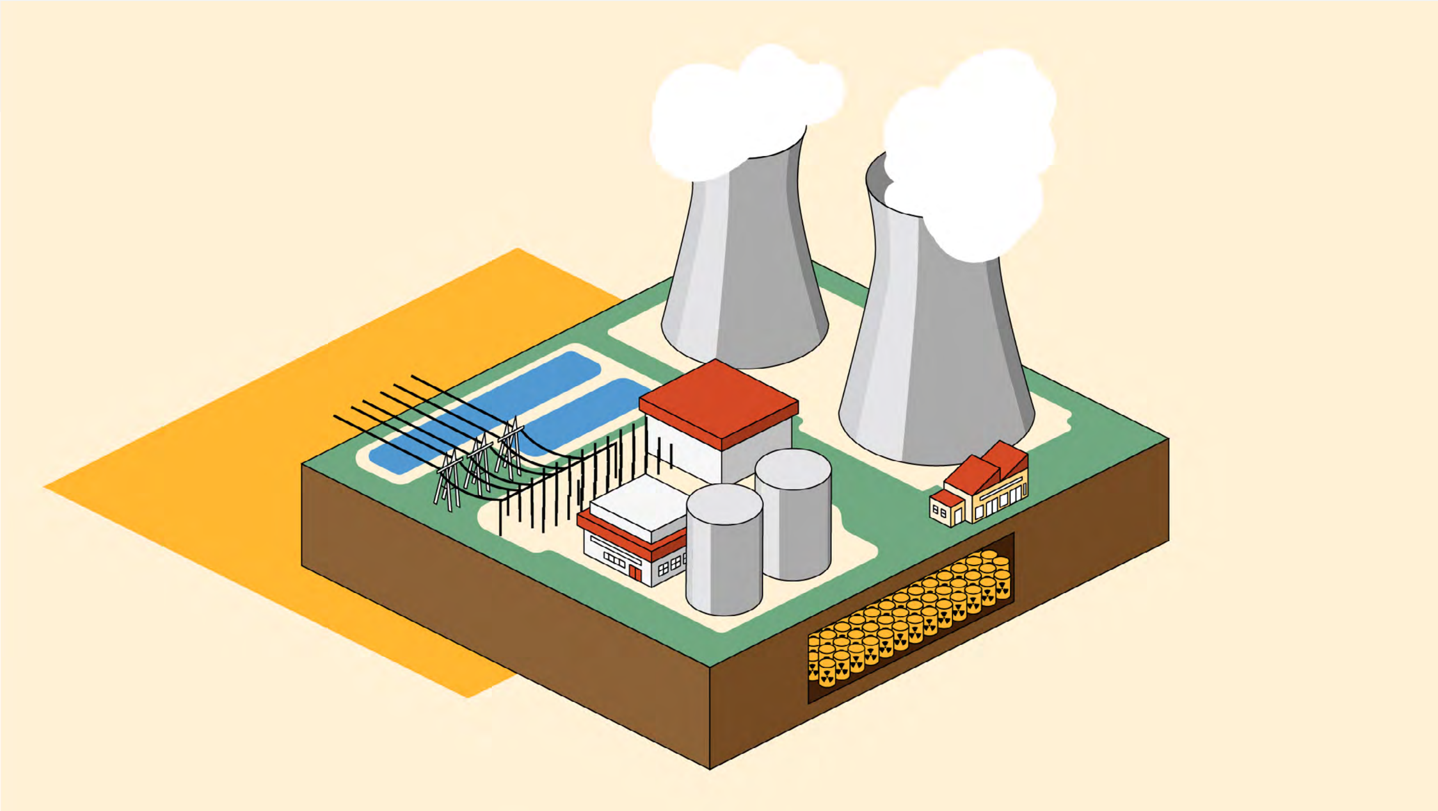
Nuclear Energy is Clean, Safe, and Really, Really Expensive to Build

Tech companies looking for a clean energy source to power AI data centers are turning to nuclear, which has the ability to produce carbon-free electricity at scale; but the price tag will be high.

June 11, 2025



Key Takeaways

- Nuclear energy is drawing renewed attention amid a global push for electrification and tech companies that need carbon-free fuel sources to power their energy-intensive data centers and AI platforms.
- A nuclear plant provides a source of clean electricity generation that runs virtually uninterrupted for decades—some plants have been approved for 80 years and could operate even longer.
- The biggest problem with nuclear power surprisingly isn't safety, it's cost. Nuclear power is more than twice as expensive to build as any other power source. And the difficulties often result in projects that end up costing twice as much and taking twice as long to build.

After decades of being an afterthought in the US, there is renewed interest in nuclear power as the need for reliable, low-carbon power increases amid a global movement toward electricity. Moreover, deep-pocketed tech companies such as Microsoft, Amazon, Meta, and Alphabet are investing in nuclear energy to power their AI data centers and balance their growth goals and decarbonization ambitions.

It's easy to see why nuclear energy appears attractive. Electricity consumption has grown at twice the rate of total energy demand over the past decade and ongoing electrification efforts should fortify this trend for the foreseeable future. The International Energy Agency projects that electricity demand just from data centers will more than double by 2030 to about 945 terawatt-hours—more than the current electricity consumption of Japan. Nuclear energy can be a significant part of that. A running nuclear plant provides a source of carbon-free electricity generation that runs virtually uninterrupted for decades—some plants have been approved for 80 years and could operate even longer.

The demand for clean power is a positive for the nuclear-energy industry. The problem is that demand is immediate but building nuclear plants takes years, is very complicated, and is extremely, even prohibitively, expensive. The challenge for the industry is to make the production of nuclear energy cost effective. It won't be easy.

Most people assume nuclear energy stalled over safety concerns, and those concerns were (and are) real. In the 1960s and 1970s nuclear energy had been a rapidly growing industry. In 1960 there were about 40 units under construction globally. That number hit about 240 units in 1979. Then came the partial meltdown in 1979 at Three Mile Island's Unit 2 reactor; the accident terrified people. The actual meltdown in 1986 at Chernobyl solidified their fears. Those accidents virtually halted the nuclear industry. After Three Mile Island, the number of units under construction globally plunged. It did not start growing again until about 2005, and currently stands at about 60 units.

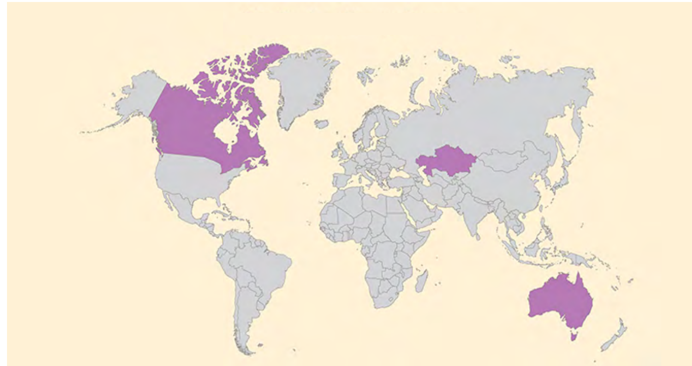
But the industry learned from all those disasters. Improved standards and practices since Chernobyl have made a difference. Plants now are built with containment structures designed to withstand the impact of a commercial airliner, for example. A measurement called deaths per terawatt hour is near zero for nuclear energy, putting it on par with wind as the safest form of electricity generation. Coal is the most hazardous, with a rate near 100,000 deaths per terawatt hour. You are, in fact, more likely to receive a (very nonlethal) dose of radiation living next to a coal plant than a nuclear reactor.

The problem with nuclear energy today isn't safety. It's cost and time, specifically the upfront costs to build a new plant and the years, or decades, that it takes to get a new plant up and running. And the challenges don't end once it is up and running. Between preparing fuel for use, the actual use of it to generate power, and the very long disposal period, a nuclear plant's life revolves around what is called the nuclear fuel cycle. This, too, is expensive. Making usable nuclear fuel is hard, and the industry is very concentrated.

Nuclear energy is by far the most expensive to build from scratch. The cost to build new power generation for nuclear energy is more than US$7,000 per kilowatt hour. Coal is US$4,000. Hydro is US$3,000. Solar is less than US$2,000. Gas is US$1,000.

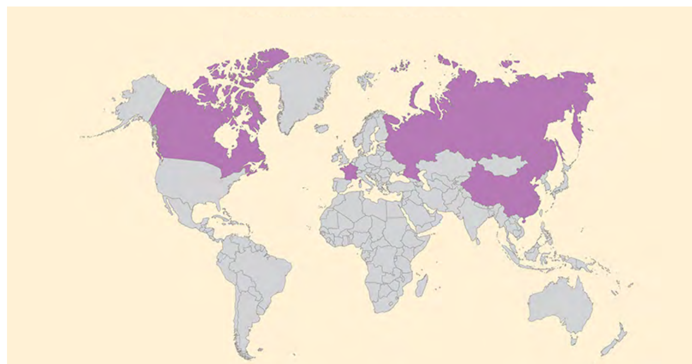
Half of the total cost is in the construction alone, including specialized features such as nuclear-grade reinforced concrete containment structures. Equipment such as reactor vessels and fuel rods and support systems are another quarter of the cost. Cost overruns are typical as these projects are very complicated, and only 40% are built in less than six years. Some plants have taken more than ten years longer to build than their original estimates, and at a cost two or three times more than projected. Given the high costs to begin with, and the lengthy project timelines, the cost of capital can have a major impact.

The Nuclear Energy Process



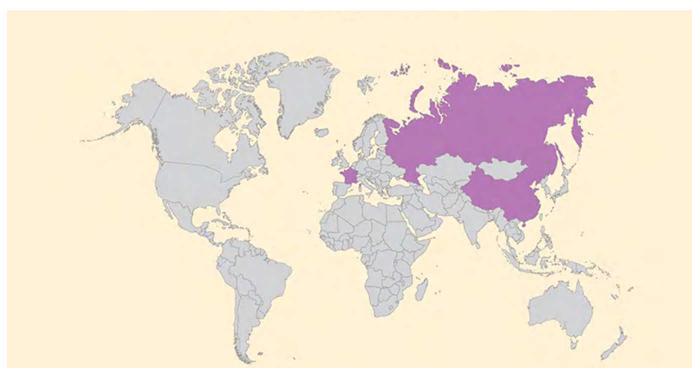
1 | Milling and Mining

Uranium ore is extracted from open pit or underground mines. The product at this point is U308, also called yellowcake. Two-thirds of natural uranium comes from Kazakhstan, Canada, and Australia. It contains 80% uranium but is not yet ready to be used in a reactor.



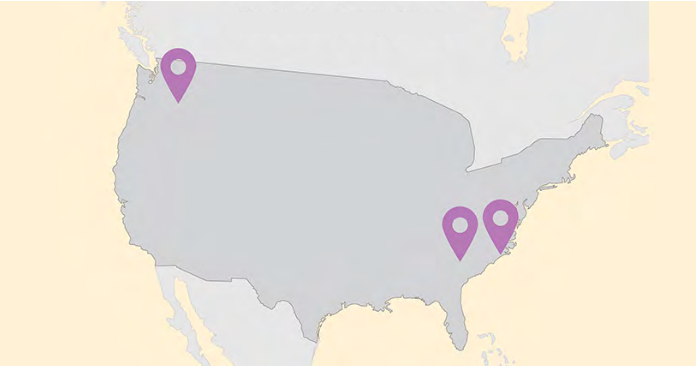
2 | Processing

Yellowcake undergoes a number of chemical processes to turn it into a gas called UF6. Four countries—France, China, Canada, and Russia—share 90% of conversion capacity.



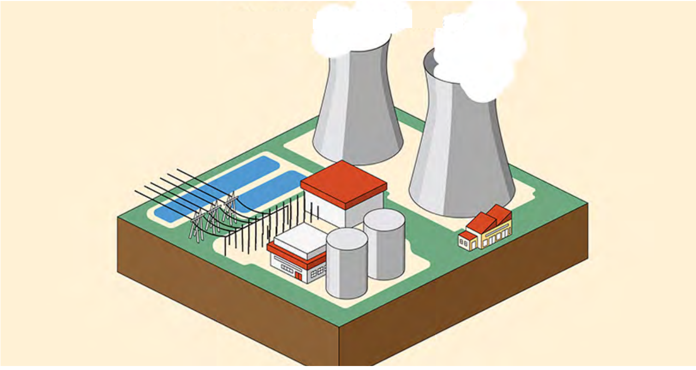
3 | Enrichment

Natural uranium contains less than 1% of U-235, the isotope comprising fissile material. Enrichment gets the number up to 2-5%. Enrichment accounts for half of the final cost of nuclear fuel. About 70% of all enrichment occurs in China, France, and Russia.



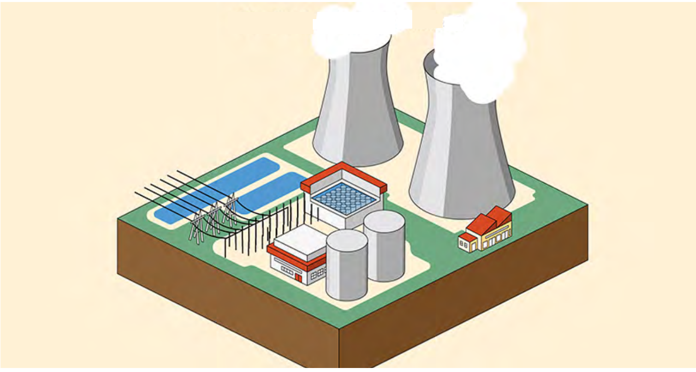
4 | Fuel fabrication

Enriched UF6 is converted into uranium dioxide (UO2) powder, which undergoes a ceramic process (heated at more than 1,400 degrees Celsius) to form pellets. The pellets are clad in a protective structure, typically zirconium alloy, to form fuel rods. This form of UO2 is the fuel used in all US nuclear reactors and the majority of global reactors. This happens locally; there are three sites in the US, for instance.



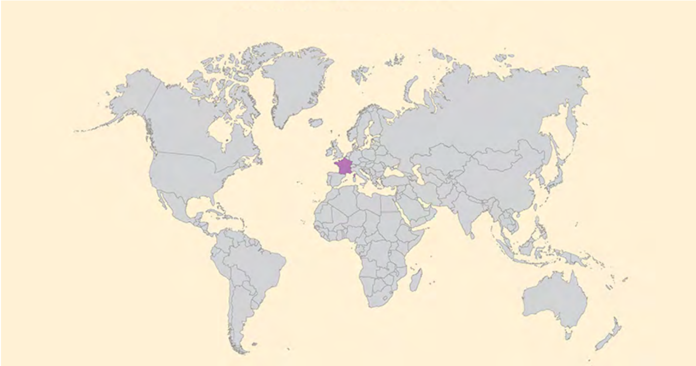
5 | Reactor (electricity generation)

A nuclear reactor loaded with fuel produces a controlled fission reaction whose resulting energy release is used to heat water and produce high pressure steam to spin a turbine and generate electricity. Plants are refueled every 12-24 months.



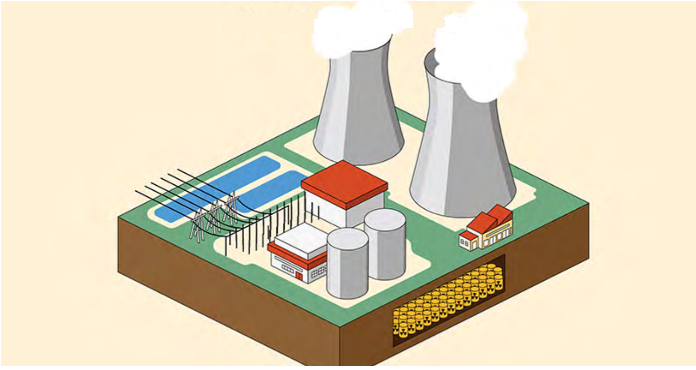
6 | Interim storage

Used fuel is moved from the reactor into adjacent storage ponds, where it cools as water is circulated. The fuel may remain under 20-40 feet of water for months or years before being transferred.



7 | Reprocessing

Used fuel still has some fissile uranium and plutonium within. Fuel rods are cut up and dissolved to recycle that material into new fuel and reduce overall waste. This part of the process has been effectively banned in the US since 1977. Most of the reprocessing that does take place occurs in France.



8 | Final disposition

Waste from all parts of the fuel cycle is either molded into glass or encased in concrete, confined in a leakproof steel cylinder, and transported to a licensed storage facility. The most radioactive waste is stored deep underground for decades as the radiation slowly dissipates.

The Vogtle nuclear plant in the state of Georgia illustrates the problems with building new reactors. Southern Company, which operated two existing reactors at its Vogtle plant, received approval in 2012 to build two new reactors, the first approvals in the US in 30 years. The project was projected to cost about US$6,000 per kilowatt—for a total of about US$14 billion—and take less than five years. But a series of issues plagued construction. The project was delayed by the implementation of a regulation related to the containment building; applying the new rules required a temporary halt of the entire project. At one point, the original contractor left the project amid delays and was replaced by Westinghouse Electric. In 2017, Westinghouse declared bankruptcy, caused primarily by the costs of its nuclear-construction projects. By 2018, the costs had ballooned to US$25 billion, which included federal government loans and guarantees of US$12 billion.

The two new Vogtle reactors ended up costing more than US$14,000 per kilowatt—for a total of about US$37 billion—took more than 10 years to build, bankrupted a company, and required billions in financing from the government. But units 3 and 4 went online in 2023 and 2024, respectively, each generating more than 1,100 megawatts. If nuclear energy is going to have a future the key is going to be to find ways to get those costs down. In this, western countries may look to Asia, where streamlined regulations, investments in specialized labor, and greater value-chain integration have contributed to lower development costs and therefore a more favorable investment landscape. China, where nuclear-energy investments rose 50% just between 2020 and 2023, has become the biggest growth market for nuclear and is expected to overtake the US and EU in terms of capacity by 2030.

The first way to reduce costs in the west is to extend the life of existing plants rather than build new ones. In September 2024, Microsoft signed a 20-year contract with Constellation Energy to reopen Three Mile Island's unit 1 reactor (the one that didn't have a partial meltdown). Unit 1, which was shut down five years ago, would generate energy dedicated to powering Microsoft's data centers. Renamed the Crane Clean Energy Center, the plant is expected to go online in 2028 and produce 835 megawatts of energy. The Pennsylvania State Building & Construction Trades Council estimates the plant will avoid more than 61 million metric tons of carbon emissions over the life of the contract.

Another possible way to lower the cost of nuclear power is by building a smaller kind of reactor called a small modular reactor, or SMR. In October 2024, Amazon signed a US$500-million contract with Dominion Energy in Virginia to explore building SMRs. That same month, Google signed a contract with Kairos Power to get electricity from SMRs that are expected to come online in 2030. While there is no standard definition of an SMR, they are generally defined as reactors that produce less than 300 megawatts. There are competing ideas for how these can be employed or built—some are smaller conventional reactors, some are scalable designs where each reactor is a module. The problem with SMRs, though, is that they are more concept than reality. Only a few have even made it to the pilot-project phase, and only two are operating commercially. China has one it uses for research. Russia has one on a floating nuclear-power plant.

Meta may have found an even cheaper option. Last month, the tech company signed a contract with Constellation to buy energy generated by the company's existing 1,100-megawatt Clinton plant in Illinois. It's a good deal for both sides; Meta's cost per megawatt may be lower than Microsoft's since it's tapping an already running plant, and Constellation needed a customer, as a ten-year subsidy it received from the state of Illinois expires in 2027, which is when the Meta contract would begin.

Once plants are built, there is another, possibly even bigger challenge: fuel supply. Nuclear plants need enriched uranium to run and virtually all of it comes from outside the US. Two thirds of natural uranium comes from Kazakhstan, Canada, and Australia. Four countries control 90% of the conversion capacity: France, China, Canada, and Russia. Additionally, the renewed interest in nuclear energy could create supply constraints. The World Nuclear Association estimated that global conversion capacity could face a 30,000 ton shortfall by 2040. And that's not even accounting for geopolitical issues. Congress in 2024 passed a ban on Russian uranium imports, though it included a waiver that would allow reactor operators until 2028 to find new supplies.

The nuclear-energy generation that is already built and running can compete with renewables and traditional forms of generation in terms of emissions—nuclear accounts for nearly half of emissions-free electricity in the US, though it produces only 4% of total electricity generation—and it's competitive on the cost of delivery. If nuclear energy is going to become a larger share of the energy picture, though, it is going to have to lower the significantly higher upfront costs. That will be the key to watch in the years ahead.

Contributors

Analyst Michael Purtill, CFA, contributed research and viewpoints to this piece.

Disclosures

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