ADVANCED NUCLEAR TECHNOLOGY BUILDS ON DECADES OF EXPERIENCE

MATT WALD
NUCLEAR ENERGY INSTITUTE, WASHINGTON, DC

Advanced reactors will break the mold of how we think about nuclear energy. Some will be smaller, some will use new kinds of fuel, in different forms, and some will make more than just electricity. This new technology may seem like uncharted waters, with different coolants, different moderators or no moderator at all, but when operators, technicians and other workers start up the first reactors of the next generation, they will bring with them thousands of years of nuclear operating experience, to run machines that have been optimized with lessons from the current fleet.

While advanced reactors are often portrayed as the future of nuclear energy, it's our current plants that have paved the way for these exciting innovations.

Advanced reactors will be standing on the shoulders of giants.

Reactor veterans are bringing their expertise to the new designs.

Many of the workers who will operate the next generation of reactors come from a nuclear background. Even though the design of an advanced reactor may be drastically different, the experience and instincts these operators have gained from working at the current fleet will help new plants run smoothly from the start. Staff at new reactors will arrive with nuclear attitudes.

"They have a questioning attitude; they are always exploring what could go wrong, and always understanding the notion of risk management in nuclear operations, whether it's the oldest design or the newest design," said Chip Pardee, the president of Terrestrial Energy, who is the former chief operating officer at two nuclear utilities, Exelon and the Tennessee Valley Authority. "They have a clear recognition that things have to be done right the first time," "They have respect for the technology and a bias towards conservative decision-making."

Jhansi Kandasamy, vice president of engineering at GE Hitachi Nuclear Energy, agrees. She said that the presence of industry veterans will benefit the new models—like the 300 megawatt boiling water reactor her company is developing.

From the beginning, a new reactor will have "people who have touched it, worked on it, and experienced it," she said.

"They're going to be able to tell you if something doesn't look right, because they've lived through it."

Kandasamy, who worked on the start-up of the Limerick reactors in the early 1980s, said that because of the industry's experience base, it was now drawing from the operators of older reactors, not fossil fuel plants. "With the advanced reactors, you're expediting the process" of achieving smooth operations, she said.

They also begin with an orientation towards constant training and drilling, which is different from the early days of reactors operating now.

Designers are also bringing their experience. Advanced reactors are designed by engineers who are fully familiar with existing plants and can use that experience to optimize the new ones, like a family building a house and wanting the kitchen just so. New reactors will be simpler to operate because of insights gained from years of operations of the current fleet.

NuScale Power, for example, has a very different design from the current fleet: up to twelve small reactors—instead of one or two large reactors—managed from a single digital control room—instead of one full of analog switches and dials. When the company designed its control room, it brought in industry veterans who had collectively worked at more than two dozen nuclear plants.

"We baked their experience into the human/machine interface," said Tim Tovar, manager of plant operations. "We wanted to build it so that it worked well for operators."

The experts that NuScale brought in critiqued everything, even down to the shape of the symbols on the computer screens, to make them easier to read for operators, who sometimes need to quickly interpret lots of incoming data. The control panels for NuScale Power's small modular reactors organize and present information according to its importance and automatically call up appropriate procedures for operators.

Many advanced reactors are also smaller than those currently operating, which makes their components simpler and less expensive. Kandasamy pointed out that the giant mechanical pumps in today's reactors generate a lot of heat and require a lot of supporting systems, including air conditioning in the rooms that house them.

In GE Hitachi's small modular reactor design, there are fewer pumps, because the system relies on natural circulation, and the pumps that remain are smaller and use magnets, so they don't require external cooling. They also take up less space, which allows for a smaller building to house them, and thus reduces cost.

Terrestrial's design includes core internals that would be difficult to inspect for the effects of temperature, corrosion and neutron fluence. So, Pardee said, the designers, having experienced the difficulties of inspecting some parts in current-generation plants, found a solution: build the plant so that ever few years, the parts can simply be swapped out.

In this time of climate crisis, advanced reactors with further the work of the current fleet.

Advanced reactors promise improved flexibility and the ability to do more kinds of work, to displace carbon-based fuels in industry as well as in electricity generation, and thus will help stabilize the climate. And they will continue nuclear energy's legacy of providing their carbon-free electricity reliably.

As new designs come on line over the next decade, we will continue to rely on operating plants which provide nearly 55 percent of the carbon-free electricity in the United States, and substantial amounts around the world. And the new reactors will share part of the supply chain of the old, to the benefit of both.

As the world scrambles to slow down climate change by adding carbon-free generation, the importance of the existing fleet becomes more obvious. As John Wagner, the director of the Energy Department's Idaho National Laboratory, said recently, "If we lose our existing fleet, it's going to make it much more difficult to achieve the advanced fleet we're after." The world will need all the carbon-free generation it can get for many years to come, as companies, states and countries aim for zero emissions by mid-century. That means it will need wind, solar, advanced reactors and current plants.

There are many advanced reactor designs, in various stages of development. Here are four that are closest to deployment:

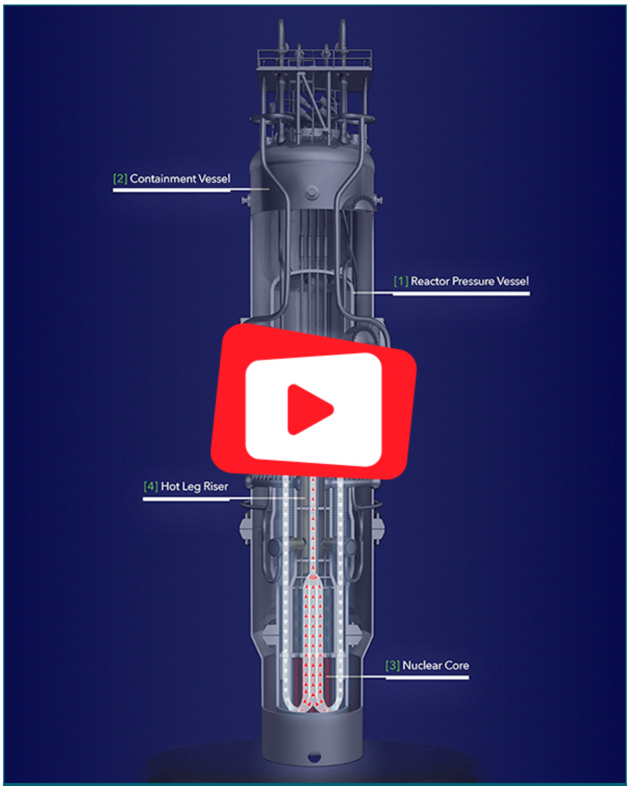
NUSCALE POWER

The staff of the U.S. Nuclear Regulatory Commission, which licenses reactors, approved a Final Safety Evaluation Report for the NuScale Power small modular reactor, in August, 2020. That meant that the staff was independently verifying the company's own safety analysis, which showed that the reactor design met all applicable safety standards.

"Applicable" is a key word here, because the design omits many features of today's light-water reactors. The NuScale design does not need any additional water supplies for safety; it relies instead on natural forces for cooling. So a whole complex of tanks, pumps, valves and piping doesn't need to be built, inspected, tested and evaluated.

The design also does not require emergency electricity supplies for safety, so there are no safety-grade diesel generators.

The NuScale design is a cluster of small modular reactors. The company is working with the Utah Associated Municipal Power Systems to deploy the first plant at a site owned by the U.S. Government in Idaho.



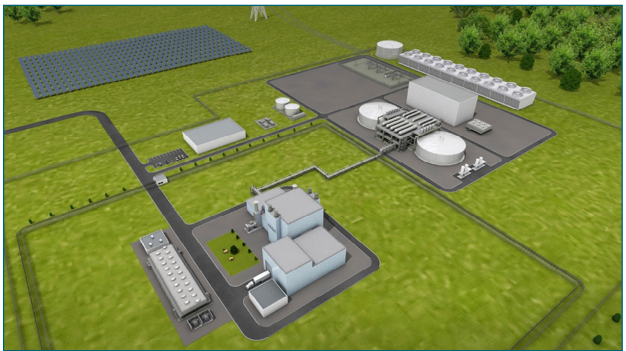
Video Copyright © NuScale Power, LLC.
https://youtu.be/vU-IlqiP4sU

NATRIUM

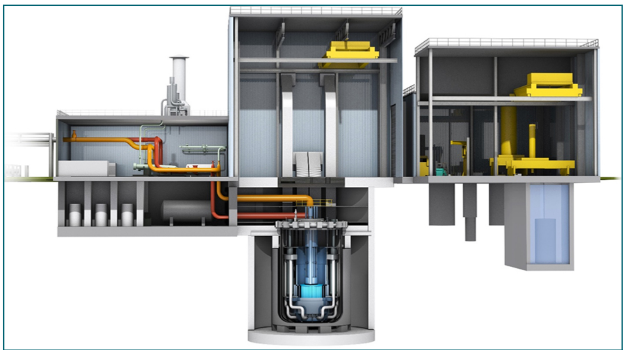
The reactor is a high-temperature model with roots in GE-Hitachi's PRISM design, a sodium-cooled fast reactor, and TerraPower's Traveling Wave Reactor. It runs uninterrupted 24/7 at full power, 345 Megawatts-electric, regardless of demand, and delivers its heat to a giant tank filled with molten salt. Operators can use the stored heat to make steam and then electricity as the customer desires.

Because of the Natrium technology's integrated energy storage system, electricity output can vary from 100 megawatts to 500 megawatts without the reactor needing to change power. This system would allow zero-carbon energy from solar farms to power the grid during the day, while the reactor stores energy in the tank. In the late afternoon, when demand reaches a peak and solar generation declines, heat from the tank can be tapped faster than the reactor is adding it. Likewise, Natrium could create space on the grid for electricity made by strong night-time winds, by storing the reactor's output, but could still assure adequate electricity in the morning.

Moving the steam generators, turbine and electric generator away from the reactor allows those systems to be made from standard, commercial off-the-shelf components, which are less expensive than nuclear-grade equipment. And Natrium won't be affected by disturbances on the grid or in the generator, which today can make a reactor go offline.



Natrium Site Layout. © Natrium.



Natrium Cutaway of Reactor Building, Reactor Auxiliary Building, and Fuel Building. © Natrium.

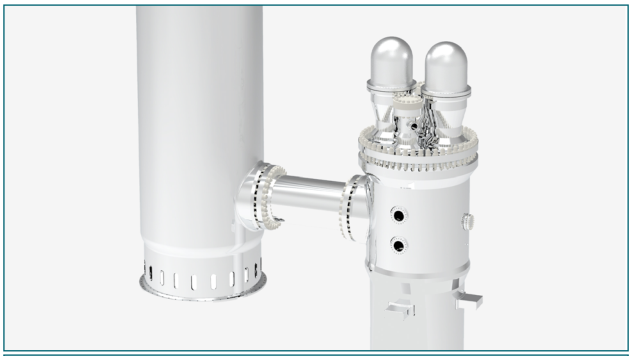
Webinar: "TerraPower and GE Hitachi Nuclear Energy (GEH) recently announced the launch of a new reactor and energy system architecture called Natrium™. On Monday, September 21, ClearPath Executive Director Rich Powell moderated a panel with experts from TerraPower, Duke Energy and Centrus". https://www.youtube.com/watch?v=Fb7L1PUuh-8&t

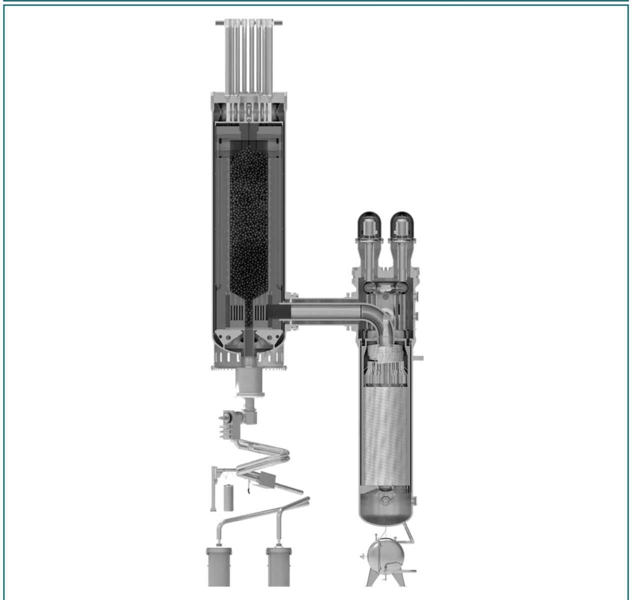
X-ENERGY

The Xe-100 is a high-temperature, gas-cooled reactor that produces 80 megawatts of electricity. The fuel is approximately 220,000 fuel pebbles, small kernels of uranium coated in concentric layers of heat-resistant materials, including graphite, and wrapped together in polished spheres. The fuel is called tristructural isotropic particle fuel, or TRISO, which has applications in a variety of designs. The pebbles are inserted at the top of the reactor and can be withdrawn from the bottom, while the reactor is running, with no need for refueling shut-downs.

The Xe-100 uses helium as a coolant, and thus can operate at higher temperatures and lower pressures than a light-water reactor. It can heat the helium to 750 degrees C, compared to about 300 degrees C for a water-based reactor.

Late last year, the U.S. Department of Energy's Advanced Reactor Demonstration Program recently chose the design for financial support, under a program intended to allow deployment within five to seven years.





© X-Energy.

OKLO

Today's nuclear reactors are pillars of our grid, but not everybody lives on the grid, and in remote places, most electricity comes from burning diesel fuel, which is dirty and expensive.

If the place is remote enough, diesel fuel can be hard to deliver. And even electricity customers who are on the grid need an alternate supply in case the grid goes down.

Oklo Power is among the companies working on micro-reactors that can run longer without refueling.

In June, 2020, Oklo became the first advanced fission company in U.S. history to have its combined license application accepted for review by the U.S. Nuclear Regulatory Commission.

Oklo said that its Aurora powerhouse would provide 1.5 megawatts of electricity. That's a little more than 1 percent of the capacity of a reactor on the power grid today. But the Aurora could also provide heat for other purposes, which U.S. grid-scale reactors typically do not do, but would be very useful in the off-grid arctic.

Because of its inherently safe design, the Aurora does not require operator actions, or on-site operators. Its safety relies on natural forces. The reactor module would be installed underground, with an A-frame building on top that would have space for community use.

The A-frame is not entirely for show; it sheds snow and supports exterior solar panels, and supports a crane that can be used to move fuel and equipment. But the building is intended to make an attractive addition to a rural settlement, serving as the main point for community interaction.

The fuel is low-enriched uranium but above the 5 percent currently used in U.S. reactors, so it can operate for 20 years

© Oklo.

without having to be refueled. The fuel is metallic like the fuel demonstrated for 30 years at EBR-II, which also demonstrated inherent safety characteristics. The material that transfers heat from the reactor to the part of the plant that makes electricity is different, too: it's carbon dioxide, and the system is generally smaller than other power conversion systems.

Oklo says that with a design that is so small and able to operate without water, that there is a very small environmental impact for both the construction and operation. It can be built in a much wider variety of places.■