR Part 54 and a report detailing lessons learned regarding the generic aging of equipment (NUREG 1801). This report contains recommended aging management programs that are implemented by each company to monitor, understand and prevent the loss of function for the systems, structures and components.

In 2014, the NRC staff recommended to the commission a new rulemaking to change license renewal requirements. The NRC commissioners rejected the staff's recommendation and reinforced the existing license renewal process. The commission directed the staff to update license renewal guidance where necessary.

## Benefits of Second License Renewal

Maintaining the operation of a nuclear energy facility during a second license renewal period will extend the economic, environmental, energy security and energy diversity benefits of the reactors.

Over 20 years (the period of a renewed license), a typical 1,000-megwatt reactor will generate $9.4 billion of economic output, $800 million in labor income, $320 million in state and local taxes and $1.3 billion of federal tax revenue. This includes approximately $470 million in economic output and more than $40 million in total labor income every year. These sums include the plant's expenditures for goods, services and labor as well as spending attributable to the presence of the plant and its employees as expenditures filter through the local economy (e.g., housing, food). It also generates $16 million in state and local tax revenue annually, which helps support schools, roads and other infrastructure. The typical nuclear plant pays approximately $67 million annually in federal taxes.

Even with aggressive expansion of nuclear energy, the U.S. will nonetheless lose substantial capacity to generate clean air energy unless licenses are extended. Over 20 years, a single reactor will prevent approximately 120 million metric tons of carbon dioxide from being emitted into the air. This is equal to 5 percent of the carbon dioxide emissions from the entire electric sector in 2014 (2.2 billion metric tons).

In 2011, then-Assistant Secretary of Energy for Nuclear Energy Peter Lyons said there was a "national strategic interest in the long-term operation of existing [nuclear] plants," to support climate change objectives and enhance U.S. energy security. In fact, political and policy leaders of both parties support nuclear energy as a critical part of a diverse, secure electricity supply and the effort to reduce climate change.

A 2014 report by IHS Energy demonstrated that a national energy portfolio without nuclear power and coal, with about three-quarters of power generation from natural gas and the rest from hydroelectricity and other renewables, would increase U.S. electricity costs by $93 billion per year, including a 25 percent increase in retail electricity prices, which would mean $2,100 more per household in annual bills. The U.S. would lose $200 billion in gross domestic product and 1 million jobs.

*A mechanic at DTE's Fermi 2 in Michigan works on repairing a cannon cable on a unitized actuator.*

The polar vortex during January and February of 2014 clearly demonstrated the value of a diverse electricity portfolio. More than 20 percent of the installed electric generating capacity in mid-Atlantic states that comprise the PJM transmission network was forced out of service because coal piles and coal-handling equipment froze, gas wells froze at the wellhead, fuel oil deliveries and barge traffic were interrupted, or gas-fired plants simply could not purchase natural gas at any price. Approximately 10,000 MW of gas-fired capacity in PJM could not run due to lack of fuel. In MISO (a regional transmission organization mostly covering the Midwest), approximately 33,000 MW of capacity was forced out of service, 25 percent of which was gas-fired capacity. Nuclear power plants produced electricity undeterred, with reliability in the mid-90 percent range.

## What is at Stake?

By 2040, half of the nation's nuclear power plants will have been operating for 60 years. By 2030, the United States could experience electricity shortages if a significant number of nuclear plants are retired during a short period of time.

If all of today's nuclear plants retire after 60 years of operation, given the electric load growth expected by the U.S. Energy Information Administration (EIA), electricity production equivalent to approximately 20 new large reactors would be needed by 2030, and 50 new large reactors by 2035, to maintain nuclear energy at 20 percent of U.S. electricity supply. If the reactors operate to 80 years, the equivalent of 16 large reactors would be needed by 2030, and 20 reactors by 2035, to maintain a 20 percent share of electricity generation.

A better way to meet our needs is by renewing the operating licenses of nuclear power plants a second time. Continuing operation of existing reactors is affordable for consumers, given that electricity can be produced at today's nuclear power plants for an average of $36.27 per megawatt-hour. By comparison, the cost of producing electricity at a new combined cycle natural gas plant ranges from $72 to $86 per megawatt-hour, according to the EIA.

Reliable nuclear energy provides low operations, maintenance and fuel costs while providing a hedge against environmental regulations to limit carbon dioxide and other emissions from gas- and coal-fired plants. Companies that own and operate nuclear energy facilities need regulatory clarity and legal certainty now—both from research and national energy policy and regulation—to make decisions about whether to pursue a second license renewal.

Renewing licenses at nuclear power plants will ensure a continued, reliable and carbon-free supply of electricity to satisfy the increasing demands of the digital economy.

Not all nuclear plants will seek a license renewal to operate past 60 years. Additional capital investment will almost certainly be required to operate past 60 years and, in some cases, market conditions or other factors may not justify that capital investment. However, producing electricity through 80 years will be economically feasible for many nuclear plants, but there are other factors and uncertainties that will influence a company's decision to apply for a second license renewal. Technical, political and economic factors to be considered for second license renewal include:

- future wholesale electricity prices
- need for, and cost of, equipment upgrade and replacement
- national energy policy, carbon policy and security of energy supply.

NEI has prepared a Second License Renewal Roadmap, which documents the industry's assessment of the milestones that must be reached so that the NRC can review second license renewal applications for the first companies that seek them.

In November 2015, Dominion was the first company to announce its intent to apply for a second license renewal for its twin-reactor Surry Power Station in Virginia. In June 2016, Exelon announced it would do the same for the two reactors at its Peach Bottom Atomic Power Station in Pennsylvania.

## Technical Factors

The industry—in cooperation with EPRI, DOE, and international partners— has conducted extensive research and development and will continue to increase the knowledge base and allow the industry to manage issues safely during a second license renewal period.

Depending on the design of a nuclear plant, applying for second license renewal may require replacing large components such as reactor coolant pumps, steam generators and reactor vessel heads. Other, smaller components that may need to be replaced include pipes, valves, cables and electronics. Further, other major refurbishments or replacements could be required for the turbine, generator, condenser and transformers.

Some parts of a nuclear power plant, specifically the reactor pressure vessel and the containment building, would be cost-prohibitive to replace. Irradiation of the reactor pressure vessel over a long period can potentially alter its metallurgical composition to the extent that it may no longer be acceptable for use. In addition, the primary containment building is a key safety-related concrete structure of a nuclear plant and its robustness and integrity are essential. If the containment building is unable to perform its main function, repair may be prohibitively expensive.

## Economic Factors

Second license renewal may be economically feasible for many nuclear plants if future electricity prices in the region seem likely to be adequate to justify the cost of refurbishment.

Most nuclear plants that have undergone major refurbishments have remained economically competitive; but some have not, and ceased operations (Crystal River 3 in Florida and San Onofre 2 and 3 in California shut down because of failed steam generator replacements; Oyster Creek Generating Station in New Jersey will shut down by 2019 because it was not economically feasible to upgrade its cooling systems).

Electricity prices in the future do not guarantee a power plant will be economically competitive. In a few cases, nuclear plants have shut down because future electricity prices were estimated to be too low for plants to remain economically viable (Kewaunee Power Station in Wisconsin in 2013 and Vermont Yankee Nuclear Power Plant in 2014). Other plants could be economically challenged if electricity prices in competitive markets remain depressed because the price of natural gas remains extremely low for a long period of time.

## Public and Political Factors

Public support for nuclear power facilities and energy policies at the state and national levels are important factors in determining whether to pursue a second license renewal for a nuclear power plant.

Nationwide, 64 percent of Americans favor the use of nuclear-generated electricity and 82 percent support the renewal of reactor licenses if they continue to meet federal safety standards.[2] On average, this support is even stronger among residents who live near nuclear power plants. For example, 91 percent of residents within 10 miles of U.S. reactors agree that nuclear plants that continue to meet safety standards should have the licenses renewed; 66 percent strongly agree.[3]

Nuclear power plants are the most reliable providers of electricity and deliver added value such as clean air compliance and diversity in a portfolio of energy technologies. In a cap-and-trade system designed to reduce emissions, nuclear energy reduces the compliance burden that would otherwise fall on coal or natural gas power plants. Nuclear plants also serve as a hedge against price volatility or supply disruptions in any part of a state's portfolio. These attributes, however, are not valued in the marketplace, which creates an additional challenge to second license renewal.

Nuclear plants also provide large numbers of high-paying jobs (larger numbers and higher-paying than other sources of electricity) and anchor the local tax base. Communities reap the benefits of these attributes, which is one reason why nuclear plants have high favorability among local residents.

## Appendix A: Partners in Research

### Nuclear Regulatory Commission Research

The NRC is engaged in research to confirm the safety of nuclear power facilities. The NRC's license renewal division is responsible for the licensing activities for plants that request extensions beyond 40 years and will be the division responsible for regulatory approvals to extend the license of any plant beyond 60 years.

In addition, the NRC's Office of Nuclear Regulatory Research is investigating issues to confirm the safety of operating plant systems and equipment during a second license renewal period. Major NRC initiatives include:

- revising its expert-panel report on materials safety assurance to include longer time frames and long-lived structures and components

[2] Source: "U.S. Public Opinion about Nuclear Energy," October 2015. Report details the results of a national public opinion survey on nuclear energy conducted Aug. 30–Sept. 16, 2015, by telephone (landline and cell phone) with a national sample of 1,000 U.S. adults. NEI sponsored the survey as part of a 32-year public opinion tracking program.

[3] Source: Bisconti Research Inc. with Quest Research Group. Telephone interviews with 1,080 randomly sampled adults in the 10-mile radius of the 60 national nuclear power plant sites, households with electric company employees excluded; margin of error is plus or minus three percentage points.

- participating in an International Atomic Energy Agency-sponsored project to provide state-of-the-art guidelines for developing and implementing aging management programs for reactor designs used around the world

- evaluating the implementation of aging management programs for plants operating beyond 40 years.

## Crosscutting Issues and Technical Integration: EPRI and DOE Programs

Technical integration is an important and significant part of the EPRI and DOE programs. Research and development within these programs is integrated across scientific and technical disciplines to achieve the greatest value for the investment. These programs are also integrated with outside sources of information and parallel research and development programs in industry, universities and other laboratories, both domestic and international. EPRI and DOE memoranda of agreement support cooperative research with the NRC on relevant materials issues.

Many other countries that use nuclear energy are investing resources to understand the effects of long-term operations on plant components and systems.

## International Atomic Energy Agency

The International Atomic Energy Agency's coordinated research projects are an important mechanism for organizing international research. Examples include research into low-voltage cables. The goal is to provide current- and next-generation nuclear facilities with information and guidelines on how to qualify new cables, monitor the performance of existing cables and establish a program for management of aging cables.

IAEA also is reviewing and benchmarking pipe-thinning caused by corrosion. Wall-thinning of steel piping due to turbulent and fast-flowing water or steam wears away the protective film and leads to corrosion of the underlying metal. Wall-thinning in piping and vessels can cause sudden ruptures, resulting in leaking water and steam, risking personnel safety.

## Materials Aging Institute

The Materials Aging Institute (MAI) is a utility-oriented research center founded in 2008 and financed by Électricité de France (EDF), the Tokyo Electric Power Co., the Kansai Electric Power Co., EDF Energy, China Guangdong Nuclear Power Holding Co. Ltd. and EPRI. MAI directs research and development to extend the durability of materials used in nuclear plant components and systems. Sharing research, experimental results, feedback and scientific information will contribute to understanding various materials used in power plants of all types, including how they perform during a second license renewal period. The combination of reactor operational experience, experimental knowledge and computer modeling can then be used to monitor and improve the durability of materials, components and structures.

MAI launched Project CORTEX in 2010, based on a partnership between EDF and EPRI. CORTEX is investigating corrosion of instrumentation nozzles mounted on the bottom of commercial reactors. The project follows earlier investigations in the United States to repair the cracking of two such nozzles at the South Texas Project Electric Generating Station. Using feedback from EPRI on that project, MAI obtained samples from the plant's cracked nozzles to investigate the mechanical properties of the material in tension and define an index of sensitivity to stress corrosion cracking of the metal.