What are small modular reactors, a new type of nuclear power plant sought to feed AI’s energy demand?

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Workers examine an experimental small modular reactor at a research institute in China.
Liu Kun/Xinhua via Getty Images)

As U.S. electricity demand rises and technology companies seek to build more and larger data centers to drive artificial intelligence systems, the main question arising is how to generate all that power.

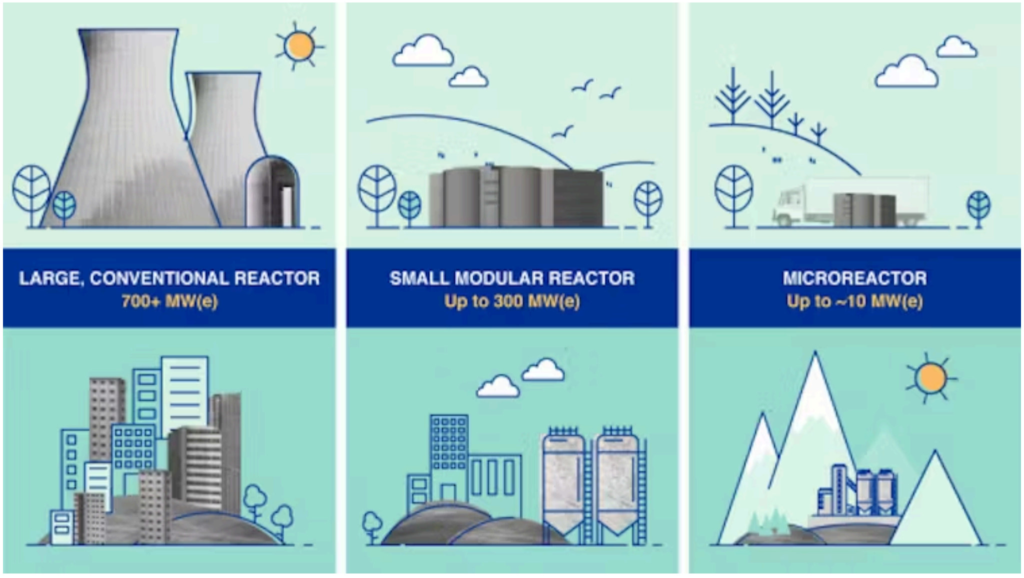
According to the International Energy Agency, large-scale data centers around the world used about 460 terawatt-hours of electricity in 2022, a figure that analysts expect to continue rising years into the future.

One potential solution being proposed is nuclear energy – produced by existing large-scale nuclear power plants, reactivated old ones, new ones that might be constructed with government subsidies, and other, smaller types of nuclear plants that are in development and not yet available.

The discussion around powering AI data centers, in particular, has involved a type of nuclear power plant called a small modular reactor. According to the International Atomic Energy Agency, there are about 70 different designs being researched and developed around the world, including reactors that could one day serve small or remote communities, military applications and even ships at sea or spacecraft.

Proponents say these reactor designs provide consistent power without climate-changing carbon emissions. They can also be located close to places that need their energy, reducing dependence on the electricity grid. They are still years from being commercially available: Demonstration projects may begin construction before 2030, with commercial ones reaching operation perhaps by the mid-2030s. And there is not yet a plan from the U.S. Department of Energy to handle the radioactive waste they would generate.

I am an engineer whose work focuses on the nuclear industry, including waste handling and decommissioning of nuclear reactors. Here's what this type of reactor is, how it works and what it can do:



Small modular reactors, at the top, are in between the other two sizes of reactor, and serve different sizes of communities, at the bottom.

A. Vargas/IAEA

The basics

There are three general sizes of nuclear reactors – only one of which, conventional nuclear plants, has been built commercially. Conventional plants are built in permanent locations on large plots of land around reactor cores as tall as 30 feet (10 meters). They usually generate more than 1,000 megawatts of power, enough to supply 700,000 to 1 million homes.

The other types are still being researched and are considerably smaller. Microreactors have cores that are small enough to fit into the trailer of a semitruck. They can be installed on land about as big as a football field and generate less than 20 megawatts.

Small modular reactors are in between. Their cores are roughly 9 feet (3 meters) across and 18 feet (6 meters) tall. The entire operation occupies an area of about 50 acres and can generate up to 300 megawatts of electricity.

Because of the reactors' size, they can be built in factories from various components and then be shipped by truck, rail or water to the location where they are assembled.

All the different types of small modular reactors generate heat the same way: by splitting heavy atoms and capturing the heat into a variety of materials – like water, liquid metal or molten salt – that circulate through water to generate steam that drives a turbine.

They are also designed with safety features to reduce the risk and severity of accidents that might release radiation or radioactive material into the surroundings. For instance, passive systems and those based on fundamental principles like gravity can terminate nuclear reactions before they reach levels where explosions or leaks might occur. These reactors also produce less heat and have far smaller amounts of nuclear material than traditional large reactors, which can reduce the radioactivity risk as well.

The green-wrapped core module of a small nuclear reactor is readied for transfer to a ship.

Liu Xuan/VCG via Getty Images

Construction and deployment

Small modular reactors are well-suited to provide electricity in remote places or regions without a large power grid – places where large nuclear power plants are impractical.

Their compact design and flexible placements make them ideal for small geographical regions or industrial installations, like desalination plants, or in countries just starting to develop nuclear power.

They can be built and put into operation within two or three years – more quickly than the decade or longer it can take to secure permits and construction of standard nuclear power plants and complete construction of a large nuclear plant.

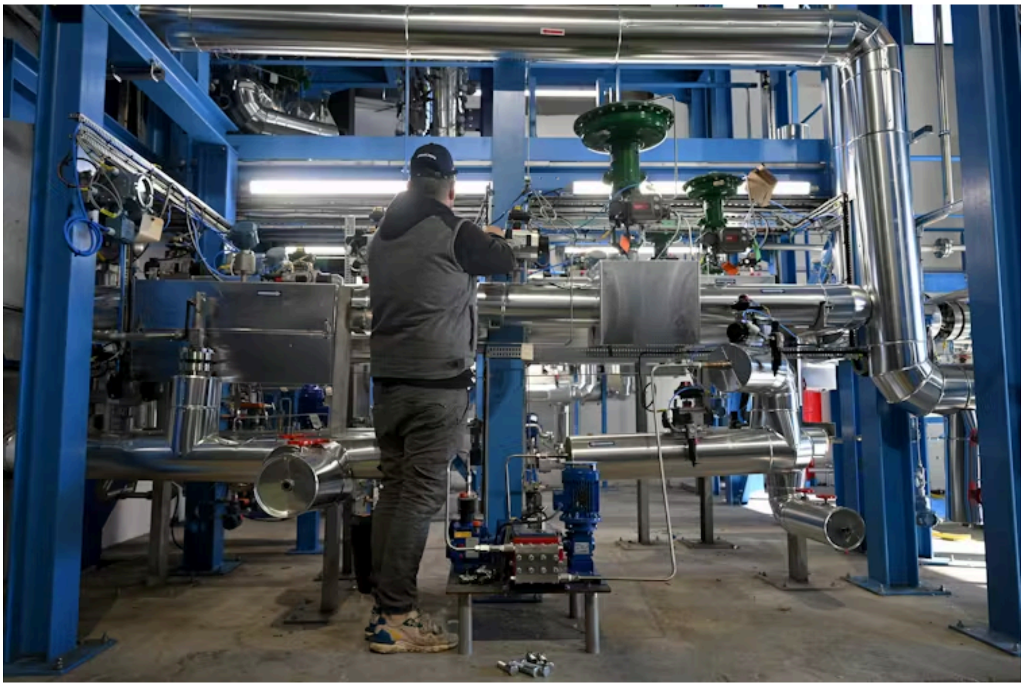
There remains a range of technical challenges before small modular reactors can actually be built and put into use. These include relatively straightforward questions like how many people are needed to operate each reactor, and more complex decisions about refinements to safety regulations, both in the U.S. and internationally. It's also not yet clear what the best way is to manage the transport of radioactive materials, especially for reactors that use coolants other than water, which could produce new forms of radioactive waste.

Understanding the fuel

Larger nuclear power plants use fuel that is about 5% uranium-235, the element that splits in a nuclear reaction, releasing heat. But many small modular reactor designs use a different fuel, with between 5% and 20% uranium-235.

This different fuel, called "high-assay low-enriched uranium," lets the reactors generate more electricity from a smaller volume of fuel material. And though it contains significantly more uranium than standard nuclear fuel, it remains far below the concentration of 90% uranium-235 that is used in nuclear weapons.

The more concentrated fuel also allows reactors to run longer between refueling and reduces the amount of radioactive waste that remains after the fuel is spent.



An engineer at a French research center works on equipment as part of efforts to develop a small modular reactor.

Nicolas Tucat/AFP via Getty Images

US efforts

The U.S. Department of Energy is working to develop domestic manufacturing of this type of uranium for small modular reactors, to avoid being dependent on foreign sources.

Under a government contract, a Maryland-headquartered nuclear fuel company called Centrus Energy has produced nearly 1 ton (920 kilograms) of that fuel since 2023 under a contract estimated to cost taxpayers US$120 million. In mid-2025, Centrus received a $110 million contract extension to produce that amount again by the middle of 2026.

The Department of Energy is distributing the fuel Centrus has made to five companies for demonstrations and development projects.

Managing waste

All nuclear plants require safe handling of the fuel and the resulting waste. There is no permanent place to store nuclear waste in the U.S. Most nuclear waste is stored on the land around the reactors where it was generated.

The Department of Energy says it is trying to find a place to temporarily store waste from small modular reactors, but that process has been tied up in the courts for years and may not be resolved anytime soon.

Other industrial uses

In addition to delivering electricity, small modular reactors can also directly generate large amounts of heat.

That can be useful for desalination plants, which use both electricity and heat to convert seawater into fresh water for drinking and irrigation. Remote mining operations also often need both heat and power to operate equipment, ensure living quarters are habitable and process minerals.

Small modular reactors may also be useful on university campuses. A microreactor planned for the University of Illinois will provide power and steam to campus buildings, while also teaching students how to operate nuclear plants, and offer research and demonstration opportunities for more reactor improvements in the future.

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