

## Can Nuclear Power Become More Economical and Help Address Climate Change by Modernizing Old Plants?

*Preliminary EPRI Analysis: 25% or More Cost Reduction May Be Viable for Many Plants*

*By Brent Barker*

### Facilitating Industrywide Innovation

EPRI is facilitating a new nuclear industry initiative to reduce non-fuel plant operating costs through the application of existing modern technologies. A preliminary EPRI analysis points to the feasibility of a 25% cost reduction for many plants in the United States. “The Nuclear Plant Modernization Initiative was started so that a single organization—EPRI—could help consolidate the modernization activities in progress or planned by various research organizations, industry groups, utilities, and vendors,” said Mark Sartain, Dominion vice president.

Nuclear power offers significant potential to address climate change, [generating 11% of the world’s electricity and about 30% of its low-carbon power](#). But this potential is jeopardized by competitive disadvantages stemming from low electricity load growth, growing renewable deployment, and cheap natural gas. Many nuclear plant owners face a competitive disadvantage—or are concerned that they will face this in the future. In the United States, for example, costs of single-unit and multi-unit sites average about \$40 and \$30 per megawatt-hour, respectively. In contrast, market power prices in most parts of the country range from \$25 to \$30 per megawatt-hour.

A plant may retire if its cost to generate power is greater than the cost of purchasing power on the open market. Indeed, nine U.S. plants are slated to retire over the next three years, potentially eliminating significant carbon-free gains. Nuclear now accounts for more than 50% of the carbon-free power in the United States.

A key driver of nuclear plant operation costs is skilled labor for manual inspections and compliance activities.

“Nuclear plants have used very labor-intensive processes for the simple reason that they worked,” said EPRI Senior Program Manager Robert Austin. “But they were developed when the industry was not under cost pressure. With today’s economics, this business model no longer works. Plant viability is on the line. Similar economic drivers are present in most parts of the world.”

To remain viable, nuclear plants’ operating costs must decline, or revenue must increase—whether through sales of process heat or through policies that provide credit for zero-carbon power. “Utilities have more immediate control over the costs, and there are research and technology opportunities that can help with costs, so why not start there?” said Austin.

Because the nuclear industry has focused for three decades on enhancing safety, reliability, and availability, it has not fully modernized. As a result, operating costs have not fallen substantially. Meanwhile, industries such as pharmaceuticals, information, metals, chemicals, petroleum, and other commodities have harnessed advancing technologies to drive down costs significantly. The same is true for non-nuclear power generation, such as solar photovoltaics, wind turbines, and fossil-fueled power plants.

“Automation, digital controls, artificial intelligence, and virtual reality tools offer great potential to reduce the resources and paper burden needed to accomplish many tasks at nuclear plants, enabling reductions in staffing,” said Mark Sartain, Dominion vice president and member of EPRI’s Nuclear Power Council.

“Most nuclear plants in the world are not particularly digital,” said Austin. “They still use manual work processes and either analog controls or antiquated digital controls. These plants are less economically competitive as a result.”

According to Austin, a two-unit, 2,000-megawatt nuclear plant typically employs about 1,000 workers. “Most of the work is inspections and other tasks required for regulatory and industry compliance,” he

said. “The reality is that many of these tasks can be done by digital controllers and computers. Many industries have already made this transformation. For example, coal plants have reduced their staff from hundreds to about fifty.”

“The good news is that more automated power plants offer enormous economic potential—much greater than many in the industry realize,” said Austin.

## THE NUCLEAR PLANT MODERNIZATION INITIATIVE

Recognizing this potential, nuclear industry stakeholders came together in 2018 to launch the Nuclear Plant Modernization Initiative, with a vision to preserve nuclear power as a carbon-free, safe, reliable energy resource. Participants include EPRI, its member utilities, the U.S. Department of Energy’s Light Water Reactor Sustainability program, plant owners’ groups, the Nuclear Energy Institute (NEI), and the Institute of Nuclear Power Operations (INPO). EPRI facilitates the initiative under Austin’s leadership.

In this initiative, EPRI and other organizations such as the Light Water Reactor Sustainability program are studying the feasibility of reducing non-fuel operating costs through the application of existing modern technologies. “Modernization does not require heavy construction or major changes such as replacing the reactor core, building a new reinforced building, or laying a lot of concrete,” said Austin. “It primarily entails the installation of digital process controllers, computers, and servers. I don’t see any technology barriers that would prevent nuclear plants from reducing their operating costs by 50%. But this is an assertion that EPRI needs to validate through research and testing.”

A cost reduction of this magnitude could be sufficient to return many plants to economic viability. Potential savings span components throughout the plant. For example, installing sensors and simple analytics for continuous online monitoring of vertical pumps could reduce annual maintenance costs by \$25,000 per pump. If applied to the hundreds of similar pumps in a typical plant, aggregate savings over 20 years could exceed \$50 million.

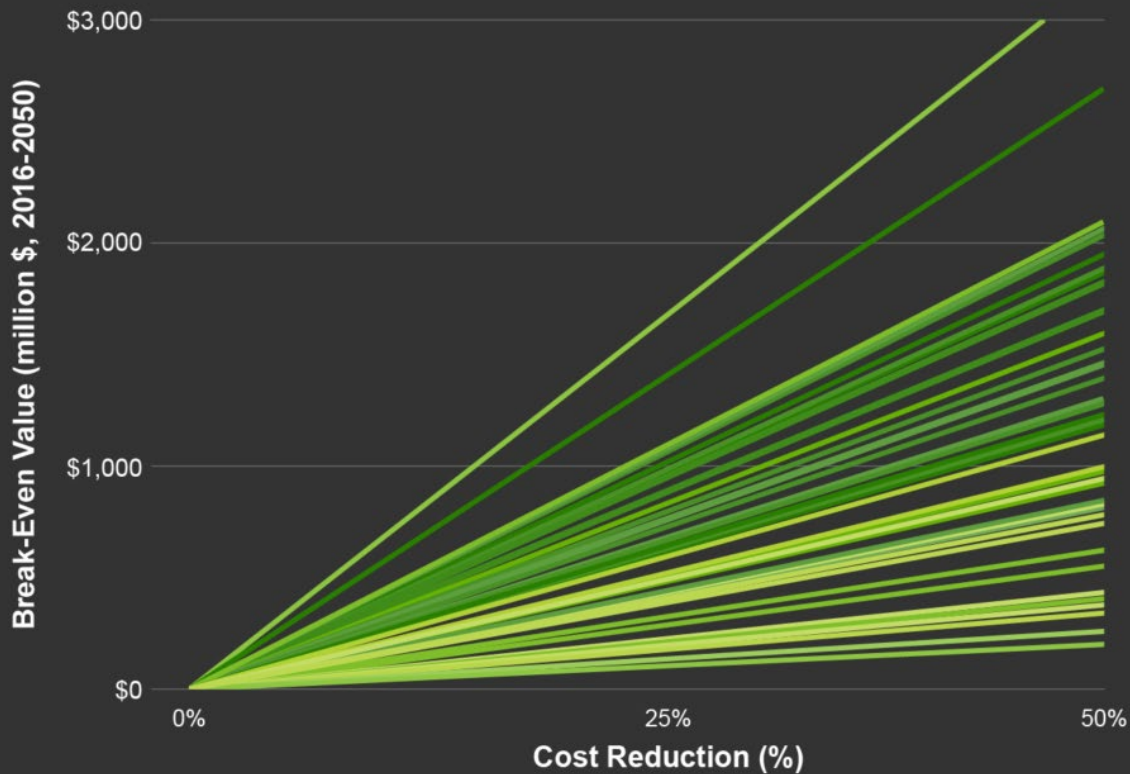
“The Nuclear Plant Modernization Initiative was started so that a single organization—EPRI—could help consolidate the modernization activities in progress or planned by various research organizations, industry groups, utilities, and vendors,” said Sartain. “The purpose is to help avoid duplication or omission of important topics, identify new R&D opportunities, and disseminate results through reports and other deliverables.”

The initiative’s goals include:

- **2019:** Assess the feasibility and economic viability of modernization with existing technologies.
- **2020:** Identify deployment methods, inform regulatory solutions, and identify plants for demonstration. Publish a plant modernization handbook to help guide interested utilities.
- **2021:** Further develop the methods with conceptual designs and detailed business cases. Add case studies to the handbook.

## BREAK-EVEN VALUES OF NUCLEAR PLANT MODERNIZATION

Using EPRI’s U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers quantified a break-even value\* for modernization investment at every U.S. plant, given a specified percentage reduction in operating costs. Initial estimates suggest that many nuclear plants can justify investment of more than \$100 million to modernize and reduce costs by up to 25%. These approximations are based on publicly available plant cost data and reveal the wide variation in break-even values across the fleet. Modeling of future electricity costs in each plant’s region was based on various assumptions such as natural gas prices, growth of renewables, and carbon dioxide emissions policies. Plant owners and operators can refine these estimated break-even values using their proprietary data or other plant-specific assumptions.



\*The break-even value is the investment amount that would be paid back completely by reduced operating costs. This value was calculated by discounting the annual savings over each plant’s remaining life to determine the savings’ present value.

Source: EPRI

## A WORTHWHILE INVESTMENT FOR MANY PLANTS?

As part of the initiative, EPRI analyzed the economics of modernizing the U.S. nuclear fleet. “The goal of the analysis is to offer preliminary estimates of the economic implications rather than precise figures,” said EPRI Principal Technical Leader John Bistline. “Plant owners and operators can refine these estimates using their proprietary data or other plant-specific assumptions.”

Using EPRI’s U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model, researchers have quantified a break-even value for modernization investment at every U.S. plant, given a specified percentage reduction in operating costs. This involves discounting the annual savings over a plant’s remaining life to determine the savings’ present value.

“[Initial estimates](#) suggest that many nuclear plants can justify investment of more than \$100 million to modernize and reduce operations and maintenance costs by up to 25%,” said Bistline. Justifiable investment for some U.S. plants could reach \$500 million for a 25% cost reduction and \$1 billion for a 50% reduction. Future EPRI research will compare these break-even costs with cost estimates for specific modernization technologies and improvements.

Given the significant potential for modernization, some plants slated for closing could become more economically competitive. “Following the work of the Nuclear Plant Modernization Initiative, utilities and other stakeholders should have more information through which to consider the future of a particular plant’s operations,” said Bistline.

## A SUITE OF 12 ENABLING PROCESS IMPROVEMENT AND TECHNOLOGY AREAS

Participants in the modernization initiative identified 12 process improvement and technology areas most important for achieving cost reductions of 25–50% when integrated as a suite at many plants:

- **Digitalization**, including integrated digital controls, virtual reality, and artificial intelligence
- **Wireless connectivity** throughout the plant

- **A common information model** enabling data exchange among different software and compatibility among databases
- **Analytics** that examine large data sets for patterns and correlations
- **Automated work planning** and management software
- **Continuous equipment monitoring** to inform condition-based maintenance, rather than scheduled maintenance
- **Risk-informed engineering and decision making** to inform a level of rigor for a task based on its importance for safety and reliability
- **Real-time, automated water chemistry monitoring** and analysis
- **Continuous, automated radiation monitoring** in critical areas of the plant
- **Enhanced physical security** using monitoring technology and real-time data processing
- **Enhanced emergency planning** for worker and public safety
- **Continuous monitoring of critical plant structures** and real-time analysis of anomalies

Ongoing EPRI research in these areas will be integrated into the modernization initiative. For example, a new EPRI [guide](#) informs utilities on deploying integrated digital controls cost-effectively while addressing safety and hazards. Other EPRI tools integrate maintenance cost analysis and monitoring to inform efficient maintenance tasks.

“We are looking at technologies and processes used in other parts of the electricity industry. For example, many non-nuclear generation facilities use remote monitoring, and a Common Information Model Standard is used in the transmission and distribution sector,” said Austin. “EPRI’s research spans various generation sources, energy and the environment, power delivery and utilization, and nuclear, and we can draw on work in all these areas.”

In addition to the cost reduction, replacing analog electronics with integrated digital controls offers these benefits:



- Operators can remove obsolete analog components that can be replaced only through costly reverse engineering.
- Industrial digital controllers work more effectively than analog counterparts and can enhance reliability and safety in various plant systems.
- Fewer critical components are needed, enhancing reliability.
- Single-point vulnerabilities can be designed out of systems.

Some U.S. plants are upgrading digital controls to reduce maintenance costs and staff. Sartain says that some power companies have created remote monitoring and diagnostic centers to streamline data collection and analysis. “Advanced digital technologies in the physical protection area have led to reductions in security staffing.”

#### RETIRE OR MODERNIZE?

The initiative is moving quickly. Most of the technology is already proven in other industries, and cost savings can be estimated. EPRI expects to complete portions of the feasibility studies this year. Plans for 2020 and 2021 include completing business cases and demonstrating the technology suite at several U.S. plants.

“Success will be utilities seeing the benefits and committing to modernize their plants to support safe, reliable, competitive, always-on carbon-free electricity to extend their service to 80 years and beyond—with some utilities deciding to modernize a plant that they had previously decided to retire,” said Sartain.

Most tasks to be automated have been carefully prescribed and refined by regulation over decades. NEI is leading efforts with the U.S. Nuclear Regulatory Commission to review and update appropriate regulatory requirements that support the use of modern processes and technology and maintain safety and reliability.

If many plant owners and operators conclude that the economics are compelling, how fast could the technology transformation take place?

“Much of this depends on individual plant circumstances, but it is likely that plants would

employ a phased approach spanning multiple years and outages,” said Sartain. “Some upgrades would be implemented with the plant online, some would require outages, and some would be a combination of both. Depending on the scope of modernization, implementation schedules could be optimized to minimize outage duration.”

“It could be that the cheapest way to guarantee and expand carbon-free electricity generation is modernizing existing nuclear power plants,” said Austin. “Other industries have reduced their costs in this fashion. Why not nuclear?”

#### Department of Energy Shifts Focus to Plant Modernization

The U.S. Department of Energy’s [Light Water Reactor Sustainability program](#) works to extend the life of the nation’s nuclear reactor fleet.

“In previous years, this objective was primarily met by providing the technical bases to support Subsequent License Renewal applications,” said Program Manager Alison Hahn. “The program has now redirected its efforts toward plant modernization, which we define as science-based, technology solutions that can improve the performance of the current labor-intensive business model.” Areas of focus include:

- Modernize or replace out-of-date instrumentation and control technologies
- Demonstrate advanced condition-based monitoring techniques and technologies
- Develop approaches to mitigate aging of materials in plant components
- Enhance capabilities for analyzing and characterizing performance of plant systems
- Diversify nuclear power plant outputs to include non-electricity products such as process heat
- Assess enhancements and regulatory requirements to improve physical security

#### KEY EPRI TECHNICAL EXPERTS

Rob Austin, John Bistline