BACKGROUNDER
Office of Public Affairs
301.415.8200
www.nrc.gov ■ opa.resource@nrc.gov

New Nuclear Plant Designs

Background

The NRC and more than a dozen new reactor vendors have been discussing several designs for the past few years. These discussions cover both small modular reactors similar to today's light-water cooled designs, and "advanced" reactors cooled by substances other than water. The NRC encourages standardized nuclear power plant designs to help enhance safety and improve the licensing process. The Commission expects new reactors' safety systems to be simpler and use natural effects (such as gravity) or other innovative approaches. The agency's new reactor regulations (Part 52 in Title 10 of the Code of Federal Regulations) provide a predictable review to approve, or certify, new nuclear plant designs. The NRC based the certification process on decades of experience and research into reactor design and operation.

Pre-Application Review

The NRC's July 1986 "Statement of Policy for Regulation of Advanced Nuclear Power Plants" encourages reactor designers to discuss licensing issues with the agency before submitting a full license application. In March 2024, the NRC issued technology-inclusive, risk-informed and performance-based guidance for advanced reactor applications through the Advanced Reactor Content of Application Project. Pre-application interactions with reactor designers are expected to identify and address topics such as:

- unique design features or systems, structures, or components;
- new methods demonstrating the acceptability of safety features;
- potential Commission-level policy decisions; and

  potential research to resolve identified issues.

Design Certification Review

Applicants must provide enough information to show their design meets the NRC's safety standards. Applicants must also show their design resolves any existing generic safety issues, as well as issues that arose after the Three Mile Island accident. Applications must closely analyze the design's appropriate response to accidents or natural events, including lessons learned from the Fukushima accident. Applications must also lay out the inspections, tests, analyses and acceptance criteria that will verify the construction of key design features. The NRC also requires design certification applicants to assess how the designs protect the reactor and spent fuel pool from the effects of a large commercial aircraft impact. Certification reviews identify key information to consider in site-specific reviews for operating licenses. The NRC certifies acceptable reactor designs by adding them to agency regulations through a rulemaking. This rulemaking certifies a design for 15 years, and a reactor vendor can seek renewal of a certified design.

Regulatory Structure for Advanced Reactor Licensing

In 2007, the NRC prepared for vendors submitting designs with advanced technologies by developing technology-neutral guidelines for plant licensing. These guidelines encourage future designs to incorporate additional safety and security where possible. The NRC issued a "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing" (NUREG-1860) in December 2007.

The NRC developed the "Report to Congress: Advanced Reactor Licensing," in August 2012 (ML12153A014) to address a provision in the Consolidated Appropriations Act, 2012. This report discusses enhanced regulatory predictability and stability for advanced reactors.

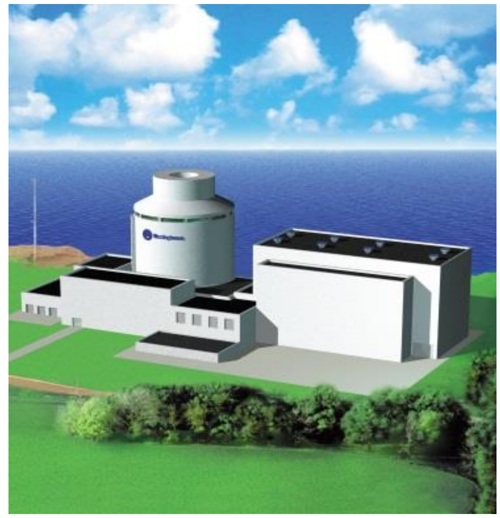
In 2013, the DOE Office of Nuclear Energy and the NRC began working on how to apply "General Design Criteria for Nuclear Power Plants," Appendix A to 10 CFR Part 50, to advanced non-light water reactor designs. The NRC and DOE have held Advanced Non-Light Water Reactors Workshops on issues related to developing and deploying advanced designs. In 2016, the NRC issued a "Vision and Strategy" on preparing for non-light water reactor designs.

Certified Designs

The NRC has certified seven designs; two of those approvals have expired. Utilities can reference the other three designs when applying for a combined license to build and operate a nuclear power plant. The certified designs are:

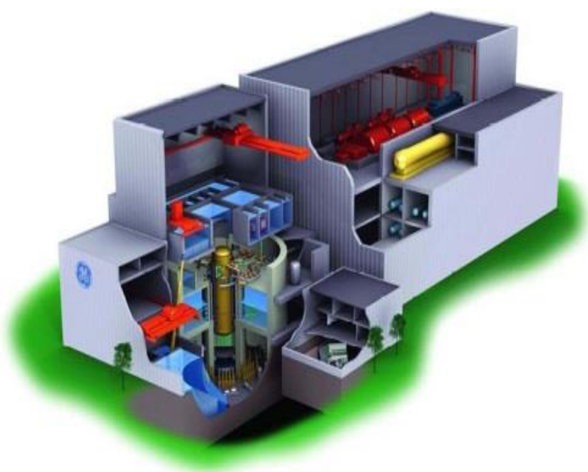
- **Advanced Boiling Water Reactor** design by GE Nuclear Energy (May 1997, amended to assess aircraft impacts in 2011, renewed in 2021) The ABWR, a 1,300 megawatts electric (MWe) design, improves on the electronics, computer, turbine and fuel technology of existing BWRs. The design includes protection against over pressurizing the containment, passive methods to cool accident debris, an independent water resupply system, three emergency diesels and a combustion turbine as an alternate emergency power source.
- **System 80+** design by Westinghouse (formerly ABB-Combustion Engineering) (May 1997, expired June 2012) This 1,300 MWe design's safety systems provide emergency core cooling, feedwater and decay heat removal. The design also has a reactor depressurization system, a gas-turbine generator as an alternate AC power source beyond the required emergency diesel generators, and an in-containment refueling water storage tank to enhance the reactor's safety and reliability.
- **AP600** design by Westinghouse (December 1999, Expired January 2015) The Advanced Passive 600 is a 600 MWe pressurized water reactor with passive safety systems and simplified system designs. The passive systems respond to emergencies by relying on gravity and other natural forces rather than electric-powered pumps and other support systems. The system uses redundant, non-safety-related equipment and systems where possible to reduce use of safety-related systems.

- **AP1000 (Amended)** by Westinghouse (January 2007 and amended January 2012) The 1,100 MWe amended AP 1000 is a larger version of the AP600 with passive safety systems and simplified system designs. It is similar to the AP600 design but generates more power by accommodating more fuel in a longer reactor vessel and using larger steam generators and a larger pressurizer. Two AP1000s are operating at the Vogtle site in Georgia.



WESTINGHOUSE AP1000

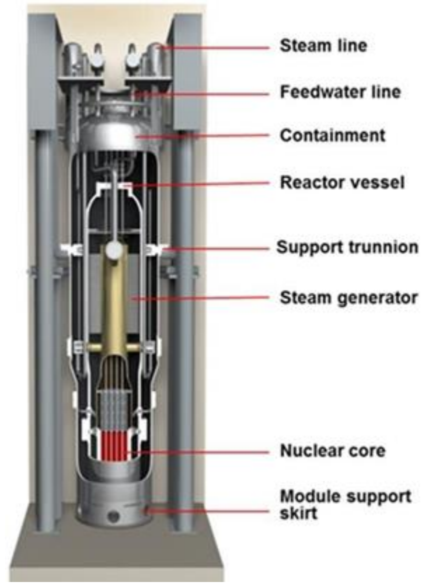
- **Economic Simplified Boiling Water Reactor (ESBWR)** design by GE-Hitachi (October 2014) The 1,500 MWe Economic and Simplified Boiling Water Reactor includes some ABWR features. The ESBWR enhances natural heat transport by using a taller vessel, a shorter core, and by enhancing water flow. The design's isolation condenser system controls high-pressure water levels and removes decay heat when active systems are unavailable. After the automatic depressurization system operates, a gravity-driven cooling system controls low-pressure water levels. Another passive system cools the reactor containment.



GE HITACHI ESBWR

- **APR 1400** – by Korea Electric Power Corporation and Hydro & Nuclear Power (September 2019) The APR 1400 is an approximately 1,300 MWe pressurized water reactor based on the Korean Standard Nuclear Power Plant. Its updated safety features include additional systems to add cooling water in an emergency, systems to prevent hydrogen buildup during an accident and a floodable space below the reactor to catch and cool any material that escapes the reactor.

- **NuScale US600 SMR – by Nuscale Power** (July 2022) NuScale US600 is an integral pressurized-water reactor, based on the Multi-Application Small Light Water Reactor developed at Oregon State University in the early 2000s. The design places the reactor core and helical coil steam generators in a common reactor vessel in a cylindrical steel containment. The reactor vessel containment module is submerged in water in the reactor building's below-grade, safety-related pool, which is also the reactor's ultimate heat sink. The reactor building is designed to hold 12 modules, each with electrical output of 50 MWe, yielding a total capacity of 600 MWe for this NuScale plant.



Active Reviews

Natrium – In March 2024, TerraPower submitted an application for a permit to build its Natrium design as the Kemmerer Power Station in Kemmerer, Wyoming. The Natrium design is a 345 MWe pool-type sodium fast reactor using high-assay, low-enriched uranium metal fuel. The reactor would use a molten salt-based integrated energy storage system in order to boost power output to 500 MWe for several hours to serve peak demand.

NuScale US460 – NuScale Power submitted its revised small modular design for approval in January 2023. The staff expects the certification review to continue into 2025. NuScale is an integral pressurized-water reactor based on the NuScale US600, but with fewer, higher-output modules. The reactor building is designed to hold six modules, each with electrical output of 77 MWe, yielding a total capacity of 460 MWe.

Pre-Application Reviews

AP300 – In May 2023, Westinghouse began pre-application interactions with the NRC on the AP300 small modular reactor design. The AP300 is a 300 MWe advanced pressurized water reactor that incorporates passive safety systems and simplified system designs. The design is based on the AP1000's passive systems. which respond to emergencies by relying on gravity and other natural forces rather than electric-powered pumps and other support systems.

ARC-100 – In October 2022, ARC Clean Technology began pre-application interactions with the NRC on the ARC-100 sodium-cooled fast reactor. The ARC-100 is a sodium-cooled fast reactor, based on the Department of Energy's Experimental Breeder Reactor-II project, with an output of 100MWe.

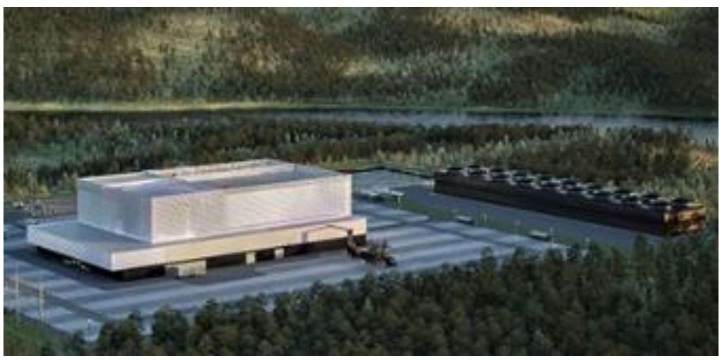
SMR-300 – In July 2022, Holtec began pre-application interactions with the NRC on its small modular design. The current iteration of the Holtec design is the SMR-300, a 300 MWe, passively safe, pressurized-water reactor.

Aurora Powerhouse – In April 2022, Oklo began pre-application interactions with the NRC on the Aurora Powerhouse, a liquid-metal cooled fast reactor with an output of 15 MWe. (note: this is separate from an earlier Oklo license application the NRC denied in January 2022)

Fast Modular Reactor – In March 2022, as part of the Department of Energy's Advanced Reactor Demonstration Program, General Atomics began pre-application interactions with the NRC on the FMR design. The Fast Modular Reactor is a helium-cooled design with uranium dioxide fuel, with an output of 50 MWe.

Energy Multiplier Module – In July 2021, General Atomics began pre-application interactions with the NRC on the EM^2 advanced reactor design. EM^2 is an advanced small modular design; its helium-cooled fast reactor has a net unit output of 265 MWe. The reactor employs a below-grade sealed containment and uses passive safety methods for heat removal and reactivity control to protect the integrity of the fuel, reactor vessel and containment. EM^2 also employs a direct closed-cycle gas turbine power conversion unit for added efficiency.

Micro Modular Reactor – In May 2021, Ultra Safe Nuclear Corporation and the University of Illinois Urbana-Champaign began pre-applications interactions with the NRC on a project to build a research reactor based on Ultra Safe's Micro Modular Reactor. The MMR is a helium-cooled fast reactor that would generate up to 15 MWe and up to 45 MWt for industrial process heat.



BWRX-300 – In December 2019, GE-Hitachi Nuclear Energy began pre-application interactions with the NRC on the BWRX-300 small modular reactor design. The NRC is cooperating with the Canadian Nuclear Safety Commission on joint reviews of BWRX-300 topical reports and related pre-application documents. The BWRX-300 is a ~300 MWe water-cooled, natural-circulation small modular reactor with passive safety systems, based on the certified ESBWR.

Integral Molten Salt Reactor – In October 2019, Terrestrial Energy began pre-application interactions with the NRC on the IMSR design. The Integral Molten Salt Reactor uses fluoride salts as both low-pressure coolant and to hold low-enriched uranium fuel. The design would generate approximately 390 Mwe, as well as provide high-temperature process heat for industrial applications.

eVinci – In September 2019, Westinghouse began pre-application interactions with the NRC on the eVinci microreactor design. The eVinci design would use heat pipe technology to generate up to 5 MWe, as well as up to 13 megawatts of heat. The design is planned to be transportable for use in remote locations.

Xe-100 – In September 2018, X-Energy began pre-application interactions with the NRC on the Xe-100 small modular design. The Xe-100 small modular design would use a pebble-bed, high-temperature gas-cooled reactor. Each reactor would generate 200MWt and approximately 80MWe, so a standard Xe-100 power plant of four modules would generate approximately 320MWe.

Fluoride Salt-Cooled High Temperature Reactor – In March 2018, Kairos Power began pre-application interactions with the NRC on its FHR technology. One application of this technology is the "Hermes" test reactor (shown here), for which the NRC approved a construction permit in December 2023. The full-scale Fluoride Salt-Cooled High Temperature Reactor technology is a modular, advanced reactor design that uses TRISO fuel in a low-pressure fluoride salt coolant. A separate heat transfer loop, also using molten salt, would boil water in a steam generator for an output of 140 MWe.

September 2024