



Energy Transition Requires Nuclear Foundation

Key Takeaways

- ▶ Nuclear energy is the ideal foundation for the energy transition, offering a safe, reliable, efficient and environmentally-friendly base power source to complement greater renewables penetration.
- ▶ While misconceptions surrounding the risks of nuclear power have made it controversial, greater fiscal support and understanding of its benefits are helping clear the way for increased usage.
- ▶ New innovations in nuclear power design and operations, such as small modular reactors (SMRs), are creating compelling long-term investment opportunities.

Nuclear Makes Renewables a Sustainable Solution

As global economies embark on a secular energy transition away from carbon-based power sources, renewable sources like wind and solar are simply not enough to satisfy the world's demand for energy. We believe nuclear power, an energy-dense power solution with vastly superior carbon emissions characteristics, can play a critical supporting role in the transition.

For all their environmental benefits, renewable power sources are limited by intermittency and a lack of sufficient energy storage. Inevitably, there will be days when the wind doesn't blow or clouds starve solar panels of sunlight, making renewables less reliable than the power sources they are seeking to replace. Successful energy sources must adequately provide for persistent base power needs, but also accommodate occasional spikes in demand. While advancements in battery technology have helped renewables narrow the gap between their intermittency and the persistent need for power, even the most advanced batteries don't have enough capacity to account for demand surges from adverse weather effects like Winter Storm Uri, which overwhelmed Texas in 2021.

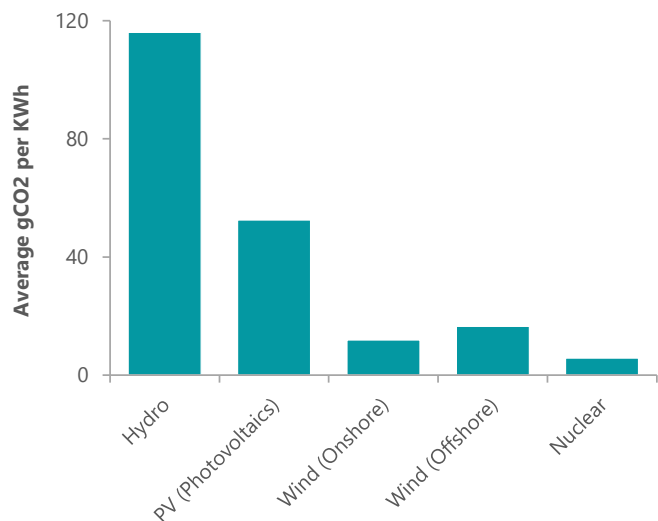
Nuclear, on the other hand, offers a safe, reliable, efficient and environmentally-friendly baseload power source that can serve as the ideal foundation to help fill the gap created by greater renewables penetration. Nuclear plants run effectively around the clock at very high utilization rates and are designed to only require refueling typically every 18 to 24 months, surpassing the capacity utilization of coal or natural gas generators, which

require more frequent refueling and maintenance. For example, Constellation Energy, the largest nuclear power operator in the U.S., has been able to operate its nuclear fleet over 94% of the time between 2013 and 2022,¹ exceeding the 55%, 54%, 37% and 27% average utilization rates of natural gas, coal, wind and solar generators, respectively.² This ability to provide high-quality, stable power generation makes nuclear the most reliable and dependable energy source to help solve for the variability in both renewable power generation and meeting energy demand growth.

Nuclear power plants also provide a potential solution to energy storage challenges. Investments in hydrogen production technology would allow operators to redirect the fission process during peak renewables production (e.g., a sunny day) to create easy-to-store hydrogen, a dense and carbon-free fuel source. This creates a whole new set of opportunities, including using hydrogen as a flex fuel for higher power demand periods, power for industrial operations and long-haul transportation where electric vehicle batteries are insufficient. In fact, in November 2022, British aerospace company Rolls-Royce announced it had successfully tested the first hydrogen-powered jet engine. While this demonstrates hydrogen's potential as a fuel source, it also highlights that widespread adoption will require it to be produced in significant quantities, a task nuclear is uniquely suited for.

While nuclear's zero-carbon emission profile is well understood (if not properly valued), its low upfront carbon cost is vastly underappreciated. Although the energy that renewables generate may be carbon free, the initial resource intensity of their construction is not. Each wind turbine or solar panel requires immense allocations of metal, concrete and other resources that are the result of carbon-emitting manufacturing, effectively creating a carbon debt to be repaid. Conversely, the lifecycle emissions produced by nuclear is extremely low relative to the power produced, resulting in a substantially shorter payback period on its carbon debt (Exhibit 1).

Exhibit 1: Nuclear Ranks Lowest on Lifecycle Emissions



As of Dec. 31, 2020. Source: United Nations Economic Commission for Europe, Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources.

Overcoming Common Misconceptions

For all its benefits, nuclear power remains controversial. While historical disasters such as Chernobyl, Three Mile Island and Fukushima loom large in policymakers' and investors' minds, the actual human costs pale in comparison to the historical death toll from the extraction and refinement of traditional fossil fuel sources. Neither the Three Mile Island or Fukushima plant meltdowns resulted in any direct deaths, and the total death toll from the Chernobyl disaster (including first responders and cleanup workers over the following weeks from radiation exposure) amounts to 30 people, according to a 2008 UN report.³ Excluding the Chernobyl disaster, the total number of nuclear fatalities globally between 1945 and 2007 was 32, with 24 of those fatalities related to military nuclear weapons programs rather than civilian power production. In contrast, the U.S. Department of Labor and Department of Transportation reported a total of 37 mining- and 11 pipeline-related fatalities in the U.S. alone in 2021.⁴ The safety of nuclear becomes even more evident when including the estimated fatalities stemming from the effects of air pollution generated by energy sources, further demonstrating that nuclear is one of the safest methods of power generation (Exhibit 2).

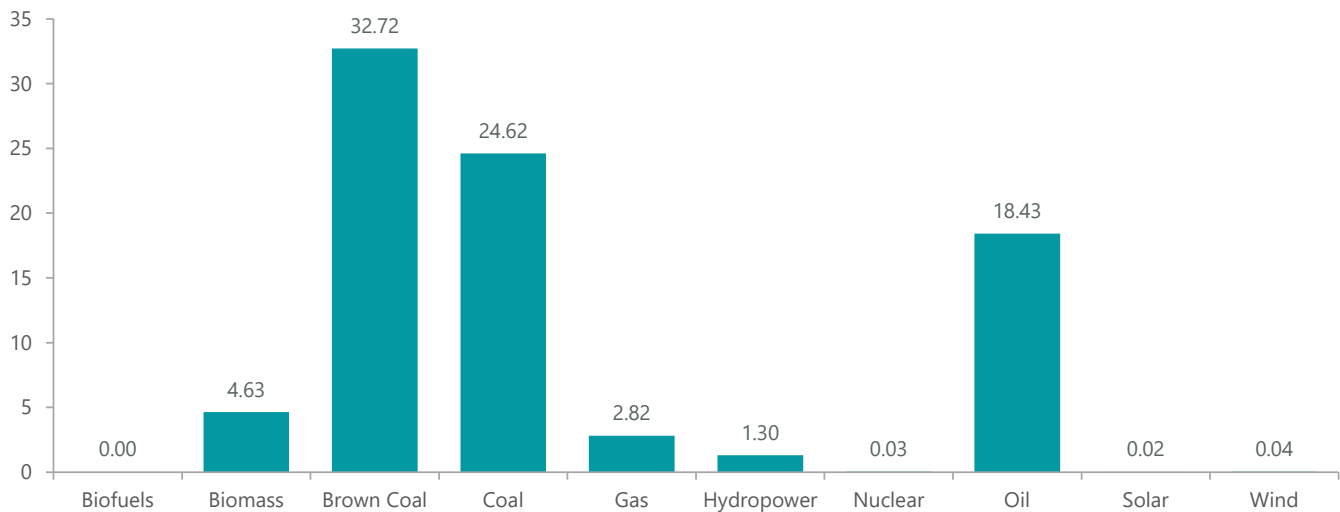
¹ Exelon Corporation, "Constellation Shares Plan to Lead America's Transition to a Carbon-Free Future as it Prepares for Separation from Exelon", January 11, 2022.

² U.S. Energy Information Administration, The Ultimate Fast Facts Guide to Nuclear Energy, 2019.

³ UNSCEAR (2008). Sources and Effects of Ionizing Radiation, UNSCEAR 2008 Report to the General Assembly.

⁴ U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration, U.S. Department of Labor Mine Safety and Health Administration.

Exhibit 2: Estimated Deaths per TWh of Electricity Production per Year



As of Feb. 10, 2020. Source: Markandya & Wilkinson (2007); Sovacool et al. (2016); UNSCEAR (2008 & 2018), Our World in Data.

Additionally, operators and engineers have learned from these situations, have retrofitted current plants and designed future plants to account for such extreme scenarios. For example, the Fukushima plant's inability to maintain power due to flooding, as well as the inability to assess the level of coolant in the reactor, caused heat and pressure to build up and be released into the environment. In response, the U.S. Nuclear Regulatory Commission required plants with similar reactors to install new, hardened ventilation systems capable of releasing such heat and pressure before they reached critical levels as well as requiring secondary, independent electrical systems for coolant level monitoring instruments to ensure a continuity of monitoring even during an emergency.

Another contention is that nuclear fission produces radioactive waste. In reality, waste products have been safely stored at nuclear facilities, without issue, for decades. In fact, in over 70 years since the first U.S. nuclear plant began operations, the total radioactive waste generated by all U.S. nuclear plants amounts to approximately 90,000 metric tons. If assembled and stacked together, the entirety of the U.S.'s nuclear waste could fit on a single football field at a depth of less than 10 yards,⁵ or within the footprint of a single Walmart Supercenter.⁶

The two biggest problems with nuclear power are cost and schedule overruns. A current example is Plant Vogtle, under construction in Georgia, a project estimated to cost over two times its initial \$14 billion

estimate with a completion date still uncertain. These challenges were directly responsible for the bankruptcy of nuclear technology company Westinghouse and create further resistance to investment in new nuclear facilities (Exhibit 3).

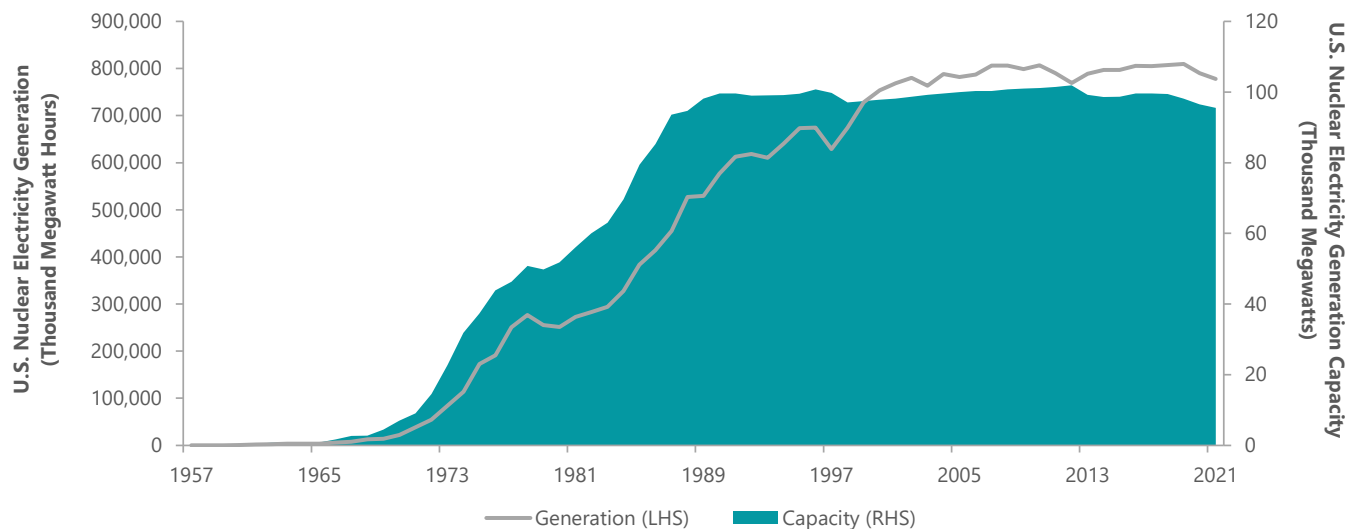
Legislation is Facilitating Investment and Innovation

Despite these headwinds, we remain optimistic about nuclear's long-term prospects. For starters, the Inflation Reduction Act (IRA) contains several provisions to help improve the competitiveness of nuclear power, incentivize investment in new facilities and upgrade and maintain existing plants to keep them operating at peak efficiency over the coming decades. For instance, the IRA's new production tax credits provide up to \$15 per megawatt-hour (MWh) subsidies through 2032 to help existing and aging nuclear plants remain competitive with other, more technologically up-to-date electricity generators. Additionally, the bill offers a tax credit equivalent to 30% of the capital cost of constructing new nuclear plants to help incentivize new nuclear infrastructure. With the average age of the U.S.'s nuclear fleet exceeding 40 years, these IRA subsidies are designed to help solidify and expand nuclear's penetration in the U.S. energy mix.

The IRA also contains a number of broad, technology-neutral tax credits that can be applied to help direct increased investment, research and development into nuclear power innovation, such as new, safer and more efficient advanced reactor designs. One such example is the sodium-cooled fast reactor, which trades traditional water coolant for liquid metal sodium,

⁵ U.S. Department of Energy, Office of Nuclear Energy.

⁶ 3Q22 Constellation Energy Corporation Earnings Conference Call, November 8, 2022.

Exhibit 3: Nuclear Expansion Has Plateaued

As of March 31, 2022. Source: U.S. Energy Information Administration.

allowing the coolant to operate at higher temperatures and higher pressures. This helps improve the ability of the system to continue operating under more adverse circumstances and enhances the overall safety of the system. There is also recent innovation in “fast” reactor designs, which eliminate the need to slow down neutrons to cause a fission reaction, enabling fast reactors to recycle and use “spent” fuel from current nuclear reactors to reduce the overall nuclear waste produced. These broad-based carbon-free subsidies allow operators to invest in these new, advanced reactors for up to \$25 per MWh through 2032 or until carbon emissions from electricity production have fallen by 75% from 2022 levels.

SMRs Offer Immense Possibilities

One of the most exciting developments in nuclear power is the design of small modular reactors (SMRs). According to the U.S. Department of Energy, the average U.S. nuclear plant has a capacity generation of approximately 1,000 MW per reactor and requires one square mile to operate. However, SMRs are designed to generate only 300 MW, allowing for a much smaller physical footprint and making them ideal for areas unable to support larger reactors. The reduced size of SMRs makes them capable of being produced in factories and transportable to their facility with minimal onsite assembly, allowing developers to leverage economies of scale in their assembly and design. Furthermore, the modular design of SMRs creates additional flexibility by allowing operators to add several reactor modules to an existing site with relative ease and speed in the case of increased

power needs or surges in demand. While SMRs are still in development, the International Atomic Energy Agency has received over 70 different proposals for SMR designs, highlighting their immense possibilities, ranging from plants suited for urban centers, underground facilities more protected from terrorism and even as a potential power and propulsion source for spaceflight. Additionally, as inflation and geopolitical conflicts send traditional energy prices higher (Exhibit 4), the affordable, reliable and flexible power generated by SMRs is particularly well-suited for resource-poor countries where the possibility of energy shortfalls outweighs the risks.

Exhibit 4: Global Energy Prices Are Increasing

As of Oct. 1, 2022. Source: International Monetary Fund, Global Price of Energy Index.

Finding Nuclear Investment Opportunities

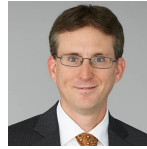
Although there are fewer opportunities to invest in nuclear energy companies than other energy providers, one of the most direct ways of doing so is through investment in nuclear-operating power utilities. Companies such as Constellation Energy, Vistra and NRG Energy have significant nuclear power operations throughout the U.S. As experienced and established nuclear operators, these companies will likely be significant beneficiaries of increased subsidies, investment and innovation in nuclear power over the coming decades.

Another compelling way to gain exposure to nuclear energy is through companies involved in the design, construction and maintenance of nuclear reactors. For example, BWX Technologies has manufactured over 400 nuclear reactors in the 60+ years of nuclear technology development, specializing in nuclear propulsion systems for U.S. Navy submarines and aircraft carriers. In addition to having a track record of safe and reliable performance, BWX's expertise has allowed it to expand into services such as plant refurbishment and inspection and specialty engineering, and it is even working with NASA on a prototype high-efficiency reactor propulsion system for future Mars missions. As the need for nuclear power becomes better understood, innovators and infrastructure support experts like BWX will be relied on to help facilitate its greater incorporation.

Conclusion

In a sea change from just a few years ago, policymakers and investors are now acknowledging the benefits of nuclear power and devoting greater research and resources into its development as a sustainable solution. We believe that greater incorporation of renewables into the global energy mix requires the kind of strong, stable and clean energy that only nuclear power can provide, making it the optimal foundation for the energy transition.

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