WITH CRITICALITY ACHIEVED, THE NUCLEAR INDUSTRY IS MORE IMPORTANT THAN EVER

*"Nuclear for us is essential. I cannot meet any target without nuclear because I start from a place where **80% of my carbon-free generation** today comes from nuclear. If you are a resident **of North and South Carolina, 50% of your power comes from nuclear.** I cannot retire those plants and replace them with something that runs 95% of the time that is carbon free."*

—Lynn J. Good, CEO, Duke Energy, speaking at Bloomberg Green Summit, April 2023 (emphasis added)

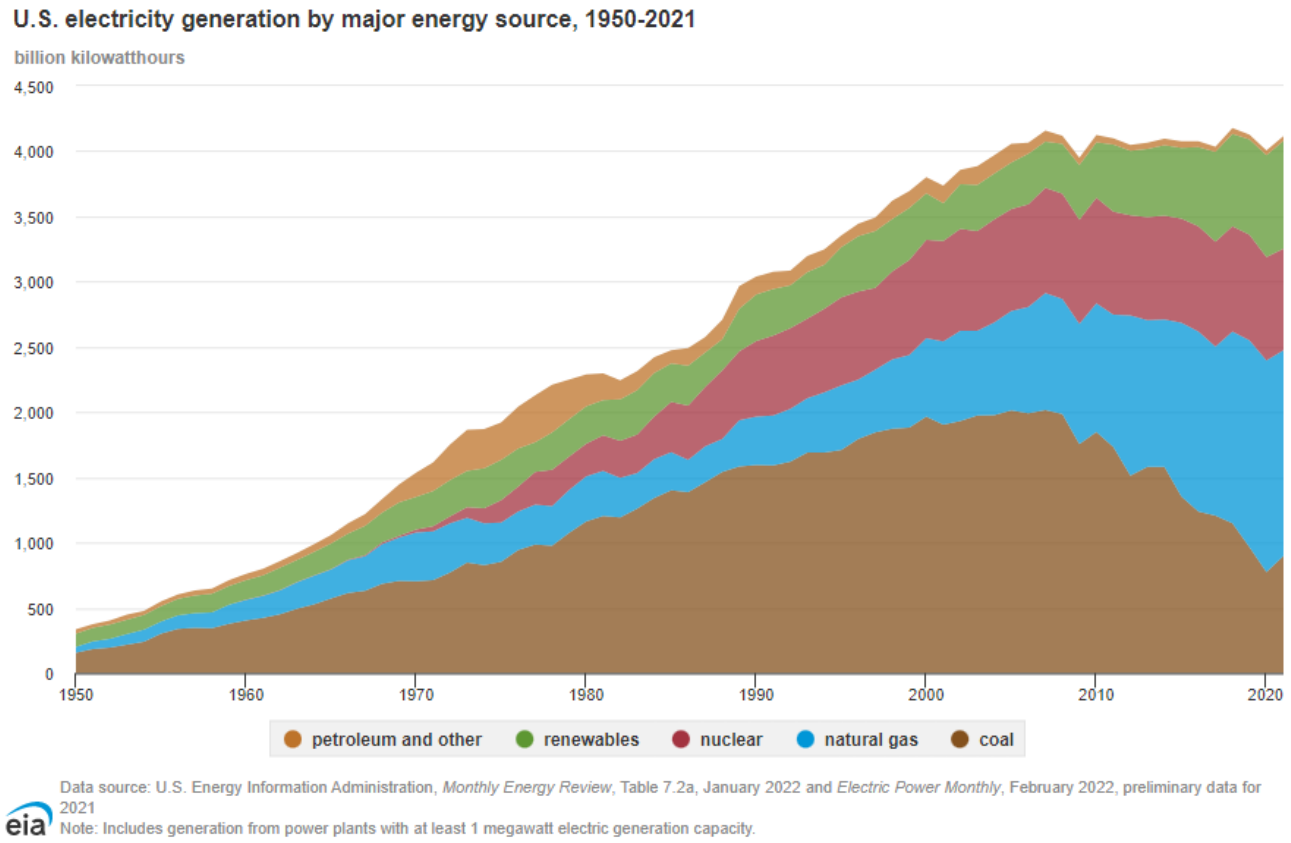
"Nuclear energy today is by far the largest source of carbon-free electricity in the United States. That's a fact. That's indisputable."

— Ernest J. Moniz, Former U.S. Secretary of Energy

Duke Energy is the second largest U.S. electric utility with over 8 million customers and historically a large user of coal. The company has committed to a 50% reduction in carbon emissions by 2030, an 80% reduction by 2040, and a net carbon zero goal by 2050. CEO Lynn Good's comments capture key attributes of nuclear energy—not only its importance in providing carbon-free energy but also its role as an "always-on" source to balance the ever-growing deployment of intermittent renewable resources. Nuclear reliability also lends stability in the form of frequency regulation and voltage support as transmission grids move an increasingly variable mix of power over long distances from production to consumption. This paper examines challenges associated with keeping the nuclear fleet running and shows how incremental economic compensation of nuclear energy can support a clean, reliable electricity supply.

Chart 1 illustrates the U.S. electricity supply since the mid-20th century. Electricity production from natural gas and renewables (including hydroelectric power) has grown significantly in the past decade at the expense of coal. At the same time, nuclear production has remained essentially flat at just under 20% of

Chart 1: Sources of U.S. Electricity



Source: U.S. Energy Information Administration

U.S. supply, despite the closure of 12 reactors since 2012. U.S. Energy Information Administration data show that nuclear plants supply roughly half of U.S. carbon-free electricity despite comprising less than 10% of installed generating capacity, thanks to their high capacity factor (run time), which rose from less than 50% in the 1970s to almost 93% in 2022.

For comparison, utility-scale natural gas, wind, and solar generation had 62%, 36%, and 25% capacity factors in 2022, respectively. These figures don't diminish the renewable contribution, but do highlight the importance of "always-on" carbon-free energy to balance the variability of fast-growing wind and solar. Moreover, nuclear energy's clean and reliable returns are realized with comparatively small financial investment, installed capacity, and land use. For example, replicating the high-capacity output of a typical 1 gigawatt nuclear plant with solar would require over 30 times the land area.

Replicating the high-capacity output of a typical 1 gigawatt nuclear plant with photovoltaic solar would require **over 30 times the land area.**

The Nuclear Operator's Challenge

As resilient, reliable carbon-free electricity becomes ever more important, nuclear facility operators will be challenged to keep plants running safely, reliably, and economically well into the future. The delicate balance between high performance, safety, and cost management—both capital and operating costs—becomes even more pronounced as existing nuclear plants are challenged to continue producing power for decades beyond their originally contemplated life span.

Most operating U.S. plants have already undergone 20-year operating license extensions. Six reactors have completed the Nuclear Regulatory Commission's "subsequent license renewal" process to extend operation from 60 to 80 years, with another ten units pending review. This activity demonstrates the feasibility of nuclear license extension, but longer-term operational extensions face multiple technical challenges:

- Some original electronic circuitry or mechanical components are no longer produced. In some cases, reverse engineering and 3-D printing have been deployed to fabricate replicas.
- Digitization of obsolete analog control systems entails operator retraining and testing.
- Neutron embrittlement of major reactor components requires complex processes to address.
- Major mass components may need replacement due to aging and wear, potentially rendering further license renewal uneconomic.

These technical issues can certainly be addressed, but costs matter:

- Overall access to and cost of capital is challenging, as higher interest rates have raised the cost of equity, debt, and hybrid financing. Nuclear plants are inherently capital-intensive, and life extension is likely to require considerable investment.
- Inflation continues to exacerbate already tight supply chain issues by raising prices and limiting availability of everything from steel to microprocessors.
- Nuclear operators compete with other large capital needs, including transmission, distribution, and renewables, and often find themselves competing for allocation of enterprise capital. The business unit with the best, most comprehensive plan wins the most funding.

Nuclear operators **compete with other large capital needs,** including transmission, distribution, and renewables.

To meet these challenges, nuclear operators must demonstrate a high probability of compelling returns on investment, considering important financial and human capital aspects:

- Robust life-cycle management planning is critical to ensure capital is spent on the right systems and components to maintain plant health.
- Sophisticated processes and tools must be implemented to facilitate robust business cases and data-driven, value-based decisions with the aim of developing a plant's overall project portfolio at the lowest possible cost.
- Operator expertise and institutional knowledge must be preserved and shared with a younger generation of workers, who often weren't even born when the plants they run and maintain went into service.

What About New Revenue? Making the Case for Additional Compensation

Nuclear energy is more critical than ever to the U.S. energy supply. Yet it receives the same economic compensation as other sources of electricity, both in the traditional utility rate base and in competitive merchant structures. Internal Revenue Code Section 45J (the production tax credit) effectively sets a "floor price" for nuclear generation in the low $40s/MWh but does not specifically compensate a nuclear facility for its carbon-free production, nor for the reliability and resilience it lends to the electricity system. We believe more targeted economic incentives would better facilitate continued access to capital, allowing the nuclear fleet to continue meeting critical needs.

Alternative ratemaking and other compensatory mechanisms could be explored at a regional or state level to economically reward nuclear facilities for providing carbon-free, dispatchable, and highly reliable electricity. While attaching a numeric value to these attributes is challenging (and no doubt subject to debate), nuclear facilities clearly add value in their reliability and carbon-free generation.

Targeted economic incentives would better facilitate continued access to capital, allowing the nuclear fleet to continue meeting critical needs.

The benefits of reliability can be quantified by showing the high economic costs of power outages and quality aberrations, such as voltage sags or frequency variations that can damage equipment. Unlike many other nations, the United States lacks a carbon market, but there are proxies in the form of tax credits for carbon capture, for example, that can be leveraged to price nuclear power appropriately to compensate

for its role in meeting these increasingly critical needs. This compensation would help level the economic playing field and extend plant life.

The Nuclear Industry Has to Get It Right

While new compensatory mechanisms will require time to take shape, nuclear operators can act today to optimize their operations and maintenance expenses to grow their margin and develop the right portfolio of capital projects to extend plant life. These critical issues are addressed in the MCR white papers O&M Reduction with Risk-Informed Budgeting and A Proven Approach to Optimize Project Spending at Nuclear Power Plants. These papers detail important processes and tools that plant operators can deploy today to improve their competitive positioning in power markets and compete for capital to fund longer-term operation.

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