How the next generation of nuclear reactors could be smaller, greener and safer

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A new type of nuclear power technology — small modular reactors that promise to produce carbon-neutral energy more safely and efficiently than traditional nuclear power plants — is becoming closer to a reality as a handful of companies push to overcome key regulatory hurdles.

The U.S. government has not yet approved the reactors, which require significantly less space than a typical nuclear plant and produce nuclear energy on a comparatively smaller scale, for construction, but it is signaling a willingness to do so in the future.

In December, the Nuclear Regulatory Commission, the independent government agency tasked with ensuring the safety of nuclear power plants, granted the Tennessee Valley Authority the **first-ever early site permit** for a small modular reactor project. The Tennessee utility currently has no plans to build and operate SMRs, but the permit gives it the option if it chooses to pursue that technology later on.

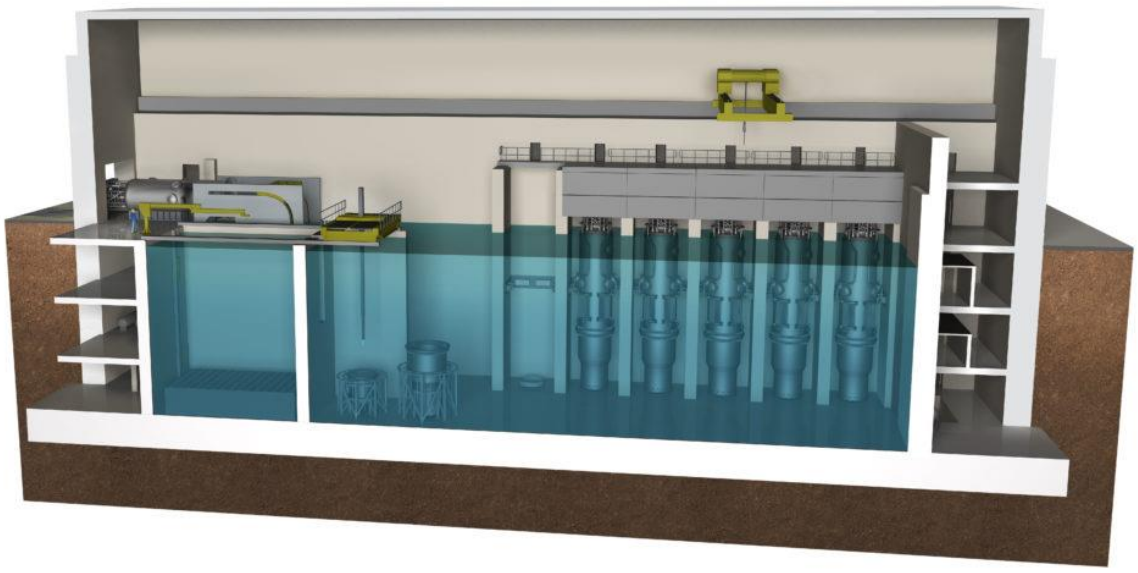
If it did, the NRC's decision would mark the first step in a long approval process, but industry watchers still see the move as an important indicator of where the technology is headed.

Last week, the Department of Energy invited companies that specialize in advanced nuclear technology to pitch their designs as part of **a government effort** to keep the U.S. competitive globally when it comes to nuclear technology. SMRs have been hailed as one way the U.S. could combat climate change. The new technology could help boost the nation's production of nuclear power, which emits no carbon dioxide.

Still, it will likely be several years before any one of the current SMR designs is in operation as businesses, federal agencies and local communities try to navigate the best path forward for the new technology.

What is a small modular reactor?

As the name suggests, small modular reactors produce smaller amounts of energy than typical nuclear reactors. To be considered an SMR, the reactor cannot generate more than **300 megawatts per module**, compared to current nuclear reactors which can produce anywhere from 500 megawatts to more than 1,000 megawatts. One SMR design from the Portland, Oregon-based company NuScale would produce 60 megawatts, enough energy to power 45,000 homes.



Left, a cross section visualization of NuScale's reactor building.

But several SMR units could be combined into a network and built to scale based on the needs of the communities they serve. Their power output could also be adjusted after they are operational based on consumer demand or the availability of electricity produced by other sources at a given time of day or year.

“Small modular reactors can be designed to ramp up and down with the demand in a very flexible way, in a more cost effective manner, in order to fit more neatly with this emerging new electricity system that will include renewables as well as other sources of supply,” said William Magwood IV, director-general of the Nuclear Energy Agency, an intergovernmental agency that promotes global cooperation on nuclear technology.

SMR companies say their reactors would also require far less land than existing nuclear plants. NuScale has designed **a 720 megawatt project that would be comprised of 12 reactors** — enough to power 540,000 homes — and **sit on 35 acres**. At that size, it would be 17 times smaller than a traditional nuclear plant producing the same amount of electricity, according to the company.
SMRs can also be built in a factory and shipped to the location where they’ll eventually operate, cutting down construction costs. Magwood compared that process to manufacturing a commercial airliner, whereas constructing a traditional large nuclear power plant is more analogous to building an entire city block.

How are SMRs designed to improve safety?

Major nuclear accidents **are fairly uncommon** and account for **far fewer deaths** than accidents in other energy sectors. But the ones that have occurred — Chernobyl, Three Mile Island and Fukushima — have led to widespread concern about the safety of nuclear energy production. The 1979 Three Mile Island accident remains **the most serious nuclear accident in U.S. history**, where “a small amount of radioactive material” was released but no injuries occurred.
The companies that are developing small modular reactors hope to address those concerns by building new safety features into their designs.

NuScale uses **light-water technology**, where water is used to keep their cores from overheating, similar to what is used in today’s nuclear power plants. But there are key differences.

Existing reactors use pumps to maintain a constant flow of water to cool their cores and are equipped with backup diesel generators to keep that process going in the event of a power outage. When these complex systems fail, as they did in the Fukushima Daiichi nuclear power plant in Japan in 2011, the core can overheat and risk catastrophic failure. **NuScale's SMR** relies on natural forces of heating and cooling that combine with gravity to circulate water through its system, eliminating the need for pumps.
Marc Nichol, the senior director of new reactors at the Nuclear Energy Institute, an industry lobbying group that promotes nuclear power, said that "greatly reduces" the potential for an accident.

"As you simplify and make these machines smaller, you actually increase the safety of these such that you can design out potential accidents and eliminate backup equipment that would have been required," Nichol said.

TerraPower, a nuclear innovation company founded by Bill Gates and headquartered in Bellevue, Washington, has designed two models that use **liquid sodium** and **molten salt** rather than water as a coolant. The boiling point of liquid sodium is higher than the temperature produced by the nuclear reaction itself, so the company says the reactor will not overheat.
TerraPower's molten salt reactor, meanwhile, mixes that heated, liquid salt with its fuel. This action creates a loop that circulates through the system naturally as it heats and cools, eliminating the need for an outside force to keep the process going.

Proponents of SMRs herald the improvements built into this next generation of nuclear technology, but these facilities have not yet been built and tested.

Edwin Lyman, director of nuclear power safety at the nonprofit Union of Concerned Scientists, said he's concerned that the companies that design SMRs are "putting too much stock" in what they claim to be inherent safety features.

It is easier to prevent the cores of SMRs from overheating and potentially melting down given their smaller size and power output, Lyman said, but he argued that backup safety measures are still important.

Reactors are complex systems, and Lyman said computer-simulated accident scenarios may miss potential shortcomings of proposed designs. Unexpected consequences can arise, he argued, once a facility is actually up and running.

Lyman argues that the new reactors will need multiple layers of safety features, “so that if you’ve guessed wrong or your analysis has uncertainties and you’ve missed something, there’s a backup.”

How close are SMRs to becoming a reality?

The Nuclear Regulatory Commission is **currently in the process of reviewing** NuScale’s SMR design. If the process goes smoothly, NuScale could be approved as early as September, making it the first to be given the green light to license out its design for construction.
TerraPower initially had an agreement to construct both a demonstration plant and, later, a set of commercial liquid sodium reactors in China. But those plans were derailed as a result of the Trump administration’s trade dispute with that country, which prohibited the export of advanced nuclear technology. Now, the company is looking to move forward in the U.S. instead.

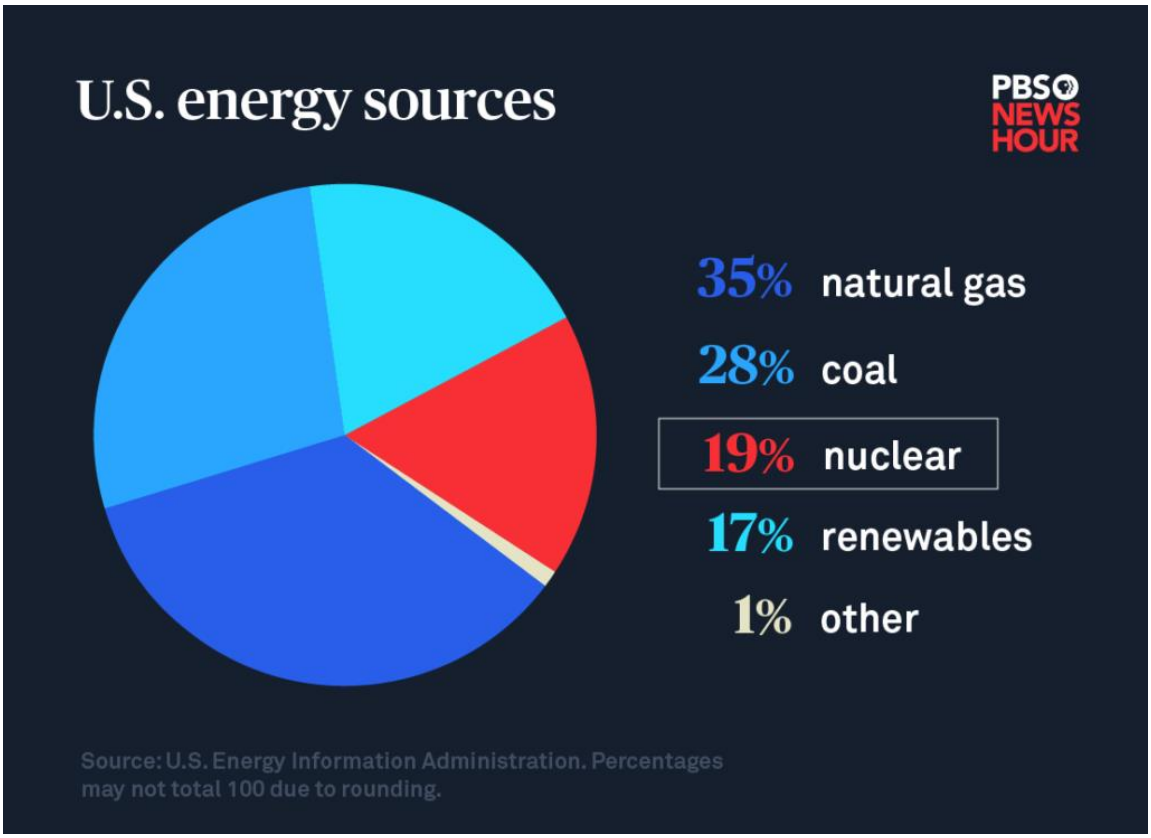
NuScale and TerraPower appear to be two industry leaders in the U.S., but several other companies are also in the process of designing SMRs and because the regulatory process takes years, it’s unclear which company, if any, will end up being the first to build and operate an SMR plant in the U.S.

As seen with **a Nevada solar plant**, fast-developing technology also provides companies the opportunity to leap-frog one another and make competitors’ projects that have been in the works for years obsolete.

Could nuclear energy help mitigate the effects of climate change?

In addition to renewable energy sources, the United Nations Intergovernmental Panel on Climate Change has said **nuclear energy** could play an important role in mitigating the effects of climate change.
But before the technology can expand, the panel pointed out that concerns regarding nuclear power, such as safety, economic efficiency and waste management, should be addressed.

Since 1990, nuclear power has accounted for **nearly 20 percent** of the United States' total electricity production. The federal government intends to continue relying on existing reactors as long as it can, and many facilities have been **permitted to extend their licenses** for several decades.



Graphic by Megan McGrew/PBS NewsHour

At a 2019 International Energy Agency conference, U.S. Deputy Secretary of Energy Dan Brouillette said **both existing nuclear reactors and new technologies** were "crucial for reducing carbon emissions and boosting energy security."

Uranium, the element needed to power nuclear reactors, is fairly inexpensive and can be both **mined from the Earth** and **extracted from seawater**. According to the International Atomic Energy Agency, the world's uranium supply is "**more than adequate**" to meet projected global nuclear energy needs for the foreseeable future.

But nuclear reactors also produce radioactive waste that can be difficult to dispose of. The waste is generally stored on site at nuclear facilities, even though the scientific community considers **deep geologic repositories** to be the best option for long-term disposal.

Since 1987, the U.S. has considered **storing its nuclear waste** inside of a $96 billion repository within Yucca Mountain in Nevada. The Yucca Mountain facility, the government argues, would solve the challenge of storing waste that can be dangerous for tens of thousands of years — radioactive materials that are now stored in facilities that some critics warn are insecure. The Yucca plan has become highly **controversial** and has stalled multiple times due to Nevada residents concerned about the safety of waste storage in their state, but the Trump administration appears to be working to restart the effort.
Some SMR companies are hoping to alleviate some of the concern about nuclear waste.

Terrapower says its liquid sodium reactor can be fueled by **depleted uranium**, a byproduct of the uranium enrichment process that is used to create fuel for both nuclear reactors and weapons. Navin explained that the reactor also utilizes more of its fuel than traditional light water reactors, which would produce "about 80 percent less waste."
John Parsons, co-director of the MIT Energy Initiative's Center for Advanced Nuclear Energy Systems, said regional needs and capabilities will dictate where nuclear will fit into the broader picture of energy production — including access to renewable energy sources, which varies across the country — as well as how successful companies are in driving down cost.

"[Nuclear energy is] clearly low carbon. It is relatively safe. But it's true that the public is anxious about safety issues and about waste," Parsons said. "So we probably need to have a good conversation about that in order to move forward as successfully as we can."

It is also up to the industry to prove that SMRs and other advanced nuclear technologies are as reliable in practice as they are in theory.

"[Manufacturers] actually have to go build these things and show they can build them cost effectively, on schedule and operate them safely," Magwood said. "Until they've done that, it's not real."

Clarification: This story has been updated to indicate that the Nuclear Regulatory Commission could approve NuScale's application as early as September.

Related

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