Advanced Nuclear Technology Overview

Nuclear Technology:

Advanced nuclear reactors represent a new generation of technologies designed to deliver carbon-free, reliable, and flexible energy for diverse applications utilizing nuclear fission. Nuclear fission is a nuclear reaction in which large atoms are split into two or more smaller nuclei releasing energy. Today all of the 94 operating reactors in the United States are large light water reactors which utilize low enriched uranium (LEU) as a fuel source. Advanced reactors include Small Modular Reactors (SMRs) and micro-reactors with different cooling mechanisms, offering outputs from a few megawatts to several hundred megawatts. They feature passive safety systems, operate at higher temperatures for improved efficiency, and can support electricity generation, hydrogen production, desalination, district heating, and industrial processes. Large Reactors that incorporate passive and inherent safety features such as the Westinghouse AP-1000 are also considered advanced reactors. Fuel innovations such as HALEU and TRISO enable longer refueling cycles and compact designs. Current projects span water-cooled SMRs like NuScale NPM, Westinghouse AP300, Holtec SMR-300, and GEH BWRX-300, non-water-cooled reactors such as sodium fast reactors, molten salt reactors, and high-temperature gas reactors, as well as micro-reactors like Oklo Aurora, BWXT BANR, and Radiant Kaleidos, with deployments planned from the late 2020s through the early 2030s. Below is a summary table of the advanced reactor technologies:

Type	Examples	Size	Coolant	Fuel	Outlet Temp	Applications	Deployment
Large Water-Cooled RX	AP-1000	1000 Mwe	Light Water	LEU Ceramic	~287–321°C	Electricity	Currently Deployed – Vogtle 3 and 4
Water-Cooled SMRs	AP300, NPM, BWRX-300, SMR-300	77–300 MWe	Light Water	LEU Ceramic	~287–316°C	Electricity, Hydrogen, Desalination, District Heating	Early 2030s
Molten Salt Reactors	TerraPower MCFR, IMSR, Natura Resources	195–500 MWe	Molten Salt	HALEU / LEU	500–735°C	Electricity, Process Heat, Fuel Recycling	Late 2020s–Early 2030s
Sodium-Cooled Fast Reactors	TerraPower Natrium, ARC-100, Oklo Aurora	75–345 MWe	Liquid Sodium	HALEU Metallic	510–540°C	Flexible Electricity, Energy Storage	2029–2030
High-Temp Gas Reactors	X-energy Xe-100	80 MWe (modular)	Helium	TRISO	~750°C	Electricity, Hydrogen, Industrial Heat	Early 2030s
Gas-Cooled Fast Reactors	General Atomics FMR	44–265 MWe	Helium	HALEU	800–850°C	Electricity, Hydrogen, Industrial Heat	Mid-2030s

Safety, Emergency Planning, Environmental Protection

Advanced nuclear reactors represent a significant evolution from the current fleet of large light-water reactors. Current plants rely on **active safety systems**—components like pumps and valves that require external power or operator action. In contrast, advanced reactors incorporate **passive safety**, which uses natural forces such as gravity and convection to remove heat without external energy, and **inherent safety**, which is built into the reactor's physics and design. For example, TRISO fuel encapsulates fission products within multiple layers, acting as containment, while negative temperature coefficients automatically slow the reaction as temperatures rise. Think of passive safety like a self-retracting lifeline or car seatbelt that locks automatically, and inherent safety like a quick-disconnect gas pump nozzle that separates under stress—both prevent harm without external intervention.

These design improvements also reduce land and emergency planning requirements. A traditional plant like Vogtle occupies about 600 acres and requires a 10-mile emergency planning zone (EPZ), while an advanced design such as X-energy's Xe-100 delivers 320 MWe on just 10 acres with an EPZ of less than one mile. This smaller footprint and enhanced safety simplify siting and environmental reviews, enabling deployment near load centers. Combined with their ability to provide high-temperature heat for applications like hydrogen production, advanced reactors are poised to expand nuclear energy's role in a resilient, integrated energy system

Waste Management

All 94 operating reactors have an agreement with the Department of Energy for Waste Storage which is required to be in place prior to obtaining an Operating License from the Nuclear Regulatory Commission. Nuclear Waste for the existing Reactor Fleet is a solid, ceramic material. The waste is removed from reactors during a refueling outage and is stored in an onsite fuel pool for 5 or more years. After 5 or more years the fuel is offloaded into a dry cask storage vessel and transported out to a concrete pad for final storage. Waste from advanced reactors that utilize ceramic fuel will be stored in the same manner. We can expect onsite storage of Nuclear Waste will continue until a final repository is identified by the Department of Energy for final waste disposal.

For advanced reactors using other fuel forms such as TRISO Fuel, Metallic Fuel, or Molten Salt, the final waste form will need to be determined prior to entering a waste agreement with the Department of Energy. When looking at new fuel waste forms and what the waste form will be it's helpful to consider comparison to a car. In the case of new fuel forms, it's like putting different engines into the same car frame – the car frame may need to be adjusted for the size or the material of the new motor and the engines will have different operating characteristics that will impact how it may need to be stored after removal. Dry Cask Storage may still apply but the storage container may need to be modified to conform to different characteristics such as higher temperatures, or different final waste forms.

Siting, Infrastructure, Timeline

Siting requirements for nuclear power plants in the U.S. focus on technical feasibility (such as geology, hydrology, slope, seismicity, and population density) and access to existing infrastructure; there are approximately 42 criteria which must be evaluated. Existing nuclear and retiring coal plant sites are especially favorable due to established transmission, water access, and local support, which can streamline permitting and reduce costs. The regulatory process involves thorough environmental reviews and licensing by the Nuclear Regulatory Commission (NRC), with two main pathways: a two-step process (Part 50) and a combined license (Part 52), the latter being more efficient for standardized designs.

The timeline to build a large nuclear power plant has historically ranged from 6 to 11 years, with recent projects like Vogtle Units 3 and 4 taking about 11 years due to design and supply chain challenges. However, with lessons learned, mature designs, and a skilled workforce, future projects (such as additional AP1000 reactors) could be completed in as little as 6 years. Small modular reactors (SMRs) and microreactors may offer shorter construction times, especially if factory production and modular assembly are maximized, though these approaches are still being proven at scale.

Early and thorough planning, design standardization, and workforce development are critical to reducing both cost and schedule risks. Engaging communities early and leveraging existing sites can further accelerate deployment and improve project outcomes.

Community Engagement/Benefits

Advanced nuclear projects are designed to deliver tangible benefits to host communities. These include economic development through job creation in construction, operations, and supply chains, as well as long-term employment opportunities in maintenance and technical roles. Communities could also gain from improved energy reliability, potential district heating, and industrial heat applications, which can support local businesses and infrastructure. Additionally, projects often incorporate workforce training programs and educational partnerships to build local expertise, ensuring that benefits extend beyond energy generation to broader social and economic resilience.

Communities can utilize engagement strategies to share information on nuclear energy by fostering trust, tailoring communication, and creating structured participation opportunities. Effective engagement begins with transparent dialogue led by trusted local leaders and integrates nuclear topics into familiar forums, such as town halls or economic development meetings. Communities should customize outreach to address local priorities such as energy reliability, job creation, or sustainability, and use clear, accessible language to demystify technical concepts. Structured programs, like readiness initiatives, can guide communities through phased learning, advisory panels, and certification processes, ensuring informed decision-making. Additionally, partnerships with educational institutions, industry experts, and government programs provide resources for training, feasibility studies, and technical assistance, empowering communities to confidently evaluate and communicate the benefits and implications of advanced nuclear technologies. Partnerships could include universities, the New York State Energy Research and Development Authority (NYSERDA), the New York

Power Authority (NYPA), and existing nuclear entities such as Constellation and Knolls Atomic Power Laboratory.

Workforce, Economic Impact

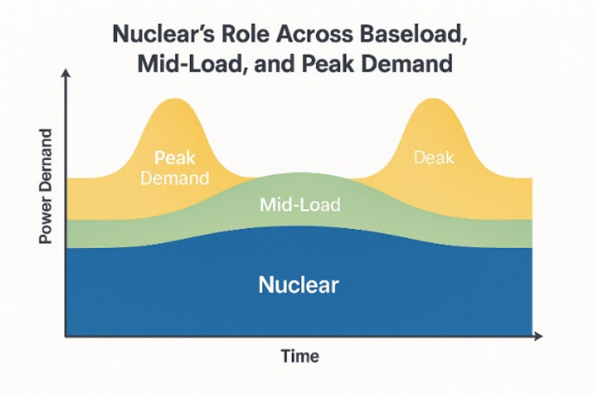
Hosting a nuclear power plant brings significant economic benefits to a community. Construction projects can last from 7 to 10 years depending on the size of the reactor and generate approximately 5000 jobs during peak construction. A single plant can sustain hundreds of jobs, with total permanent employment ranging from about 313 positions for a 500 MWe facility to nearly 1,000 for a 900 MWe plant. These jobs span direct plant operations, supply chain roles, and positions created through local spending. Annual labor income is substantial, reaching \$32–\$56 million for mid-sized plants and over \$100 million for the largest facilities. Beyond wages, nuclear plants drive local economic output and GDP contributions, adding hundreds of millions of dollars annually to the regional economy.

Workforce needs for nuclear facilities are diverse but generally require higher educational attainment than coal plants, with more roles for engineers, technicians, and specialized operators; very few nuclear engineers are required. While many positions can be filled by workers with vocational training or associate degrees, others demand bachelor’s or advanced degrees. Communities should anticipate the need for retraining programs and partnerships with local colleges, utilities, and labor unions to prepare workers for nuclear-specific certifications and safety standards.

These economic and workforce impacts often lead to broader community changes, such as population growth, increased housing demand, and expansion of local services. Indirect and induced effects strengthen local businesses through supply chain activity and household spending, making nuclear projects a catalyst for long-term economic development.

How does Nuclear fit with Existing Energy Infrastructure

Nuclear power plays a critical role in stabilizing the power demand cycle by providing firm, predictable baseload capacity that ensures grid reliability, while advanced reactors add flexibility through load-following and peak-shaving capabilities. These reactors can integrate with energy storage systems, enabling them to respond to fluctuations and support peak demand without cycling the plant. In contrast, renewables such as wind and solar are highly variable and weather-dependent, making them excellent for peak load when weather conditions are favorable but unable to guarantee continuous supply on their own. To manage demand effectively, renewables require large-scale storage solutions like batteries or pumped hydro to cover periods of low generation and meet peak loads. Together, nuclear and renewables form a complementary partnership; nuclear delivers stability and resilience, while renewables contribute to energy goals.



Additional Resources:

Advanced Nuclear Reactor Technology: A Primer
https://nuclearinnovationalliance.org/advanced-nuclear-reactor-technology-primer

NEI – Advanced Nuclear 101
https://www.nei.org/advanced-nuclear-energy/advanced-nuclear-101

EPRI Advanced Nuclear Technology: Site Selection and evaluation criteria for New Nuclear Energy Generation Facilities
https://www.epri.com/research/products/000000003002023