2025 Handbook Update

A COMMUNITY HANDBOOK ON NUCLEAR ENERGY

Understanding Nuclear Energy and Alternatives for the Future

ECA

Energy Communities Alliance

Local concerns. National impact.

Credit: Human Systems Simulation Laboratory, Idaho National Lab, flickr

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Introduction

ECA often provides members with answers to frequently asked questions about what a local community needs to know about nuclear.

Energy Communities Alliance (ECA) is releasing the third edition of a *Community Handbook on Nuclear Energy* to assist local communities in identifying and understanding the myriad issues associated with potentially hosting a facility dedicated to nuclear power production, manufacturing, defense, storage or disposal. Today, renewed interest in the American nuclear industry presents a wide range of new economic opportunities for communities across the country and the globe. This Handbook explores developments that have advanced options for the fuel cycle, highlights basic knowledge necessary for realistic discussions to develop local community strategies, profiles the changes in today's American nuclear industry, and lays out market trends that shape the economics of existing and future nuclear technologies.

This Handbook is not written by people who work for the nuclear industry, the federal government, or anti- or pro-nuclear groups. Instead, this Handbook is written from the experience of local governments that host nuclear facilities, communities which have been and will be most impacted by any policies regarding nuclear energy development and nuclear waste management. ECA's leadership consists of mayors, councilmembers, commissioners, chairpersons, judges, city and county managers, Community Reuse Organization executives and board members, economic development professionals, and others. They assisted in the development of this Handbook and provided input into the realities of hosting such a facility, including the benefits and challenges.

ECA highlights all aspects of nuclear issues to ensure that local communities have the knowledge to ask the right questions, understand the answers, and attract the companies and businesses that benefit their community.

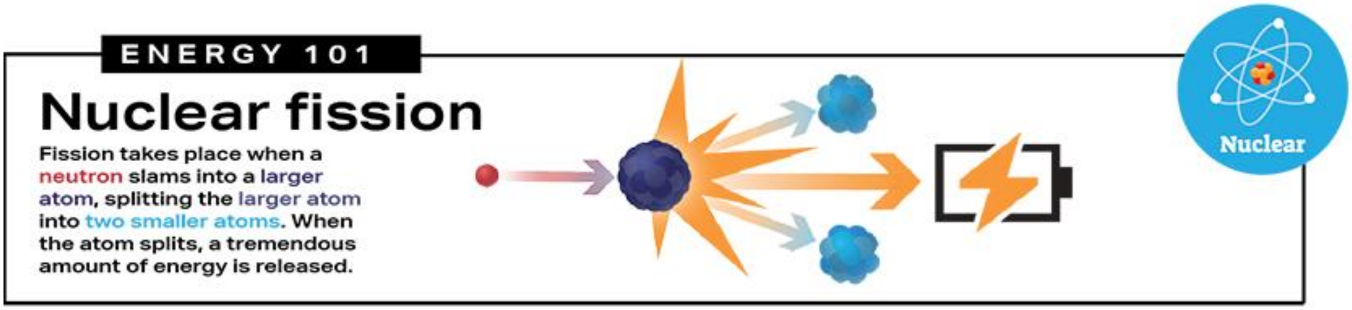
Nuclear Energy 101

Local governments that are or may become hosts to nuclear facilities must be included throughout the entire decision-making process. In some cases, the local government is both the utility purchaser and the host. In others, the local government of the region is the host. This section offers an overview of the everyday uses of nuclear science, options for fission and fusion energy, and the basic principles of how existing nuclear power plants work. Basic information allows local officials to ensure coordination with their state and federal counterparts and to maximize positive outcomes.

The Big Power of Very Small Things

As we see in popular culture, Einstein's theory of relativity which helped lead to nuclear power all started with physics. Nuclear physics serves as the foundation for advanced energy solutions. It is a branch of physics that studies the behavior of materials at the atomic level and the forces that bind atoms together. Physics provides the theoretical framework for understanding atomic and nuclear phenomena.

Similarly, nuclear science focuses specifically on the interactions and energy associated with the center of the atom, the nucleus. The nucleus is super small compared to the whole atom, but it holds almost all the atom's weight. Atomic nuclei are important because the number of protons in the nucleus decides the type of atom.



[1]

Physics at the atomic scale plays many roles in the economy, from providing clean energy to supporting healthcare, industry, and scientific progress. By recognizing the diverse applications for radioactive materials, communities can make informed decisions on whether and what kinds of nuclear projects they might want to host. Examples of how nuclear science and technologies affect everyday life in the United States and abroad include:

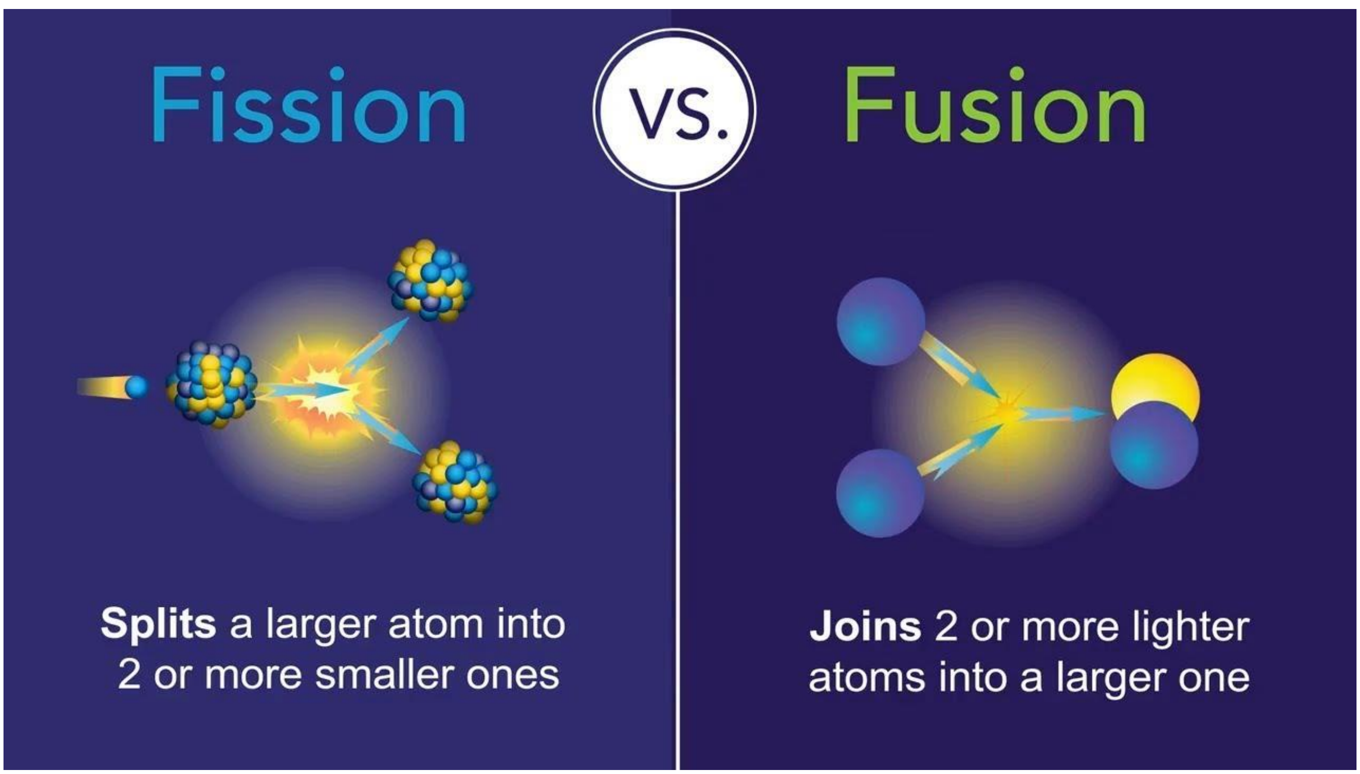
- **Creating Electricity:** Nuclear fission has a long history as a stable and reliable emissions-free energy source which has helped decrease greenhouse gas emissions and increase energy independence. Further, the steam created by the heat of a nuclear fission is used in commercial applications.
- **Healthcare and Medical Innovation (Such as X-Rays):** The use of radiation has had transformative applications in healthcare, including diagnostic imaging, X-rays, radiation therapy, nuclear medicine. Irradiation of medical equipment and single-use medical devices also puts nuclear technology to valuable use, ensuring everything from medical masks and bandages to joint replacements and implants are properly sterilized before use.
- **Consumer Safety in Food and Cosmetics:** In the food industry, radioactive isotopes are used for irradiation to treat foods, spices and ingredients; making them safer for consumers, reducing spoilage and extending their shelf life. The irradiation kills parasites and microorganisms that cause food poisoning and reduces microbial contaminates in makeup and cosmetics.
- **Economic Development:** Nuclear projects can attract investment, foster collaboration between academia and industry, and stimulate the growth of high-tech industries in many ways, contributing to the local economy and promoting prosperity.
- **Non-destructive Testing and Industrial Applications**: Sealed radioactive sources are used by a number of various industries for numerous applications including household-use in smoke detectors, well logging for the oil and gas industry, preserving cultural items like paintings, gauging moisture density of soils, cargo screening of large ship containers, and pipeline weld examinations.

[1] Los Alamos National Laboratory, (November 29, 2023), https://www.lanl.gov/media/publications/national-security-science/1123-fission-forward.

- **Education and Workforce Development:** Nuclear education and training programs cultivate a skilled workforce, empowering residents with the knowledge and skills needed to thrive in the modern economy and contribute to scientific innovation.
- **National Security and Environmental Protection:** Nuclear research is essential for advancing technologies for national security, including nuclear safeguards, non-proliferation efforts, and environmental monitoring. Radioactive materials can be used to precisely measure and monitor various environmental factors such as water and air quality.

Fission and Fusion

Fission and fusion are two fundamental processes in nuclear physics. Both carry significant implications for energy production and industrial processes. Fission involves splitting the center (or nucleus) of a heavy atom into smaller fragments, releasing a significant amount of energy in the process. This process powers nuclear reactors, which produce electricity for millions of homes and businesses worldwide. Fusion is the process of combining the nucleus of light atoms to form a heavier nucleus, releasing even greater amounts of energy.



[2]

[2] Department of Energy Office of Nuclear Energy, (April 1, 2021), https://www.energy.gov/ne/articles/fission-and-fusion-what-difference.

Fission reactors currently play a significant role in global energy production, providing a reliable and low-carbon source of electricity in many parts of the world. Meanwhile, fusion power remains a goal for the future due to its potential for abundant and clean energy and significant investment is being made today to make it a reality.

Today's Nuclear Power

As of 2025, the United States has 94 reactors currently operating, producing more than 800 billion kilowatt hours of electricity per year - supplying about 18% of America's electricity. Today, nuclear power comprises 55% of carbon-free energy in the U.S.[3] The U.S. also has 56 proposed advanced reactors. Within a nuclear reactor, energy is produced by a process called nuclear fission. Power is produced in the reactor's core, which contains the fuel. Fuel must be an atom with a large and unstable nucleus. When the reactor is turned on, the fuel is bombarded with neutrons which collide with the fuel atoms, causing them to split and releasing large amounts of heat and radiation.

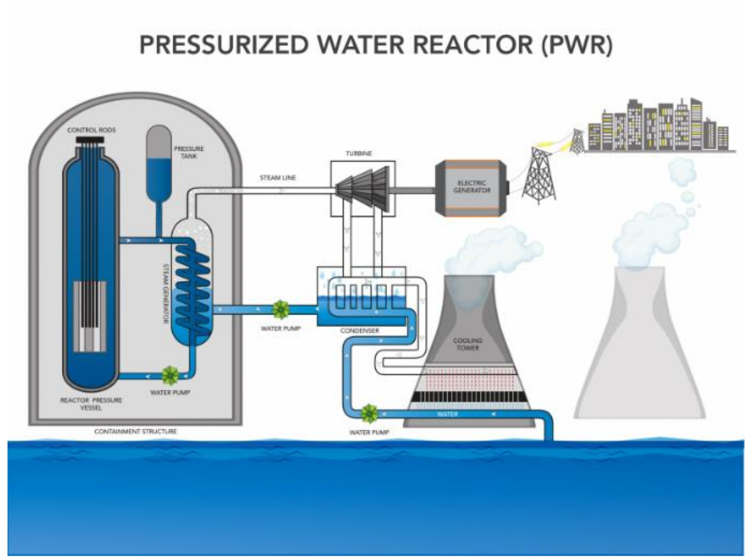
Nuclear fission technology falls under two distinct categories – conventional reactors and advanced reactors – each encompassing different designs, energy capacities, coolants, and fuel requirements. Despite the many designs, the primary uses for nuclear energy relate to electricity production and the generation of heat.

Commercial reactors that are currently operating in the US are high-capacity, water-cooled, light-water reactors (LWRs). Light water reactors use fission reactions and uranium fuel to heat normal water into steam which turns a turbine and generates electricity. The steam is then condensed back into water and recycled. Nuclear reactors can also serve as reliable sources of heat for various industrial, commercial, and other power generation applications, such as district heating for homes and businesses, desalination, industrial process heating for factories and operations, and hydrogen production.[4]

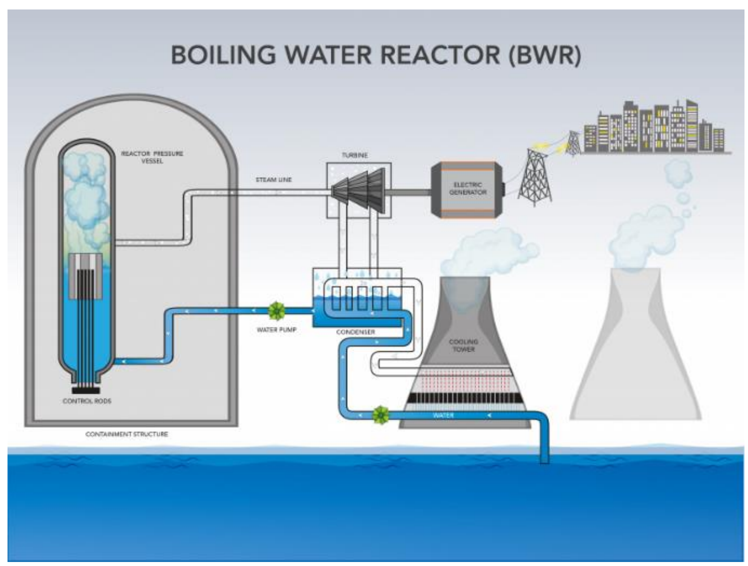
[3] World Nuclear Association (Nov. 1, 2025) https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power
[4] Vogtle turbine hall. Image from https://vogtlegallery.georgiapower.com/vogtle-photos/2024_03/WCK_6353.jpg

Utilities use two types of light-water reactors today. Boiling water reactors (BWR) and pressured water reactors (PWR) both rely on water as the coolant and the neutron moderator. The BWR core is comprised of thousands of long uranium rods which are submerged in the water. The fuel comprises a column of ceramic pellets of uranium oxide, clad and sealed into zirconium alloy tubes that are bundled together.

In pressurized-water reactors, the reactor core is kept under high pressure, so the water cannot boil. Fission reactions heat the pressurized water in the core. Then, it is pumped to a structure called the steam generator, where it indirectly boils different water into steam. That steam is used to turn the turbine, while the original pressurized water is recycled back to the reactor.



In boiling-water reactors, conversely, there is only one circuit of water. The energy from fission directly causes water to boil within the reactor chamber. The resultant steam is pumped out to turn the turbine and then condensed back into liquid to be reused in the reactor. [5]



Since the U.S. opened its first civil nuclear power plant in Idaho in 1957, nuclear technology has become safer, more efficient, and cheaper. New reactors can be made smaller or in modular units; some use alternative fuels or coolants. These non-traditional designs are collectively known as advanced reactors. Small modular reactors, known as SMRs, and advanced reactors with new fuel forms or innovative cooling systems present new opportunities for nuclear energy for electricity and heat applications.

[5] DOE Office of Nuclear Energy (May 19, 2025) *https://www.energy.gov/ne/articles/nuclear-101-how-does-nuclear-reactor-work.*

Nuclear reactors are often referred to by generations.

I. **Generation I** reactors represent the earliest designs for reactors. Often prototypes, these reactors were primarily experimental and research oriented.

II. **Generation II** reactors include boiling water reactors and pressurized water reactors with added safety features, efficiency, and reliability over their predecessors. Most of the conventional reactors currently operating in the U.S. are Generation II.

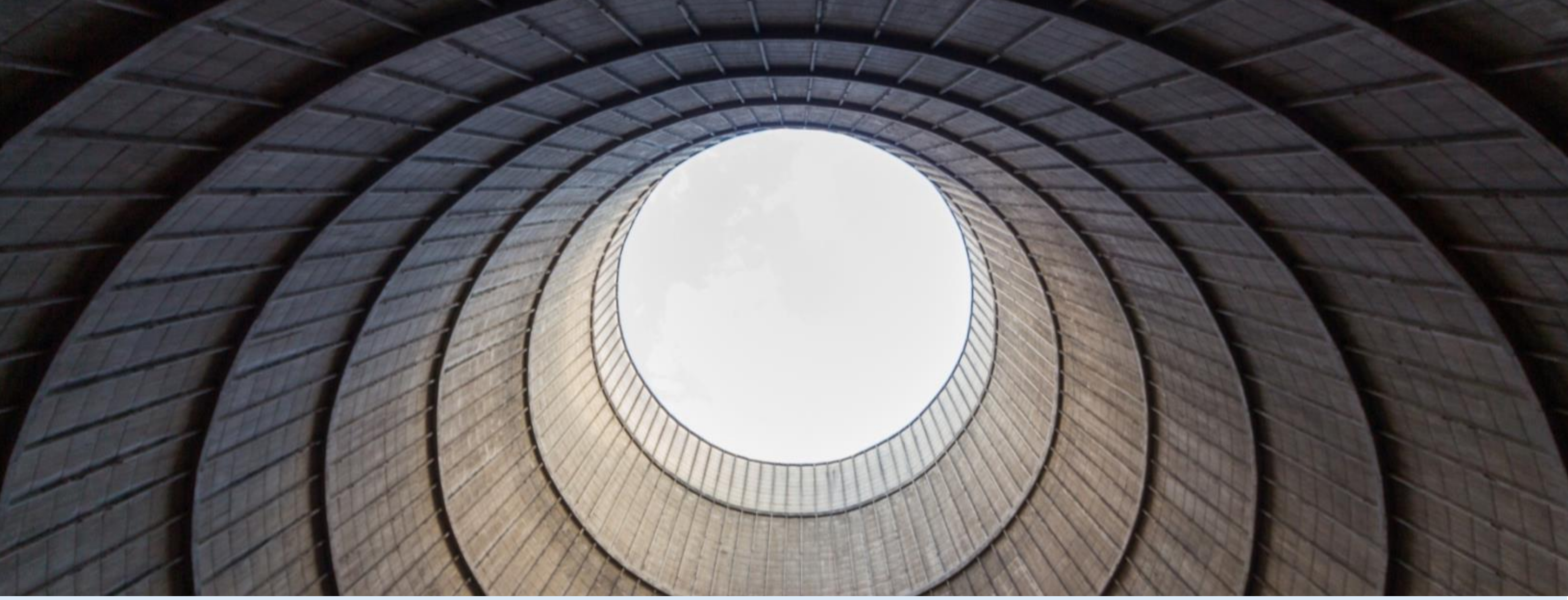
III. **Generation III** reactors include the four certified types developed by the Nuclear Regulatory Commission (NRC) in the 1990s. These include an advanced boiling water reactor, an advanced pressurized water reactor, and two Westinghouse designs: the AP600 and the AP1000. An AP1000 reactor came online in 2023 at Georgia's Vogtle nuclear power plant, serving as the first Generation III advanced reactor in the United States. A sister unit came online in 2024. New designs are simpler, add updated safety features and reduce costs for construction.[6]

IV. **Generation IV** reactors exist primarily in the research and development stages. The Generation IV International Forum (GIF) was established in 2001 and currently consists of 14 member countries, including the United States, Canada, France, Japan, Russia, and others, as well as several international organizations. The forum serves as a platform for member countries to share knowledge, expertise, and resources in nuclear technology research and development.

Recommendations

Technological advancements in nuclear science and technology present local governments with a wide range of opportunities for economic development and industrial investment. Real progress requires that all necessary parties are engaged, that there is trust among the parties, and confidence in the path forward. Local governments play an essential role in developing the political will and means to implement new policies or governance plans. Stakeholders must identify and ask for resources in order to build support within a community for new nuclear missions. Local governments must define what they need and develop legally enforceable agreements and conditions that minimize political influence over time and should not expect a one-size-fits all approach. They will need to become educated and actively engage with DOE, NRC, federal policymakers, the state, and industry as early as possible in the decision-making process on siting new nuclear facilities.

[6] U.S. Energy Information Administration, (Oct. 1, 2025), https://www.eia.gov/todayinenergy/detail.php?id=57280



Radiation Basics

Safety and security concerns related to hosting a nuclear facility typically focus on concerns about radiation. Local officials need to ensure they address risk in education and outreach programs, as perception and reality need to align for a community.

Heightened perception of radiation risk could be one of the most significant challenges — along with the economic environment — for the industry and local or state governments interested in hosting new nuclear facilities to overcome.

What is Radiation?

Radiation is energy that travels through space in the form of waves or high-speed particles. Sources of radiation may be naturally occurring in the earth's crust or atmosphere, or human made. Artificial sources of radiation include uses such as X-ray machines, exit signs, and power plants.

There are two types of radiation: non-ionizing radiation and ionizing radiation.[7] [8]

Non-ionizing Radiation

Non-ionizing radiation has enough energy to move atoms around in a molecule or cause them to vibrate – but not enough energy to remove electrons from atoms. Non-ionizing radiation is essential to life and includes

[7] Occupational Safety and Health Administration, http://osha.gov/SLTC/radiation/index.html.
[8] Centers for Disease Control, https://www.cdc.gov/radiation-health/about/electromagnetic-spectrum.html

visible light. It ranges from extremely low frequency and low frequency to radio waves, microwaves, infrared and ultraviolet. This runs the gamut of sources from static fields and power lines to AM/FM radio transmissions, microwave ovens, and Wi-Fi to cafeteria food heaters and tanning booths.[9]

The most familiar form of electromagnetic radiation is sunshine, which provides light and heat; and consists primarily of radiation in infrared, visible, and ultraviolet frequencies. Microwave ovens work on long wavelength, non-ionizing frequencies to excite water molecules, creating heat from friction to warm up the food.[10] Lasers also emit electromagnetic radiation in "optical frequencies."

Excessive exposure to non-ionizing radiation can inflict tissue damage. Ultraviolet radiation exposure is commonly known as a sunburn. Radiofrequency and microwave exposure may damage tissue with heat.

Ionizing Radiation

The higher frequencies of electromagnetic radiation, such as x-rays and gamma rays, are types of ionizing radiation.[11] Ionizing radiation has much more energy than non-ionizing radiation. It can knock electrons out of atoms. This is a process known as ionization, which creates ions and destabilizes the nucleus of an atom to form radionuclides (also known as radioactive atoms and radioisotopes). Ionizing radiation is what people often mean when they refer to "radiation."[12]

A radionuclide is an unstable form of a chemical element also known as a radioactive isotope. Some radionuclides, such as radium, uranium and thorium, occur naturally. Human activities, like the splitting of atoms inside nuclear reactors, can also create radionuclides.[13]

As unstable atoms, all radionuclides seek to become more stable by releasing radiation. This process is called radioactive decay. By ejecting particles and high-energy waves, the unstable chemical element reduces the excess numbers of neutrons or protons that give it excess energy to return to a stable state.

Not all the atoms of a radioactive isotope decay at the same time. Instead, they decay at a rate characteristic to the isotope at a fixed rate called a half-life. The half-life of a radioactive isotope refers to the amount of time required for half of a quantity of a radioactive isotope to decay.[14]

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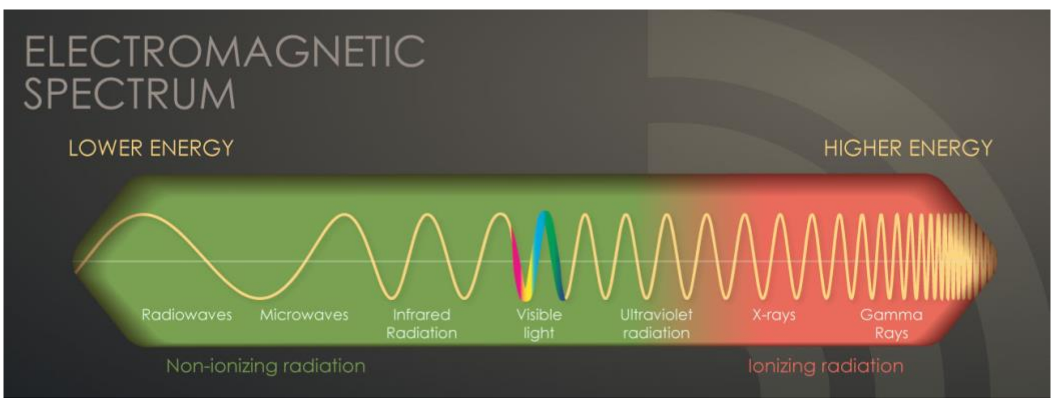
[9] Occupational Safety and Health Administration, http://osha.gov/SLTC/radiation/index.html.
[10] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.
[11] Occupational Safety and Health Administration, U.S. Department of Labor, http://osha.gov/SLTC/radiation/index.html.
[12] Occupational Safety and Health Administration, U.S. Department of Labor, http://osha.gov/SLTC/radiation/index.html.
[13] Occupational Safety and Health Administration, U.S. Department of Labor, http://osha.gov/SLTC/radiation/index.html.
[14] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.

The two types of ionizing radiation are particulate radiation (alpha particles, beta particles, and neutrons) and electromagnetic (X-rays and gamma rays) radiation. X-ray machines and cosmic rays are also sources of ionizing radiation.[15 16]

Ionizing radiation poses a health risk to living organisms because the depositing of energy (radiation) into the body can destabilize molecules within cells and even damage tissue. In some cases, there may be no noticeable effect but in other cases, damaged cells that survive may become temporarily or permanently abnormal with the potential to become malignant. The extent of damage to the body tissue depends upon the total amount of energy absorbed, the time period and the dose rate of the exposure, as well as the particular organs exposed.[17]

Radiation is known to cause cancer in humans and can cause other adverse health effects. Much of the knowledge about the risks of radiation is based on studies of Japanese survivors of the World War II atomic bombs and of people receiving large doses of medical radiation.

- The more radiation a person receives, the greater chance of developing cancer.
- It is the chance of cancer occurring, not the severity of cancer, that increases as the radiation dose increases.
- Radiation-induced cancers do not appear until years after the radiation dose is received.
- The risk from radiation exposure varies between individuals.[18]



Graphic credit: CDC Radiation Explained

[15] Occupational Safety and Health Administration, U.S. Department of Labor, http://osha.gov/SLTC/radiation/index.html.
[16] U.S. Environmental Protection Agency, https://www.epa.gov/radiation/radiation-basics#ioniandnonioni.
[17] U.S. Environmental Protection Agency, (April, 2012), EPA-402-K-10-008, https://www.epa.gov/sites/default/files/2015-05/documents/402-k-10-008.pdf.
[18] Centers for Disease Control "Radiation and your health" https://www.cdc.gov/radiation-health/about/non-ionizing-radiation.html

Radiation and How Radiation is Measured

Background radiation refers to the natural and constant low-level radiation present in our environment. It comes from various sources, including cosmic rays from space, radioactive elements in the Earth's soil and rocks (like uranium and radon), and even within our bodies. Human activities, such as medical procedures and the use of nuclear power, contribute slightly to background radiation levels.

While radiation is everywhere, the levels are generally very low and harmless, as life on Earth has evolved to coexist with this natural radiation over billions of years. The average person is exposed minimally on a daily basis. Greater radiation risk is controlled with much oversight through regulatory agencies such as the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA), which set science-based standards of safety and monitor the impact of radiation and the impacts it has on both individuals and society as a whole.

In the U.S., radiation doses are measured in a unit called a "rem." Scientists estimate that the average person in the United States receives a dose of about 620 millirems (mrem) of radiation per year:

- 50 percent of the average American's annual dose comes from natural sources background sources, like cosmic radiation from outer space, terrestrial radiation from soil, rocks, and radon, and even internal radiation generated by the human body. Our bodies contain tiny amounts of radioactive elements, such as potassium-40 and carbon-14, which are naturally found in living things.
- 48 percent of the average American's dose comes from medical procedures like X-rays. For people who undergo radiation therapy used in the treatment of cancer, this dose is typically many times larger.
- Nuclear power plant operations account for less than one 1/100 of 1 percent (<0.01%) of the average American's total annual radiation exposure.
- Americans living within 50 miles of a nuclear power plant receive less than 1 millirem a year in additional exposure; a tenth the size of a single chest X-ray. [19]

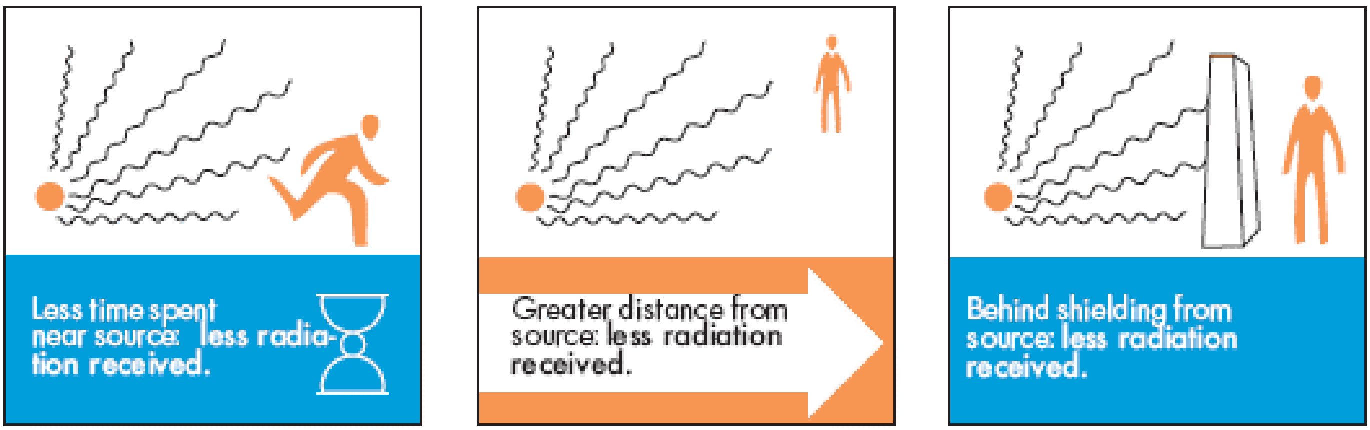
In addition to the radiation from natural background sources, the U.S. Nuclear Regulatory Commission's health and safety standards allow radiation exposures of up to 5,000 mrem per year for workers working with radioactive materials or in the nuclear sector, and 100 mrem per year for members of the public. [20]

The NRC has a personal annual radiation dose calculator to help individuals estimate how much radiation they are exposed to.

Exposure to the harmful impacts of radiation can be reduced by following general guidelines. Safety and environmental standards reflect the use of these techniques to protect people and their surroundings from levels of radiation exposure that could pose danger.

[19] U.S. Environmental Protection Agency, (2024), https://www.epa.gov/radiation/radiation-sources-and-doses.
[20] U.S. Nuclear Regulatory Commission, (May 13, 2021), https://www.nrc.gov/about-nrc/radiation/around-us/calculator.html.

- **Time**, or the duration of exposure, influences the radiation dose. For professionals who work with nuclear materials, their exposure time is both monitored and limited.
- **Distance** from a radioactive source also reduces exposure. Dose decreases rapidly as a person moves away from a source, just like the heat of a fire.
- **Shielding** also mitigates risks. Many types of materials offer great protection from different types of radiation, just as moving into the shade can protect one from sunburn.



[21]

Time, distance and shielding are the three principles of radiation protection.

Types of Ionizing Radiation and their applications

The four types of ionizing radiation are unique in their applications and how they can be blocked.

1. **Alpha particles**, which are large and heavy, cannot travel far and, thus, are useful in devices like smoke detectors. Alpha particles can be stopped by a piece of paper, your skin or even a few inches of air.
2. **Beta particles**, smaller and more energetic than alpha particles, can be stopped by thin aluminum.[22]
3. **Gamma radiation and x-rays** are high-energy waves. These can travel great distances at the speed of light, and both can penetrate deeply into matter. They are the foundation of nuclear medicine. X-rays are useful for medical diagnosis and practices as they are stopped by dense materials like bone, tumors, or lead. Gamma radiation can be used to precisely target and eliminate tumors; and has a number of other industrial and agricultural applications. Gamma rays can be stopped by several inches of lead.[23]

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[21] U.S. Environmental Protection Agency, (January 19, 2017), https://19january2017snapshot.epa.gov/radiation/protecting-yourself-radiation_.html.
[22] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.
[23] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.

4. **Neutron radiation** is created from fission chain reactions and is what emitted inside nuclear reactors. Neutrons are extremely high energy, so they need many feet of dense materials like water or concrete to contain them. Neutron radiation can make other materials radioactive and, as a result, is used to create the radioisotopes used in medical treatments.[24]

The American Nuclear Society provides resources to learn more about the beneficial uses of radiation and its various applications, from food and medicine to outer space technologies.[25]

Concerns about radiation at low doses have continually influenced public perception of nuclear power, as well as policies surrounding nuclear reactor deployment and waste management. However, risk estimates of the effects of low-dose radiation have become more precise over the years. A National Academy of Sciences committee conducted a 2023 study on new ways to evaluate low-dose radiation effects. According to the report, there is no well-established relationship between cancer risk and exposure to radiation at very low doses.

What is Tritium?

Tritium is often discussed in relation to nuclear power plants. Tritium is a form of hydrogen found in nature in the upper atmosphere when cosmic rays make contact with gasses. It is a naturally occurring isotope that, despite being radioactive, emits weak beta radioactivity that cannot penetrate skin tissues. Tritium is also a by-product of nuclear power plants that is subject to ongoing environmental monitoring.

Like normal hydrogen, tritium can bond to oxygen, creating “tritiated water,” which can be found naturally in most groundwater. Humans around the world are exposed to minor levels of tritium daily because they consume water or food affected by this natural process. Within 10 days of exposure, the body excretes most of it, although trace amounts can remain in the body.

Nuclear plants routinely release levels of tritium parallel to those found in nature. The presence of higher levels of tritium near these plants can occur if high levels of this tritiated water are released. The regular monitoring of local groundwater, along with state and federal oversight of these nuclear facilities, helps to reduce risk of such contamination.

The health effects of long-term exposure to tritium from nuclear plant discharge are debated since it is difficult to distinguish the source from background radiation in the atmosphere. Tritium exposure is inevitable as a part of nature, and nuclear operators remain responsible for minimizing the release of tritium into the environment.

The Health Physics Society and the U.S. Nuclear Regulatory Commission both maintain helpful resources on tritium releases from nuclear power plants.

[24] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.
[25] American Nuclear Society, Occupational Safety and Health Administration, https://www.ans.org/nuclear/radiation/.

Recommendations

Local governments can engage with existing operators and developers to better understand the safety and environmental aspects of nuclear facilities. Local governments interested in policies to recycle used nuclear fuel in the future also could benefit from being engaging with DOE and the private companies interested in building new recycling facilities.

Communities need to work together to support advanced nuclear development at multiple sites across the country. Geographic dispersion of new nuclear projects can help build political support, incorporating both manufacturing supply chains and workforce development issues.

Efforts to integrate the waste discussion when evaluating new nuclear technology development also help ensure the costs and issues related to waste management and disposal are included as early as possible in developing a vision for new nuclear facilities.

The Nuclear Industry is Growing

Some of the most significant discussions for a community are focused on implementing an effective siting process for new nuclear facilities. The Administration and Congress recognize that the chance for success is greater for a nuclear project if the process allows "affected communities to decide whether, and on what terms, the affected communities will host a nuclear waste facility."

New and existing energy communities have an opportunity to affect how their roles will be defined and under what conditions. This Handbook should be viewed by communities as a starting point for public discussions about the local desire and consent to host nuclear power facilities. Recognizing that each community, whether as a power purchaser, a host, a provider of services, or otherwise will bring its own input into the process of siting.

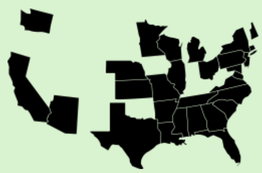
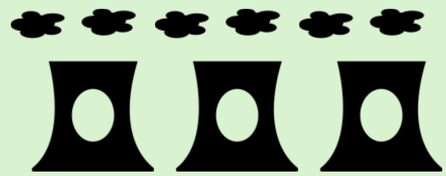
Existing U.S. Nuclear Power Plants

The United States is the largest producer of nuclear energy in the world, responsible for 30 percent of the world's nuclear power.[26] Within America, nuclear power is the single largest source of carbon-free electricity; having steadily provided approximately 19–20 percent of total annual U.S. electricity generation since 1990. For 2023 alone, American nuclear energy, supplied 775 billion kilowatt-hours (kWh) of electricity for the power grid or 18.6 percent of U.S. utility-scale electricity generation that year.[27 28]

As of 2025, there are currently 94 commercial nuclear reactors operating at 54 nuclear power plants across 28 American states. The latest reactors (Vogtle 3 and 4) came online in 2023 and 2024, respectively. The total

[26] U.S. Energy Information Administration, (August 24, 2023), https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.
[27] U.S. Energy Information Administration, (August 24, 2023), https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.
[28] U.S. Energy Information Administration, (February 29, 2024), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3#:~:text=In%202023%2C%20about%204%2C178%20billion,facilities%20in%20the%20United%20States.&text=About%2060%25%20of%20this%20electricity,%2C%20petroleum%2C%20and%20other%20gases.

number of operating reactors in the U.S. steadily declined from a 1990 peak of 112.[29] Even with these decreases, the fleet of nuclear power plants represents the second largest generator of electricity in the U.S., led only by gas generation.

Current Operations			
94 reactors	54 plants	28 states	3 new reactors online since 2000
			

Potential Future Plants[30]			
Approved Locations: 6 active early site permits issued	**New Technologies:** 8 design certifications for new reactors issued by the NRC	**New Build:** 5 licensees with Combined Licenses (COLs) for 8 new reactor units	**Lifetime Extensions:** Two plant restart applications and 8 license renewals granted

Between 2007 and 2009, the NRC received 18 applications for a total of 28 new nuclear units. Of these 18 applications, two have been suspended and eight have been withdrawn. NRC issued eight licenses, three of which were subsequently terminated. Four other licensed projects are either canceled or on hold. As of publication, the NRC lists only one active combined operating license application for new reactors. [31] In addition, several companies are working on the process to "restart" closed nuclear reactors.

Only three new commercial reactors have entered service in the U.S. in the 21st century, both after significant delays and cost overruns. In 2015, Tennessee Valley Authority's Watts Bar 2 in Tennessee entered operational testing to ensure all systems performed as designed, 42 years after construction began. It began commercial service in October, 2016. In 2023 and 2024, Units 3 and 4 at Southern Company's Alvin W. Vogtle Electric Generating Plant in Georgia entered commercial service in Georgia (seven years behind schedule and $17 billion over budget).

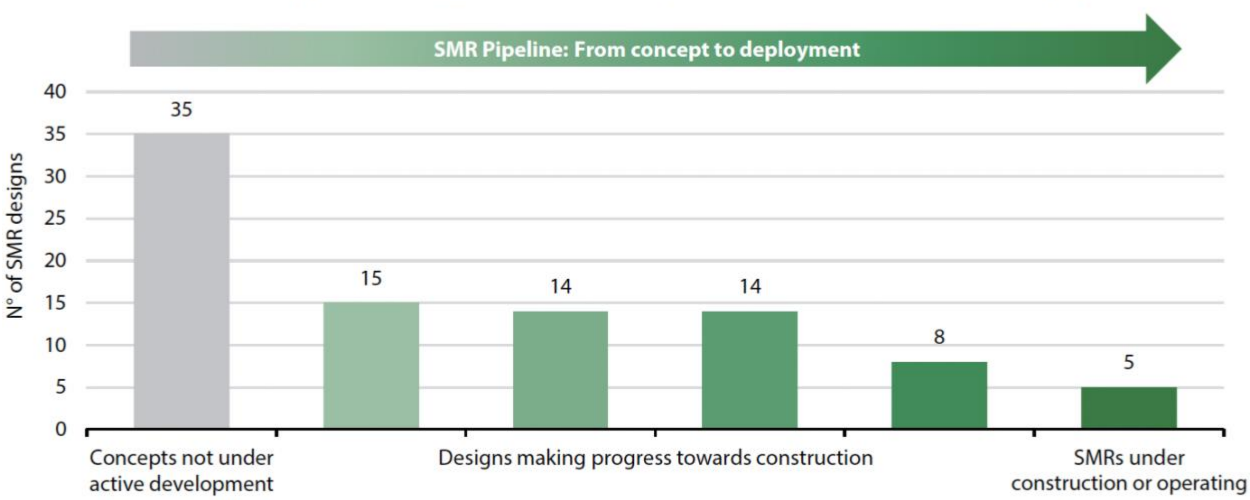
[29] U.S. Energy Information Administration, (August 24, 2023), https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.
[30] U.S. Nuclear Regulatory Commission, (September 15, 2025), https://www.nrc.gov/reactors/new-reactors/large-lwr/design-cert#appreviews.

[31] U.S. Nuclear Regulatory Commission, (Oct. 2025), https://www.nrc.gov/reactors/new-reactors/large-lwr/col-holder.html.

Twelve U.S. nuclear reactors have been retired since 2012, the most recent of which was Indian Point 3 in 2021.[32] Despite these reactor closures, nuclear power output actually grew in the U.S. thanks to efficiency updates to existing plants. Operators can make upgrades to the systems, components, or materials of turbines, generators, or reactors that allow for higher energy production while staying within the safety limits. Today, total U.S. nuclear electricity generation is surpassed only by gas-fired generation. [33]

In addition to system upgrades, new and advanced designs are gaining momentum in the nuclear sector. Small Modular Reactors (SMRs) are designed for modular construction, enabling faster deployment, reduced capital investment, and the ability to serve diverse energy needs. The Nuclear Energy Agency's Small Modular Reactor (SMR) dashboard launched with 21 small modular reactor concepts reviewed. The second edition showcases 56 reactor types in licensing around the world today (see chart below). These innovations will enable new end-uses and applications from powering remote areas to complementing renewable energy systems. [34]

Figure 25. **SMR pipeline: Progress from concept towards first commercial deployment**



Demand Projections

In its 2023 Annual Outlook projections, the U.S. Energy Information Administration (EIA) forecast that U.S. nuclear electricity generation will remain steady at supplying 807 billion kWh annually until the mid-2030s,

[32] Congressional Research Service, (June 10, 2024), https://crsreports.congress.gov/product/pdf/R/R46820/3#:~:text=Twelve%20U.S.%20nuclear%20power%20reactors,%25%20of%20U.S.%20nuclear%20capacity).
[33] U.S. Energy Information Administration (November 24, 2021), https://www.eia.gov/electricity/data/browser/
[34] OECD Nuclear Energy Agency, https://www.oecd-nea.org/jcms/pl_90816/the-nea-small-modular-reactor-dashboard-second-edition?details=true.

before declining by 2050 to a high estimate of 734 billion kWh (under the most favorable scenario) or a low estimate of 434 billion kWh (under the least favorable scenario).[35]

Two new units are currently planned at Florida's Turkey Point nuclear power plant. The planned projects are each 1,117 MW AP1000 reactors. NRC authorized the construction and operating license application for the units in 2018, but building has not yet commenced.[36]

Capacity Factors

Improved operating efficiency and maintenance have allowed the nuclear industry to increase the capacity factor for nuclear power plants from 56.3 percent in 1980 to an average of 92.7 percent in 2022. The capacity factor is a measure of how often an electric generator runs. It compares how much electricity a generator actually produces with the theoretical maximum output it could produce during a specific period of time (nameplate capacity).

The average capacity factor for nuclear power plants has remained around 90 percent since 2000, the highest of any energy source in the U.S. To compare, in 2022 when the average capacity factor for nuclear was over 90 percent, natural gas-fired generation had a capacity factor of about 65 percent, coal-fired generation operated at 48 percent capacity, and onshore wind generation had a capacity factor of 36 percent.[37]

Long Term Operations and LWR Sustainability

All existing domestic nuclear reactors in the United States are currently light-water reactors (LWRs); which come in two standardized forms: pressurized water reactors (PWRs) or boiling water reactors (BWRs). In LWRs, ordinary water, or "light water," is used to help moderate the chain reactions, to act as the cooling agent and to help remove the heat used to produce steam for turning the turbines of the electric generators.

- Many reactors have also had their operating licenses renewed so that they can continue to provide clean generation decades past their original 40-year operating lifetimes. The first 20-year license renewal period for any U.S. reactor began in 2009. Since then, the NRC has approved 94 reactors for extended service, including eight reactors now permanently shut down. Eight reactors operate under their original licenses. Additional license renewals beyond the initial 20-year license renewal period are expected in coming decades.[38]

Reflecting growing recognition of the need to preserve the carbon-free baseload generation of existing nuclear power plants amid unfavorable market pressures in the 2000s and 2010s, the DOE Office of Nuclear Energy's Light Water Reactor Sustainability (LWRS) Program was launched with the aim of supporting the long-term

[35] U.S. Energy Information Administration, (March 16, 2023), https://www.eia.gov/outlooks/aeo/ppt/AEO2023_Narrative_Figures.pptx.
[36] World Nuclear News, (April 6, 2018), https://www.world-nuclear-news.org/NN-Regulator-approves-licences-for-new-Florida-units-0604184.html.
[37] Statista, (2022), https://www.statista.com/statistics/183680/us-average-capacity-factors-by-selected-energy-source-since-1998/.
[38] Nuclear Regulatory Commission, Nov. 1, 2025 https://www.nrc.gov/about-nrc/nrcataglance

operations of high-performing existing nuclear power plants beyond 60 years through technical research and development.

Many commercial nuclear power plants in America are now operating beyond their original licensing period of 40 years, and their 60-year licenses issued by NRC will begin expiring between 2029 and 2039. In August 2012, after the termination of funding for the Yucca Mountain repository project, NRC issued an order suspending actions related to the issuance of operating licenses and license renewals. However, it resumed issuing licenses in 2014 after revising its Continued Storage of Spent Nuclear Fuel rule.[39] As of December 2023, the NRC has granted license renewals to 91 operating reactors. NRC is currently reviewing license renewal applications for 3 reactors, not including the renewal applications for Diablo Canyon's two units, which are under acceptance review.[40]

After the first license renewal, nuclear reactor licensees can apply for a subsequent 20-year extension for a total of 80 years of operation. The NRC in 2017 released new guidance on subsequent license renewal, focusing on aging management requirements for 60–80-year-old reactors. The first three licensees to submit subsequent applications were Turkey Point (Units 3 and 4), Peach Bottom (Units 2 and 3), and Surry (Units 1 and 2) in 2018, all of which the NRC approved. Another six subsequent renewal applications are under review, and seven applicants have submitted a Letter of Intent to apply for a subsequent extension.[41]

Reliable Baseload Energy

The Energy Information Administration (EIA) reported that electricity consumption grew by 2% in 2024 after nearly two decades of relatively steady demand. Electricity demand is forecast to continue growing at that rate in 2025 and 2026, which would be the first three years of consecutive growth in electricity demand since 2005–07. Demand growth is expected to be fastest in the industrial sector—by 2% in 2025 and 3% in 2026—as new semiconductor and battery manufacturing operations come online. In the commercial sector, demand will increase as data-center power consumption increases.[42]

Carbon free (nuclear and renewable) energy sources accounted for almost 40 percent of the country's electricity generation. The growth in carbon free energy sources has largely come from renewable sources including solar (3.1%) and wind (10.2%) which are intermittent electric power sources and do not supplant the need for reliable baseload generation.[43]

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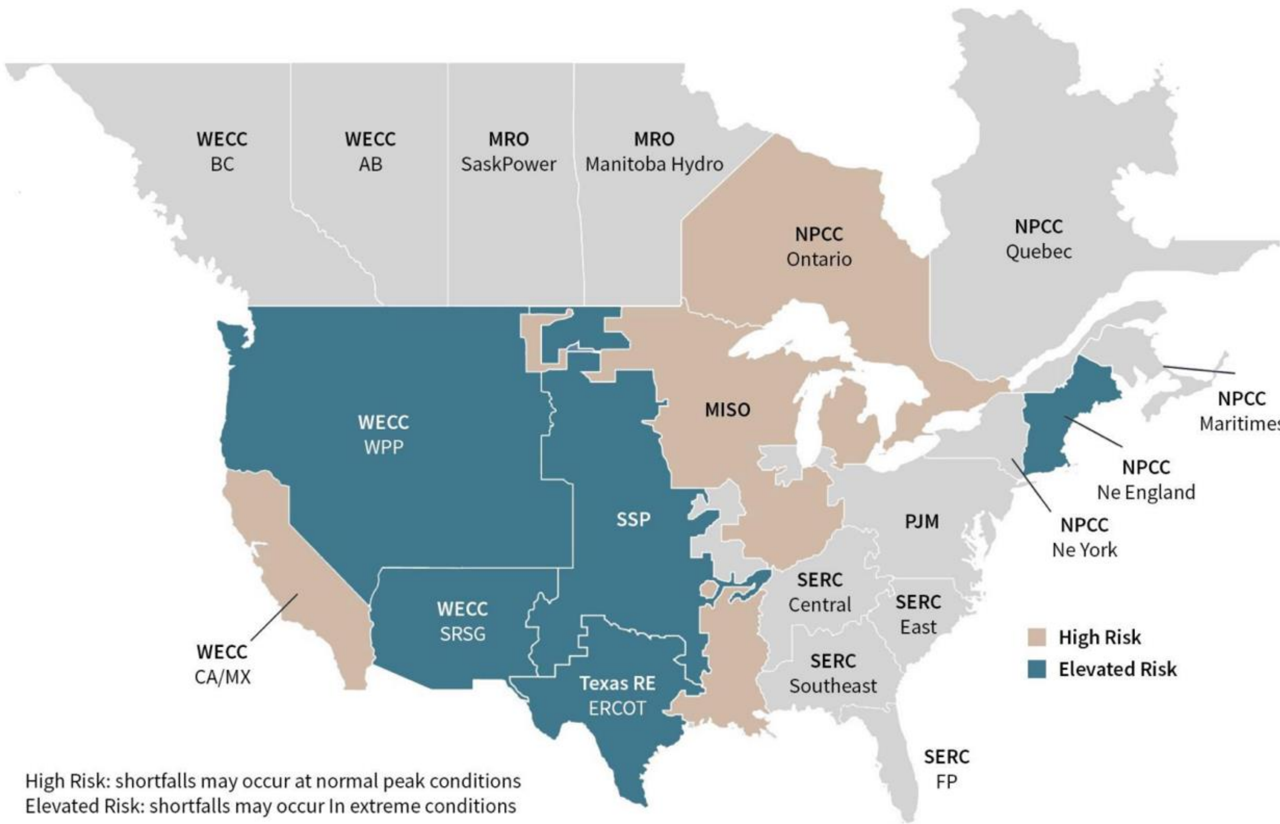
[39] Energy Information Administration, (October 29,2014), https://www.eia.gov/todayinenergy/detail.php?id=18591.
[40] Nuclear Regulatory Commission, (November 17, 2023), https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html
[41] U.S. Nuclear Regulatory Commission, (September 30, 2025), https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.
[42] Energy Information Administration, (October 28, 2025) https://www.eia.gov/pressroom/releases/press564.php
[43] Kutak Rock, (November, 2023), https://www.kutakrock.com/-/media/files/news-and-publications/publications/2023/november/what-is-the-cost-of-carbon-free-baseload-power-a-c.pdf.

The term “baseload” refers to the minimum amount of electric power delivered or required over a given period of time at a steady rate. Baseload electric power sources are power generation facilities which can consistently generate the electrical power needed to satisfy this minimum demand.

The comparison of alternative sources of power generation is complicated by trends impacting the power sector. While the rapid growth of renewables in some regions has resulted in excess capacity during certain hours of the day, additional baseload resources remain a critical need.

Today, there are regions around the country that face potential supply shortfalls in the near term. The North American Electric Reliability Corporation’s (“NERC”) Long Term Reliability Assessment released in December 2022 concluded that several independent system operators (“ISOs”) in the United States face high or elevated risks of resource shortfalls over the next five years.



The figure above highlights the ISOs at high and elevated risk. Potential electricity supply shortfalls 2023-2027 NERC attributes the supply challenges to the frequency of extreme weather events that need to be considered in resource adequacy planning and on planned retirements of generating assets. In total, over 88 GW of generating capacity is confirmed for retirement over the next ten years and much of this capacity comes from traditional baseload generation sources.

Water Use at Power Plants

Today's nuclear power plants typically use water for cooling. On average, a nuclear power plant withdraws about 270 to 670 gallons of water per megawatt-hour of electricity produced. For comparison, the Energy Information Agency shows coal-fired power plants withdraw about 20 to 50 times more water per megawatt-hour than nuclear plants do. And even natural gas power plants, which are considered relatively water-efficient, still withdraw about 8 to 18 times more water than nuclear plants.

Case Study: Protecting Aquatic Life at FPL

ECO Magazine describes the work by Florida Power and Light (FPL) to build a breakwater to address severe erosion damage caused by hurricanes. The nuclear operator added reef mats near its St. Lucie Nuclear Power plant to replicate the substrate of a natural reef. These reef mats reduce the force of waves and the likelihood of further erosion while creating new healthy coastal habitats to encourage biodiversity. The project serves both mitigation and conservation needs along the fragile coastline.

Nuclear power plants can help support aquatic life. How? By hosting artificial reefs. The warm water discharged from nuclear plants creates a kind of oasis for fish and other aquatic organisms, attracting them to the area. This can have positive effects on local fisheries and biodiversity. Plus, because nuclear plants don't emit greenhouse gases during operation, they help mitigate the impacts of climate change and reduce threats to aquatic ecosystems that are vulnerable to changes in temperature and precipitation.

Advanced Reactor Safety and Security

Advanced reactors use "novel coolants" and fuels. Novel coolants integrate different materials or components to safely manage higher temperatures and pressures while new fuels aim to last longer and create less waste. Because these technologies differ from what is used in Light Water Reactors, advanced reactor safety and security will require new rules that differ from conventional nuclear safety and security.

The Nuclear Regulatory Commission (NRC) primarily funds its activities through fees charged to licensees for the services provided by the agency. These fees cover the costs associated with licensing, inspection, and oversight of nuclear facilities and activities, including the review and licensing of advanced reactors. For advanced reactors specifically, the NRC may also receive funding from various sources such as government grants, appropriations, or collaborative agreements with other government agencies, industry stakeholders, or research institutions. These funds may be allocated specifically for advancing the regulatory framework for advanced reactor technologies, conducting research and development, or enhancing the NRC's technical capabilities to assess and license these innovative designs.

To facilitate changes at the NRC, Congress took several key actions:

- **Nuclear Energy Innovation and Modernization Act (NEIMA) of 2019:** This law directed the NRC to develop a new, faster, and more flexible licensing process for advanced reactors. It aimed to encourage innovation and streamline regulatory processes.
- **Funding Appropriations:** Congress has provided funding to the NRC specifically to support research and development of advanced nuclear technologies. This financial support allows the NRC to hire experts, conduct studies, and engage with new reactor designs.
- **Energy Act of 2020:** This act further supported the development of advanced nuclear reactors by promoting research, development, and demonstration of new technologies. It also directed the NRC to collaborate with other federal agencies and the private sector on these efforts.
- **Advanced Reactor International Safeguards Engagement (ARISE):** This program is a congressionally mandated effort that supports the implementation of International Atomic Energy Agency (IAEA) safeguards. The Advanced Reactor Safeguards (ARS) program is focused on U.S. R&D and aims to address challenges that advanced reactor developers face in meeting U.S. domestic safeguards.[44]

These actions have paved the way for the NRC to explore and potentially approve new, safer, and more efficient reactor designs.

Plant Safety and Security

Known as 3S's, three priority areas ensure nuclear facilities pose minimal risk of harm to the environment and the public. Safety, security, and safeguards are each crucial to nuclear management:

- **Safety:** Encompasses radiation risk due to equipment failures or human error, and involves the design of reactors, operational procedures, and emergency preparedness to prevent and respond to any incidents.
- **Security:** Focuses on protecting nuclear facilities and materials from threats like terrorism, sabotage, or theft. Strong security measures prevent unauthorized access and ensure that nuclear materials don't fall into the wrong hands.
- **Safeguards:** Involves monitoring and verifying that nuclear materials are not diverted from peaceful uses (like energy production) to make weapons. International organizations like the IAEA oversee safeguards to ensure compliance with non-proliferation agreements.[45]

[44] National Academies of Sciences, Engineering, and Medicine, (2023), https://doi.org/10.17226/26630.
[45] National Academies of Sciences, Engineering, and Medicine, (2023), https://doi.org/10.17226/26630.

According to the Nuclear Regulatory Commission (NRC), the terms "safety" and "security" commonly describe programs that promote the common defense and security, as well as protect public health and safety from threats of theft or sabotage.[46] The NRC is the regulatory authority responsible for ensuring the safe operation of U.S. nuclear power plants. NRC serves a vital role protecting public health and safety while enabling the country to realize the many benefits of nuclear technology, most notably the large-scale, reliable generation of base load electrical power with very low emissions to the environment. Commissioners have a strong background in the science and application of nuclear technology, particularly nuclear safety and electrical power generation, and have recognized accomplishments in the technical, management, legal, regulatory, or policy fields.

The Commission makes decisions on many matters involving nuclear technology and materials safety. The majority of Commission's work relates to the regulation of safety of nuclear power plants. It is not responsible for policymaking on nuclear energy use, but it is charged with overseeing safe application of nuclear technology in accordance with laws established by Congress.

Several departments within the NRC are tasked with ensuring nuclear safety, security, and safeguards. For example, the Office of Nuclear Reactor Regulation (NRR) is responsible for NRC's nuclear reactor safety mission. NRR's jurisdiction involves licensing, oversight, siting, rulemaking, and incident response. Reactor regulation also includes several other divisions and offices.[47] The NRC's Office of Nuclear Material Safety and Safeguards (NMSS) is tasked with facilitating effective collaboration between the NRC and state governments, local governments, federal agencies, and Native American Tribal Governments. NMSS programs include the Agreement State Program, Federal and State Liaison Program, and Tribal Liaison Program.[48]

To better understand the Nuclear Regulatory Commission, visit www.nrc.gov

Risk Assessment Approaches for Regulation

American nuclear regulators are moving incrementally toward a risk-informed, performance-based regulatory approach, an effort that began several decades ago. This represents a change from historical approaches to assessing risk that do not adequately characterize uncertainty. Previously, regulators used deterministic approaches. These approaches only modelled a single input at a time. Modern risk-assessment approaches offer greater fidelity along a range of potential outcomes.[49] Today, regulators rely increasingly on probabilistic methods that examine the probability an event might occur and its possible consequences.

New tools and methodologies allow the agency to focus on areas of higher risk while maintaining safety. Better risk assessment approaches increased the regulators' capacity to review and establish the safety profiles of advanced reactor designs. The agency iterated on these risk-informed and performance-based implantation

[46] U.S. Nuclear Regulatory Commission, (August 5, 2025), https://www.nrc.gov/security.html.
[47] U.S. Nuclear Regulatory Commission, (September 30, 2025), https://www.nrc.gov/about-nrc/organization/nrrfuncdesc.html#vpo
[48] U.S. Nuclear Regulatory Commission, (June 13, 2023), https://scp.nrc.gov/.
[49] U.S. Nuclear Regulatory Commission, (September 28, 2022), https://www.nrc.gov/docs/ML2226/ML22266A267.pdf.

plans. In 1994, the agency developed the Probabilistic Risk Assessment (PRA) Implementation Plan, which was superseded in 2000 by the Risk-Informed Regulation Implementation Plan (RIRIP). From 2007 to present-day, the agency has used the Risk-Informed and Performance-Based Plan (RPP).[50] Under RPP, the agency undertakes activities to integrate risk information and performance-based measures into its regulations, regulatory guidance, and oversight processes. Current activities fall under the three primary regulatory categories of reactor safety, materials safety, and waste management. RPP also requires evaluating which regulatory initiatives ought to be continued or retired, and what new initiatives may be needed.[51]

Why Uranium is an Important Component of Nuclear

Uranium is energy-packed, making nuclear energy the densest of energy technologies. A nuclear power plant can generate a massive amount of electricity from a relatively small physical space. According to the industry trade group, a typical 1,000-megawatt nuclear facility needs little more than 1 square mile to operate.[52] The energy density of nuclear reactors leaves more land available for other uses and reduces the environmental impact associated with energy production.

A small amount of uranium can produce an immense amount of energy, reducing the need for large-scale mining. For example, 1 kilogram of uranium generates as much energy as 1,500 tons of coal or 14,000 barrels of oil. This means nuclear power requires far less material extraction compared to fossil fuels, minimizing the environmental footprint of mining for energy resources.

Uranium mining's legacy in the United States includes negative environmental and health impacts, particularly for operations from the World War II era when regulations were lax. These impacts include radioactive contamination of land and water, and health risks to workers and nearby communities. Improvements in mining practices, stricter regulations, and better safety protocols have reduced these risks in modern uranium mining, but the legacy of past damage persists in some parts of the country.

Despite these challenges, current uranium resources can fuel a nuclear-powered future for decades. The International Atomic Energy Agency (IAEA) estimates that known uranium resources, totaling about 6.1 million tons, could supply nuclear power for over 130 years at current consumption rates. Furthermore, advanced technologies like fast reactors and fuel recycling could extend these resources with more efficient use of uranium and less waste generation.

In May 2024, Congress passed and signed into law a ban on the import of Russian uranium and made provisions to revive domestic nuclear fuel production by unlocking $2.72 billion to expand domestic uranium

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[50] U.S. Nuclear Regulatory Commission, (September 20, 2021), https://www.nrc.gov/about-nrc/regulatory/risk-informed/history.html.
[51] U.S. Nuclear Regulatory Commission, (July 7, 2020), https://www.nrc.gov/about-nrc/regulatory/risk-informed/concept.html.
[52] DOE Office of Nuclear Energy, (2019), https://www.energy.gov/sites/default/files/2019/01/f58/Ultimate%20Fast%20Facts%20Guide-PRINT.pdf.

enrichment and conversion capacity.[53] Called the "Prohibiting Russian Uranium Imports Act," the ban came into effect in August. However, utilities may apply for waivers until the end of 2027, based on determinations by the Secretary of Energy that alternative sources of uranium are not viable. At the same time, the Department of Energy is working with the private sector to expand domestic enrichment capacity.

Recommendations

The nuclear landscape evolves as new energy technologies emerge, and electricity markets change. Currently, all of the nuclear production sites and sites where defense nuclear waste activities occurred are de facto waste storage sites. Communities need to understand that until a disposition path becomes a reality, any community that undertakes new nuclear projects will become a waste storage site.

Local governments should work together to highlight the need for DOE and Congress to act as quickly as possible to develop long-term waste disposal and storage solutions so that waste currently sitting in communities and at reactor sites longer than originally expected can be removed. Communities should highlight and educate state and federal policymakers on the effects of this waste remaining in place, including increased security costs and the suspension of new nuclear development.

[53] DOE Office of Nuclear Energy, (May 14, 2024), https://www.energy.gov/articles/biden-harris-administration-enacts-law-banning-importation-russian-uranium.

Nuclear Sector History

Agencies that influence today's nuclear power sector continue to evolve. Local officials will benefit from understanding some of the reasons why the U.S. has only completed a few new nuclear projects in the last three decades.

Today's nuclear resurgence must address the questions of economics, political support, nuclear waste management and the federal budget outlook which have historically restricted new nuclear development. The political stalemate over the future of Yucca Mountain and subsequent court cases over fee adequacy and the Nuclear Waste Fund also will have a significant impact on when and how new nuclear facilities will be developed.

U.S. Nuclear Energy Before the NRC (1942-1974)

The field of nuclear science developed from the 1895 discovery of ionizing radiation and progressed through a series of experiments in the 1930s that discovered that splitting nuclei causes a fission chain reaction, which can create huge amounts of energy.

The outbreak of the Second World War refocused an international scientific competition between physicists to create a controlled fission chain reaction into a race between the warring Allies and Axis powers to build an Atomic Bomb. As part of joint American-British efforts led by the U.S. military-run Manhattan Project, the first controlled fission chain reaction occurred in December 1942 within the world's first artificial reactor, the Chicago Pile-1 (CP1), an experimental graphite pile secretly built under the football field at the University of Chicago. In July 1945, the first atomic device was tested successfully by the U.S. at Alamogordo in New Mexico, followed by the dropping of atom bombs on Japan at the cities of Hiroshima and Nagasaki in August 1945, which hurried the end of the war.[54]

After the war, the Atomic Energy Act of 1946 established the U.S. Atomic Energy Commission (AEC) to assume control over the Manhattan Project. This put the scientific and industrial complex for the designing and production of nuclear weapons and the development of nuclear reactors for naval propulsion under civilian control. Under the AEC and its National Laboratories, the world's first nuclear reactor to produce electricity – the small Experimental Breeder reactor (EBR-1) – started up in December 1951, in the state of Idaho. Meanwhile, U.S. Admiral Hyman Rickover applied lessons he learned building the Navy's nuclear-powered submarines to the development and deployment of reactors for civil on-land use.[55]

Following President Dwight Eisenhower's "Atoms for Peace" speech at the United Nations in December 1953, Congress passed the Atomic Energy Act of 1954. This act ended exclusive federal government use of the atom, directed the AEC to embark on peaceful applications of atomic (nuclear) energy, and kickstarted the commercial nuclear energy industry. The Atomic Energy Act bestowed the AEC with the dual role of promoting the development and deployment of nuclear energy and regulating nuclear technologies to ensure public health and safety. That same year, AEC initiated the construction of the world's first full-scale nuclear power plant at Shippingport, Pennsylvania, which came online in 1957.[56] [57]

The AEC's support in the development and deployment of the first wave of commercial nuclear reactors was the largest undertaking in the energy sector by the federal government since the electrification of rural America and the construction of hydroelectric dams under the Roosevelt administration of the 1930s and 1940s.[58] The first demonstration reactors proved pricey with first-of-a-kind costs but within a decade, private companies were taking advantage of economies of scale to drive down costs to build bigger nuclear power plants.[59]

The economic breakthrough for American nuclear energy occurred in 1963 when General Electric was contracted by a utility to build a reactor at Oyster Creek power plant in New Jersey at the same price as a coal-fired unit of the same generating capacity size at the same location.[60] By the mid-1960s, 75 reactors were on

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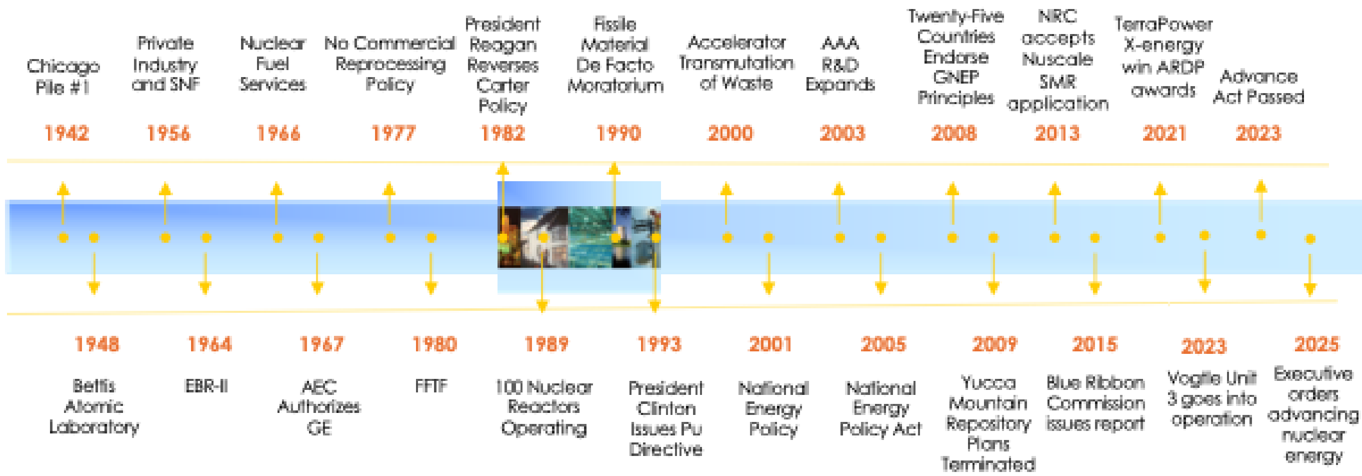
[54] World Nuclear Association, (April 2024) https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx.
[55] World Nuclear Association, (April 2024) https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx.
[56] DOE Office of Lead Management, https://www.energy.gov/lm/brief-history-department-energy.
[57] Yergin, Daniel. The Quest: Energy, Security and the Remaking of the Modern World. The Penguin Press, (2011), p. 360-368.
[58] DOE Office of Lead Management, https://www.energy.gov/lm/brief-history-department-energy.
[59] Plumer, Brad, (February 29, 2016), https://www.vox.com/2016/2/29/11132930/nuclear-power-costs-us-france-korea.
[60] Weinberg, Alvin M. and Young, Gale. "The Nuclear Lecture Revolution: 1966" Proceedings of the National Academy of Sciences of the United States of America. Vol. 57, No. 1. (January 15, 1967). pp. 1-15. National Academy of Sciences, https://www.jstor.org/stable/57836?seq=1#page_scan_tab_contents.

order across America.[61] [62] By decade's end, construction costs for new reactors were lowered by a third – making nuclear power plants cheaper to build than today's natural gas-fired combined-cycle power plants.[63]



Origins of Today's Licensing Process

The Atomic Energy Commission (AEC) came under increasing scrutiny in the 1960s. Critics questioned its dual mission of regulating and promoting nuclear energy as a conflict of interest that undermined nuclear safety and regulatory oversight. This criticism was compounded by the 1970s energy crisis. The resulting substantial petroleum shortages and price hikes hastened a series of reorganizations of federal energy programs and policy by the White House and Congress. The controversy over AEC culminated in the Energy Reorganization Act of 1974, which split the agency into (what eventually became) the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC).[64]

The DOE brought most federal energy activities under one umbrella and framework for national energy planning; with the DOE being responsible for the research, development, and promotion of energy technologies–-including reactors, the nuclear weapons program, and more. Established in 1975, the NRC was given regulatory oversight in reactor safety, radiation protection, management of nuclear materials, including commercial waste, and the licensing of reactor designs, nuclear technologies, and nuclear projects.[65] [66]

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[61] DOE Office of Lead Management, https://www.energy.gov/lm/brief-history-department-energy.
[62] U.S. Nuclear Regulatory Commission, (September 10, 2021), https://www.nrc.gov/about-nrc/history.html.
[63] Plumer, Brad, (February 29, 2016), https://www.vox.com/2016/2/29/11132930/nuclear-power-costs-us-france-korea.
[64] U.S. Nuclear Regulatory Commission, (September 10, 2021), https://www.nrc.gov/about-nrc/history.html.
[65] U.S. Nuclear Regulatory Commission, (September 10, 2021), https://www.nrc.gov/about-nrc/history.html.
[66] U.S. Nuclear Regulatory Commission, (September 10, 2021), https://www.nrc.gov/about-nrc/history.html.

Other Relevant Agencies and Laws

Throughout the 1960s and 1970s, the overlapping environmentalist, consumer advocacy, anti-nuclear energy, and nuclear disarmament movements continued to rise to prominence. Environmentalism became a priority for the Nixon administration, which ushered in a new safety-focused and litigation-driven regulatory regime with the enactment of the National Environmental Policy Act of 1970 (NEPA) and the creation of the U.S. Environmental Protection Agency (EPA) in 1971. The 1971 landmark ruling by the D.C. Circuit Court of Appeals, in favor of a citizen group challenge over the environmental impact of Maryland's Calvert Cliffs nuclear power plant, ordered federal agencies to comply with NEPA and required nuclear power plants to perform full Environmental Impact Statements (EIS). Now, federal nuclear regulators had to consider non-radiological environmental issues such as the thermal effects of water-cooling intake and discharge of nuclear power plants into rivers.

The *Calvert Cliffs decision* did more than require nuclear projects to receive EIS approval before receiving construction and operating licenses. The ruling opened nuclear project litigation and greater public input. The decision increased the time to construct a nuclear power plant by two years from the then-expected nominal six years. Overnight, according to the AEC, the revised regulations directly affected 66 license applications involving 97 reactors, five reactors that received operating licenses after the effective date of NEPA, and 10 provisional operating licenses issued before 1970.[67]

Case Study: Three Mile Island

In March 1979, Pennsylvania's Three Mile Island (TMI) nuclear power plant suffered a series of minor equipment failures, instrumentation malfunctions, and operator errors that impeded adequate cooling water circulation to the reactor core. This resulted in the overheating and partial meltdown of TMI Unit 2's reactor core and the subsequent minor release of radioactive steam.[68]

Thousands of people fled their homes; residents were instructed to keep their windows tightly shut and their air conditioners turned off to prevent intake of contaminated air. Almost a million people were told to prepare for immediate evacuation amid nationwide fears of a major radioactive leak and total meltdown.

Ultimately, no injuries, deaths or direct health effects were caused by the accident. Detailed studies by experts and health officials determined that approximately 2 million people in the nearby area were exposed to the radiation release and received an estimated average radiation dose was about 1 millirem above the area's

[67] Davis, Will. "Nuclear Plant Construction Delay and Cost 3." ANS Nuclear Cafe, American Nuclear Society, (November 2, 2018), https://www.ans.org/news/article-2087/nuclear-plant-construction-delay-and-cost-3/.
[68] DOE Office of Nuclear Energy, (May 4, 2022), https://www.energy.gov/ne/articles/5-facts-know-about-three-mile-island#:~:text=Experts%20determined%20that%20the%20approximately,100%2D125%20millirem%20per%20year.

natural background of about 100-125 millirem per year. This is a sixth of the dose from a chest X-ray (about 6 millirem).

Radiation released from the Three Mile Island accident's exposure had no detectable adverse effects on the health of plant workers, the public, or the surrounding wildlife, vegetation and environment. The United States' 1990 Biological Effects of Ionizing Radiation (BEIR) report concluded that "[t]he collective dose equivalent resulting from the radioactivity released in the Three Mile Island accident was so low that the estimated number of excess cancer cases to be expected if any were to occur, would be negligible and undetectable."[69]

A $973 million, 12-year-long cleanup ensued for TMI Unit 2.[70] Its fuel and damaged reactor core debris were removed and shipped to Idaho National Laboratory. In 1993, the unit was put into long-term, monitored storage to await decommissioning at the same time as Unit 1, which continued to operate for 40 years before shutting down in 2019.

The Three Mile Island accident led to an overhaul of safety management, with greater focus on human factors and preventing operator errors. Adequate technical standards established and enforced, increased training of operators, and standardization of industry technical standards and plant control designs, and the founding of the Institute of Nuclear Power Operations (INPO) to prevent another accident from occurring.

In the wake of the nonfatal accident that released less than 100 millirem outside plant boundaries, every U.S. reactor still under construction at the time—51 in total—suddenly faced significant regulatory delays, changes in safety procedures, and new back-fit requirements. Construction times doubled, stretching out past 10 years, while costs soared. [71]

Case Study: Fukushima Daiichi

The Japan earthquake and tsunami of March 11, 2011, killed approximately 19,000 people in Japan. The natural disaster subsequently triggered the partial meltdown of Japan's Fukushima Daiichi nuclear power plant. The Fukushima Daiichi facility suffered little damage from the 9.0 magnitude earthquake. Its reactors "scrammed" – shut down automatically – as soon as the earthquake struck. However, the earthquake sent the region into a blackout and with the loss of external power supplies, the nuclear power plant found itself in the dark.[72]

Fukushima Daiichi plant operators had counted on emergency, on-site backup generators to kick in but subsequent 33-foot tsunami waves had breached the plant's sea walls, flooding the station and making the backup generators inoperable. Without electricity, Fukushima Daiichi's reactor operators were unable to keep

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[69] National Research Council (US) Committee on the Biological Effects of Ionizing Radiation (1990), https://www.ncbi.nlm.nih.gov/books/NBK218714/.
[70] American Nuclear Society (July 11, 2012), https://wx1.ans.org/pi/resources/sptopics/tmi/cleanup.php.
[71] Corey, G.R., IAEA Bulletin, https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull21-5/21502795459.pdf.
[72] Yergin, Daniel. The Quest: Energy, Security and the Remaking of the Modern World. The Penguin Press, (2011), p. 411-414.

the water pumps working for cooling the reactors. The resulting nuclear accident unfolded over a period of weeks. The loss of coolant water occurred over time and left reactors over-heating. The damaged plant led to a hydrogen explosion and fires, resulting in radiological releases into the environment, and a partial meltdown of reactor cores. Fukushima Daiichi workers brought water into the reactors to prevent a full meltdown, drained out radioactive water from the flooded station, restored backup generators, and got plant controls working again.[73]

No civilian deaths or discernible cancer rate increases can be attributed to radiation released from Fukushima Daiichi, concluded the United Nations Scientific Committee on the Effects of Atomic Radiation after a decade-long investigation.[74] However, thousands were evacuated, and numerous deaths did occur due to exposure to cold weather, stress and inadequate access to housing and healthcare.

Over a decade later, cleanup activities continue at Fukushima Daiichi under the supervision of the Japanese government and the UN's International Atomic Energy Agency (IAEA). This involves the gradual release of treated water from the damaged nuclear power plant. The water recovered has been treated by a processing system to remove radionuclides other than tritium and to dilute the tritium concentrations to safe levels consistent with international standards.[75]

Recommendations

Past experiences regarding nuclear activities, siting and oversight offer important insights for future projects. As a community considers whether to host a new nuclear mission, the local government will benefit from factoring in its primary responsibilities into the decision-making process. History provides examples of how officials have met these responsibilities, including:

- Securing a viable economic future through retail, housing, industrial and commercial development.
- Providing services such as police and fire protection, emergency response, public works, and public health services.
- Developing and maintaining park and recreation opportunities; traffic management; education; land use planning; property recordkeeping; and property protection through zoning control, building permits and deed notices.

Local governments play a key role in addressing these responsibilities and balancing competing interests (e.g, protection of public space such as parks versus the need for development). A major concern in this regard is the possible conflict between environmental protection and economic development. To be credible in this role, local government officials must demonstrate a transparency in their decision-making. Interest groups do

[73] Yergin, Daniel. The Quest: Energy, Security and the Remaking of the Modern World. The Penguin Press, (2011), p. 411-414.
[74] United Nations Information Service Vienna. (March 9, 2021), https://unis.unvienna.org/unis/en/pressrels/2021/unisous419.html.
[75] Nuclear Newswire, (April 30, 2024), https://www.ans.org/news/article-5997/release-of-fukushimas-treated-water-going-as-planned-iaea-says/.

not expect to get all they want, but they do expect to be heard, to be taken seriously and to be informed of their local government's decisions and processes.

There are many provisions communities may want to adapt for future projects, and those options can be explored under five themes:

1. Early Engagement & Transparency
    - Has engagement begun before major decisions?
    - Is information clear, plain-language, and complete?
    - How will ongoing dialogue be maintained?
2. Credible Oversight & Independent Verification
    - Which independent bodies will verify safety claims?
    - Are inspection reports and monitoring data public?
    - Can we request third-party reviews or resources to hire third-party engineers to help us?
3. Realistic Benefits & Avoiding Over-Promising
    - Are job and revenue projections conservative and data-backed?
    - How does this project support our local priorities?
    - Are comparable project outcomes provided?
4. Community Consent & Participation
    - How do residents influence decisions—not just comment?
    - Is an advisory or technical committee planned?
    - What mechanisms ensure community input is used?
5. Full Lifecycle Accountability
    - What happens after construction?
    - Is there a long-term waste, monitoring, and emergency plan?
    - Who pays if obligations outlast the company?

To address these questions throughout the various stages of a project, potential host communities may also consider whether they want to require a position on an oversight board of advisory committee (if a new waste management organization is created) as a condition for hosting a new nuclear facility.

Economics of Nuclear Power

This section explores the economics related to building nuclear power plants and explains some of the reasons why the U.S. has only completed a few new nuclear projects in the last three decades. Elected officials possess many tools to facilitate risk reduction strategies and creative financing options to support new projects as economic drivers in their communities. Understanding the underlying market dynamics can help shape creative solutions, especially where the community will be purchasing power from the facility.

Costs

Early-stage costs of building a nuclear power plant, which typically are much higher than the cost of building a new coal-fired plant, are by far the biggest costs in the lifecycle of a plant. Once nuclear plants are operating, they are cheap to run and are typically cost-competitive with other forms of electricity generation.[76]

According to a World Nuclear Association report, "Nuclear Power Economics and Project Structuring," upfront capital cost heavily influences the economics of nuclear plants, accounting for roughly 60% of their total levelized (i.e. lifetime) cost.[77] For the 75 commercial reactors built in the United States between 1966 and 1986, the average actual cost of construction exceeded the initial estimates by more than 200 percent.[78]

The 1970s for U.S. nuclear energy represented a decade of cost overruns brought on by runaway inflation, increasing regulation, and heightening skepticism from the public. The decade closed out with the 1979 partial

[76] World Nuclear Association, (September 29, 2023), https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx#:~:text=Uranium%20has%20the%20advantage%20of,than%20for%20coal%20or%20oil.
[77] Nuclear Power Economics and Project Structuring, (2017), World Nuclear Association. https://world-nuclear.org/our-association/publications/online-reports/nuclear-power-economics-and-project-structuring.aspx.
[78] Grunwald, Michael, (March 27, 2009), http://www.time.com/time/printout/0,8816,1888119,00.html#.

meltdown of a reactor at Three Mile Island nuclear power plant.[79] The accident had a chilling effect for utilities' appetite for new nuclear energy. Orders for more than 100 new reactors across the U.S. were canceled. Until Vogtle 3 and 4 came online in 2023 and 2024, Watts Bar 2, the last reactor within the U.S. to go into operation (in 2016), was actually ordered in 1976.[80]

In wake of Three Mile Island, the backfitting of safety equipment and imposition of new regulation and safety requirements spiked costs for reactors still under construction. As a result, the cost to build a total of four new reactors at California's San Onofre and Diablo Canyon nuclear power plants ultimately blossomed to about $4.5 billion and more than $5 billion respectively once they were completed in 1984 and 1985.[81] Other projects weren't as fortunate; construction was halted on plants that were as much as 90 percent finished, like Alabama's scrapped Bellefonte nuclear power plant. Long Island's Shoreham nuclear power plant was finished in 1984 for $6 billion only to never come online before being permanently shut down in face of local opposition and sold for one dollar.

Nuclear power plants are more expensive to build than other forms of electricity generation due to larger, upfront capital costs; however nuclear energy's low fuel costs and high-capacity factor make them affordable and even profitable to own and operate in many electricity markets. Nuclear energy plants, and SMRs in particular, carry an initial cost premium, but also provide significant value to the grid in the terms of providing reliable, dispatchable, baseload energy.

See the Section below on "How Nuclear Plants Earn Money" for more details.

Cost Factors

The discussion around sources of carbon free power often focuses on cost per unit of capacity which can be misleading when comparing technologies with different capacity factors. For example, upfront capital investment in renewables sources is comparatively low relative to new nuclear sources, but so too are the capacity factors (which drives up the delivered power cost on a per unit basis). Similarly, the timing and tenor of cashflow investments and returns vary significantly from one technology to another.[82]

The cost of different types of power plants are often compared by a metric called the **levelized cost of electricity (LCOE)**. LCOE is the net present value of the total lifecycle costs to construct and operate an electric generating plant over its lifespan, divided by a discounted total of its electricity production, expressed typically in cost per megawatt hour.

LCOE is a project's break-even price point that its electricity must fetch, after taking account of all lifetime costs, inflation and the opportunity cost of capital through the application of a discount rate. This basic

[79] Blunt, Katherine. California Burning. Portfolio, Penguin Random House. 2022. p. 54-63.
[80] Yergin, Daniel. The Quest: Energy, Security and the Remaking of the Modern World. The Penguin Press, 2011, p. 373-374.
[81] Blunt, Katherine. California Burning. Portfolio, Penguin Random House. 2022. p. 54-63.
[82] Kutak Rock, (November 2023), https://www.kutakrock.com/-/media/files/news-and-publications/publications/2023/november/what-is-the-cost-of-carbon-free-baseload-power-a-c.pdf.

economics metric encompasses all financial aspects, including the costs of capital, not just the initial 'overnight' cost. LCOE serves as a crucial economic benchmark for evaluating and comparing the efficiency of power plants.[83]

LCOE measures the lifetime costs of a power plant and divides these costs by the plant's energy production. LCOE facilitates comparisons of technologies and considers all costs associated with generating electricity, including capital expenditures, operating expenses, fuel costs, decommissioning, and cost of capital. It is expressed as the cost per unit of electricity generated, usually in dollars per megawatt-hour (MWh). The LCOE is calculated by taking the net present value of the costs of the project over the project lifetime and dividing it by the net present value of the generation of the project over the project lifetime.

While LCOE facilitates comparisons of economics, it carries several drawbacks, the most significant of which is that different sources of power serve different roles in delivering reliable and resilient power to retail, commercial and industrial loads. The LCOE of a technology ignores the value of dispatchability for energy sources to match grid demand compared to some technologies that are dependent on external factors such as the availability wind or sunlight. SMR technology can provide load-serving utilities and the grid a generation technology that can provide baseload, dispatchable, reliable, and clean power.

On a levelized (lifetime) basis, a nuclear power plant's electricity generation offers an economic source for revenue, as its electricity has inherent advantageous attributes, including offering energy security, reliability, dispatchability and avoided emissions through a constant supply of zero-carbon baseload power.

Utilities consider a variety of factors when assessing the cost of new nuclear:

- **Capital Costs**: Capital costs are incurred prior to construction, during design and licensing, and while the nuclear power plant is under construction. This includes the cost of site preparation, licensing, manufacturing, construction including equipment, engineering and labor; and financing a nuclear power plant.
    - Capital costs are expressed in terms of the generating capacity of the plant (dollars per kilowatt) that can be compared with those of different power generation technologies.
- **Construction Costs:** These costs include land acquisition, site preparation, construction, approvals, and the purchase/rental of specialized equipment
- **Cost of Capital:** Because of nuclear's long construction times, the cost of obtaining financing through debt (loans or bonds) or equity (selling shares), can increase over time with interest rate fluctuations or inflation.
- **Regulatory and Licensing Costs:** The nuclear industry is heavily regulated for safety and environmental reasons and securing licenses involves investing in these complex processes.

[83] Nuclear Power Economics and Project Structuring, (2017), https://world-nuclear.org/our-association/publications/online-reports/nuclear-power-economics-and-project-structuring.aspx

- **Plant operating costs:** This includes the costs of fuel, operation and maintenance (O&M), and a provision for funding the decommissioning the plant and interim storage and disposal of used fuel and wastes.
    - Operating and maintenance costs, which account for about 66% of the total operating costs, are divided into "fixed costs" incurred whether or not the plant is generating electricity and "variable costs," which vary in relation to generation output. Normally these costs are expressed relative to a unit of electricity (ex: cents per kilowatt-hour).
    - Fuel costs, including costs for fuel management and final disposal of spent nuclear fuel, are cost-advantageous for nuclear power plant operations and constitute up to 10 percent of a facility's overall costs.
- **Operational Efficiency:** Once running, nuclear plants have low fuel costs, high efficiency, and a long lifespan (40-60 years), providing steady long-term returns.
- **Lifetime Operating Costs:** which include the costs of decommissioning and disposal of used fuel and waste – are calculated with an estimated levelized cost at present value. Decommissioning costs are about 9-15% of the initial capital cost of a nuclear power plant.
    - When discounted over the plant's lifetime, decommissioning contributes only a few percent to the investment cost and even less to the generation cost. In the U.S., decommissioning costs account for 0.1-0.2¢/kWh, or no more than 5% of the cost of the electricity produced.
- **Incentives and Carbon Credits:** New demands on our electricity system have created financial incentives such as loan guarantees, tax credits, or subsidies for low-carbon energy projects, offsetting costs for nuclear projects.
- **External costs:** External costs paid for by "society" from the operation of nuclear energy are usually assumed to be zero as a result of its carbon-free attributes and energy density but could include the costs of dealing with a serious accident that exceeds the insurance limit and in practice would need to be covered by the federal government.
- **Other costs:** Such as grid system costs and nuclear-specific taxes.

The main economic risks facing existing nuclear energy to reflect suppressed wholesale electricity prices being suppressed by subsidized intermittent renewable and low-cost gas-fired generation.

Low fuel costs give nuclear energy a competitive advantage over coal and gas-fired generators, which have higher fuel costs and depend on volatile fuel markets and "just-in-time" fuel deliveries.

For nuclear plant operations, fuel cost figures include used fuel management and final waste disposal. The share of fuel expenditures in total costs varies largely due to reactor and fuel technologies.

Existing nuclear power plants run with a high degree of predictability and with an operating cost lower than almost all fossil fuel-fired competitors, with a very low risk of operating cost inflation. Existing reactors are now expected to operate for 60 years and longer under extended operational licenses.

Whereas nuclear power plants are characterized by high capital investment but relatively low fuel costs, this cost ratio is typically reversed in natural gas plants, which are cheap to build but costlier to operate and fuel.

The "back end" of the fuel cycle, which includes the management, storage, and permanent disposal of used fuel rods, constitutes up to 10 percent of the overall costs per kWh, or less if used fuel is directly disposed of rather than reprocessed.[84] The United States' $26 billion Nuclear Waste Fund is funded by a one mill per kilowatt hour (0.1¢/kWh) levy on the production of nuclear generation.[85]

Nuclear power plants internalize the costs of waste byproducts by including financing provisions for the disposal of used fuel and eventual plant decommissioning, fossil fuel and other generators have not internalized their external costs, such as the production of greenhouse gas emissions. The future inclusion of these external costs in the calculation of carbon-emitting generators improves the economic competitiveness of new reactors and other low-carbon sources of electricity.[86]

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[84] Congressional Budget Office, Testimony of P. Orszag Costs of Reprocessing Versus Directly Disposing of Spent Nuclear Fuel, accessed Nov. 2025 https://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/88xx/doc8808/11-14-nuclearfuel.pdf
[85] Nuclear Power Economics and Project Structuring, (2017), https://world-nuclear.org/our-association/publications/online-reports/nuclear-power-economics-and-project-structuring.aspx.

How Nuclear Plants Earn Money

America's electricity sector is divided into two electricity markets:

- **Regulated markets**, where utilities own most generation assets and all transmission and set prices under state regulatory oversight by public service commissions, and,
- **Deregulated markets**, where market competition influences pricing.

In the past, most U.S. electricity markets were fully regulated. Utilities once owned all generators and power lines (distribution and transmission). Congress put an end to the monopoly rule of state-regulated utilities with the Public Utility Regulatory Policies Act (PURPA) of 1978 and the Energy Policy of Act of 1992. This meant that utilities were vertically integrated, controlling electricity generation, transmission, and distribution within specific geographic areas. State governments or public utility commissions closely regulated these utilities, approving rates that ensured they could cover costs and provide reliable service.

The monopoly-like structure began to change in the 1990's. A legislative push for "deregulation" of electricity service in favor of consumer choice led to the creation of "deregulated" competitive wholesale electricity markets for most of America. However, "regulated" markets of state-supervised, vertically integrated utilities remain in control for a third of the country. Examples of states with regulated electricity markets include North Carolina and parts of the Southeast.

Regulated Markets

In regulated markets, state public utility commissions oversee how electric utilities set their electricity rates and safeguard consumers from being overcharged. Retail electricity prices are based on recovering the utility's operating and investment costs alongside a "fair" rate of return on those investments. This revenue requirement must be approved by the state's public utilities commission.[87]

Today's state-regulated utilities also have non-utility-owned independent power producers operating within their service areas and requirements to source so much of their electricity from wind, solar and other (often renewable) sources, as required by state portfolio standards, which have eclipsed PURPA in most states. Vertically integrated utilities can also engage in wholesale bilateral trading with neighboring areas during times of need or when it is cheaper to purchase excess electricity from others than to generate power using facilities within their own areas. These transactions are subject to regulation by the Federal Energy Regulatory Commission (FERC).[88]

Regulated Markets:

- Service one-third of U.S. electricity needs as of 2024.[89]
- Home to 54 GW of nuclear capacity, including the first reactors to be built in decades (Watts Bar 2, Vogtle 3 and Vogtle 4).[90]
- Centralized, state regulatory supervision and vertically integrated planning process.
- Offer a guaranteed cost of recovery for nuclear power plants.
- Utility customers bear the financial risks of energy investments.

Nearly all of America's existing nuclear reactors were financed in traditional regulated markets where investor-owned electric utilities operated as state-regulated, vertically-integrated monopolies in the generation and transmission of all electricity within their service areas.[91]

Cost Recovery for Nuclear Energy

Regulated markets offer a guaranteed operational cost recovery for nuclear power plants, with customers bearing the costs and risks.[92]

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[87] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[88] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[89] Nuclear Power Economics and Project Structuring, (2017), https://world-nuclear.org/our-association/publications/online-reports/nuclear-power-economics-and-project-structuring.aspx
[90] World Nuclear Association, (March 5, 2024), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[91] World Nuclear Association, (March 5, 2024), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[92] World Nuclear Association, (March 5, 2024), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.

In regulated markets, vertically integrated utilities must receive state approval for power plant investments and recover the costs of these investments through electricity rates. The utilities must demonstrate that the investments are needed to meet electricity demand in the long term through an Integrated Resource Planning (IRP) process. With state approval, regulated utilities put the levelized cost of electricity for a project into their rate base and amortize it against electricity sales. The inclusion of operation and maintenance (O&M) costs for the investments increase the utility's rate of return.[93]

Under the structure of regulated markets, ratepayers foot the bill and bear the risk of investments because utilities can recover their costs through rates, regardless of what happens to the project.

Deregulated Markets

In the name of consumer choice and economic efficiency, the 1990s saw the widespread creation of "deregulated" wholesale competitive markets across the U.S. that wrested control away from both state regulators and investor-owned utilities.

Deregulated Markets:

- Services nearly two-thirds of U.S. electricity demand.[94]
- Home to about 45 GW of nuclear capacity.[95]
- Competitive wholesale markets where power is bought by load-serving entities and sold by merchant generators across power lines owned by transmission-only utilities.

In deregulated markets, regional transmission organizations (RTOs) and independent system operators (ISOs) have assumed the role of grid operators. These organizations administer a series of market auctions to ensure electricity supply meets demand. Wholesale electricity prices are often undercut by cheap gas-fired generators and subsidized wind power that's given dispatch priority by RTOs and ISOs. Consequently, nuclear merchant generators – especially single-unit facilities – struggle to stay competitive in market conditions that favor cheap gas and subsidized wind.

In deregulated markets, neither transmission and distribution utilities, nor their competitive wholesale electricity retailers generate their own electricity and must acquire it elsewhere at market-determined retail prices. As "load-serving entities," utilities and retailers purchase electricity from "merchant generators" through power exchanges administered by not-for-profit regional transmission organizations (RTOs) and

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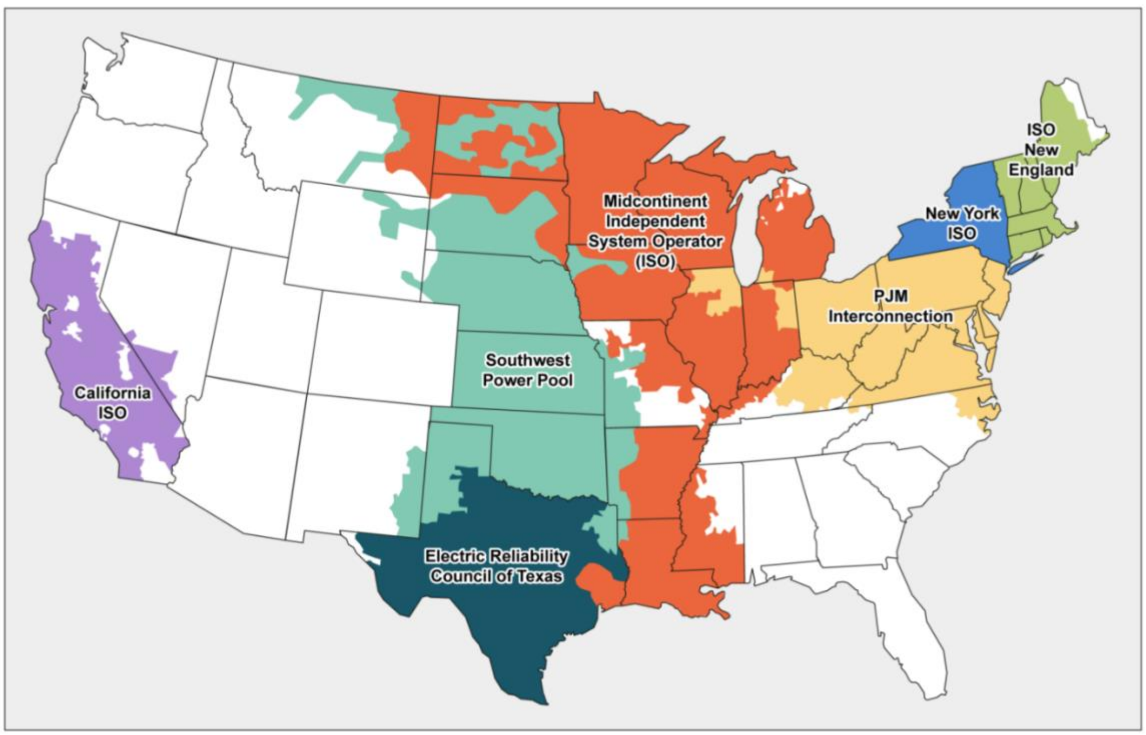
[93] World Nuclear Association, (March 5, 2024), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[94] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[95] World Nuclear Association, (March 5, 2024), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.

independent system operators (ISOs). The deregulated utilities and retailers sell the electricity to their customers at market-determined prices.[96]

The RTOs and ISOs, whose territories often traverse state lines and encompass entire regions, replaced utilities as operators of both the power grid and wholesale electricity markets in deregulated regions. With the exception of Texas's RTO and grid, FERC regulates RTOs and has oversight of all wholesale power transactions on America's two large, interconnected power grids: the eastern and western interconnections.[97]

Under the deregulated market structure, investment risks in power plants fall to the electric suppliers and not to customers:

- Under the deregulated market structure, the investment risk of power plants falls to the electric suppliers and their shareholders, not customers.
- Unlike regulated states that plan for investments, deregulated markets use competitive markets to decide which power sources are needed.



Sources: Federal Energy Regulatory Commission; Map Resources (map). | GAO-18-131

[96] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[97] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.

RTOs typically run three kinds of market auctions that set wholesale prices for these services:

- Energy markets
- Capacity markets
- Ancillary Services markets

Types of Energy Markets

Energy markets are auctions designed to coordinate the day-to-day electricity production, with generators paid for each megawatt-hour of electricity generated. Suppliers submit offers to sell their electricity generation at specified bid prices while load-serving entities place bids to buy that electricity to meet their customers' demand. Offers and bids on the supply side are organized in ascending order by price. The market "clears" when the quantity of electricity offered matches the amount demanded.[98]

- Typically, RTOs run two auctions for energy markets:
  - **Day-ahead auctions** encompass nearly all energy market transactions and are based on forecasted electric load (demand) for the next day and usually occur the prior morning.
  - **Real-time auctions** usually run once every hour and once every five minutes to account for real-time changes in load to ensure grid reliability by balancing supply and demand.

RTOs use energy markets to determine which generating unit to dispatch or run and in what order. In the day-ahead market, RTOs compile a list of generators available for the next day and order their dispatch from least expensive to most expensive to operate.

- Wind generators get dispatched first as they operate without fuel, are subsidized, and thus can bid into the energy market at $0/MWh.
- Wholesale electricity prices rise during periods of high consumer demand because more, higher cost generating units are dispatched to meet load.
- Base wholesale market prices reflect the price to transmit power freely across an RTO's territory without interference.
- To account for congestion on power lines, RTOs permit differential pricing by location so that areas with high demand and resource scarcity pay more for electricity than those with a surplus of generation.

[98] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.

Capacity Markets

Some RTOs run capacity markets to shore up grid reliability by paying generators to be available to supply power when called upon. Consequently, generators that are unavailable when needed may face penalty fees under capacity performance requirements.[99]

- Reward generators for their availability to supply power when called upon.
- Assist electricity retailers in meeting grid reliability obligations by supporting enough generating capacity to meet forecasted load plus a reserve margin.
- Provide retailers with a means of procuring their capacity requirements while also enabling generators to recover fixed costs, i.e., costs that do not fluctuate with electricity production that may not be covered in the energy markets alone.
- Penalize generators that are unavailable when needed.

The grid reliability obligations are set by the independent North American Electric Reliability Corporation (NERC), an independent not-for-profit organization in charge of ensuring reliability of the power grid for the continental U.S. and parts of Canada and Mexico.

How a capacity market auction works:

- Generators set their bid price equal the cost of keeping their plant available to operate if needed.
- Offers and bids on the supply side are organized in ascending order by price.
- Once the bids match the amount that all retailers require to meet expected consumer peak demand plus a reserve margin, the capacity market "clears" – as supply meets demand.
- Generators that "cleared" the market to provide capacity receive the same clearing price.
- The clearing prices are determined by the bid price of the last (and most expensive) generator used to meet demand.

Ancillary Services markets are run by RTOs to reward generators for other attributes not already compensated for within the energy and capacity markets. This typically includes functions that help maintain the power grid's frequency or provide a short-term backup power supply if a third-party generating unit unexpectedly stops.[100]

Despite the binary categories of regulated and deregulated, both states and RTOs vary in their practice of regulation and deregulation.

- Many states embrace a mixture of deregulation and regulation in energy policy.

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[99] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[100] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.

- Participation in RTOs does not require retail customer choice or local utilities to divest their generation assets.
- Some regulated states with vertically integrated utilities, like West Virginia, have joined an RTO for grid services or wholesale market participation.
- Other states have deregulated their wholesale markets but continue to regulate their retail markets, like California, which has its own grid-overseeing RTO but does not permit individual retail electricity choices. Instead, California communities can opt out of the local utility through "community choice aggregation," under which a company hired by the community buys power in wholesale markets for all residents who do not opt out of this arrangement.
- RTO and ISO wholesale market structures vary as well.

The Electric Reliability Council of Texas, Inc. (ERCOT), Texas's RTO, operates without a capacity market and relies on price signals in the energy market alone to ensure grid reliability. ERCOT's inherent assumption is that high energy market prices will incentivize enough generating capacity to meet rising demand; however, ERCOT's grid suffered a costly and deadly blackout when generators failed to meet demand during the winter storm of February 2021. The California Independent System Operator (CAISO) also operates without a capacity market and relies on electricity retailers to ensure resource adequacy in meeting NERC reliability requirements.[101]

Case Study: Westinghouse Deployments in Regulated Markets

In South Carolina's "nukegate scandal," electricity customers ultimately paid $9 billion for two unfinished AP1000 reactors at the V.C. Summer nuclear power plant that were canceled in 2017 following significant cost-overruns, construction delays and the filing for bankruptcy by the project's developer Westinghouse who paid $2.2 billion to walk away from the project. The costly abandoned project led to criminal convictions of energy execs who misled the public with rosier project timelines and Dominion Energy acquiring the two debt-laden utilities involved.[102] [103]

In contrast, a sister expansion project at Southern Company's Alvin C. Vogtle nuclear power plant in Georgia faced similar delays and cost overruns. However, it chose to carry on despite the cost overruns and departure of its original contractor, Westinghouse. The new reactors, Vogtle 3 and 4, came online, respectively, in 2023 and 2024 at an estimated total cost of nearly $35 billion. They were initially projected to cost $14 billion and be

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[101] Clearly, Kathryne and Karen Palmer. "US Electricity Markets 101." Resources for the Future, (March 17, 2022), https://www.rff.org/publications/explainers/us-electricity-markets-101/.
[102] S&P Global Market Intelligence, (December 3, 2020), https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/dominion-scana-formalize-25m-settlement-with-sec-over-failed-sc-nuke-project-61580946.
[103] South Carolina Public Radio, (March 8, 2023), https://www.southcarolinapublicradio.org/sc-news/2023-03-08/executive-gets-15-months-in-prison-in-doomed-nuclear-project.

complete by 2017. The final price tag does not include the $3.7 billion paid by Westinghouse to Vogtle owners to guarantee the project during its bankruptcy.[104]

"Uneconomic" Nuclear Power Plants in Competitive Wholesale Markets

Since the early 2010s, nuclear power plant operators have struggled to stay economically competitive in deregulated markets because of low electricity prices. Cheap gas and subsided wind threaten continued nuclear operations. Single-unit nuclear power plants, which have higher operating costs per megawatt-hour, are most at risk of premature closures.

In deregulated markets, nuclear merchant generators are faced with the issue of wholesale electricity prices being undercut by both cheap natural gas and subsidized wind generation:

- An abundant supply of cheap natural supplies gives gas-fired generators a competitive edge, allowing them to undercut power prices.
- Intermittent wind generators are favored by state and federal subsidies – including a federal production tax credit of $23/MWh – and given priority grid access, especially when oversupply exists.[105]
- Even though wind generation is a very small part of a power grid's generation portfolio and is intermittent or unavailable most of the time, its subsidization – at the directive of federal and state governments – has a major effect on electricity prices, warping wholesale markets and threatening the long-term viability of baseload and dispatchable generators.[106]

Increased post-Fukushima safety requirements, including industry-led FLEX portable equipment to provide backup power and heat removal from the reactor during "beyond design" human-made or natural disasters, have compounded the economic situation for nuclear power plants.

Capacity payments can offset nuclear plant losses to some extent, but where market prices are around $35-$40/MWh, nuclear plants are struggling.[107]

Starting in 2014, five reactors at three nuclear power plants in New Jersey and Illinois failed to clear capacity auctions for three years ahead within the market territory of PJM Interconnection, which serves all or parts of 13 mid-Atlantic states and Washington, D.C. The failure to clear PJM's capacity auctions meant that the

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[104] The Associated Press, (December 19, 2023), https://apnews.com/article/georgia-nuclear-power-plant-vogtle-rates-costs-c333da2957cce7a937008347f3487841.
[105] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power
[106] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[107] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.

reactors would forgo 12 months of capacity payments or an assured market for 2017-2018, even though they provided a large, reliable and zero-carbon source of baseload power for the region.[108]

Following PJM's 2014 capacity auction, the Federal Energy Regulatory Commission (FERC) started actively considering how it could shore up the power grid's reliability by ensuring that base-load power sources, like nuclear, are fully valued by markets for their attributes and their viability maintained in competitive wholesale electricity markets. However, more reactors in coming years failed to clear capacity auctions. The resulting wave of premature closures affected reactors that still had years on their operating licenses to go.[109] The closures could have been prevented if public policies corrected market flaws that failed to compensate nuclear generation for its inherent clean air and reliable energy security attributes.

Pennsylvania's Three Mile Island (TMI) unit 1, which came online in 1974 and was licensed to operate until 2034, shuttered in 2019 after the reactor failed to clear PJM's capacity auctions for four years in a row. TMI Unit 1 even failed to clear PJM's 2021-22 capacity market auction at a clearing price of $140/MW-day – an 83% increase from the year prior.[110]

Amid the nuclear power plant retirements and announced closures, a number of state initiatives led by governors and legislators stepped in to prevent the premature closures of economically at-risk nuclear power plants. Examples include:

- **ZECs, "Zero emission credits:** In New York and Illinois, followed by New Jersey, Pennsylvania, Connecticut and Ohio, states enacted market reforms that preserved their nuclear generation. These market reforms came in the form of "zero-emissions credits" or zero-carbon power purchase agreements that compensated the nuclear power plants for avoided emissions in the production of their electric generation.[111]
- **Carbon Pricing:** One proposed performance-based, technology-neutral market solution is imposing a price on carbon dioxide emissions, which would reward the carbon-free generation of nuclear alongside wind, solar and hydropower.

Utility Restructuring

It wasn't just nuclear power plants that suddenly cost more to build in the 1970s. Oil- and gas-fired power plants faced the same problem amid fuel shortages and price hikes exacerbated by the oil crisis of 1973 and

[108] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[109] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[110] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.
[111] World Nuclear Association, (October 3, 2025), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.

1979 when oil-producing countries in the Middle East slashed production and halted exports to the U.S. and the West.

Intending to reduce America's reliance on energy imports from the volatile Middle East, Congress passed the Public Utility Regulatory Policies Act (PURPA) of 1978. This act overturned the "regulated" era of monopolistic utilities that owned transmission and generation. PURPA sought to jumpstart domestic energy production by encouraging companies other than utilities to build wind turbines, solar panels, and gas-fired power plants that produce usable heat via cogeneration.

PURPA required utilities to buy electricity at above-market-prices from expensive energy sources that otherwise couldn't compete with conventional nuclear, hydro or fossil fuel-fired power plants. The utilities entered long-term power purchase agreements with the new wholesalers to meet new requirements. They paid above-market prices based on what it would have cost to produce the electricity with oil or other fuels. The assumption was the era of cheap oil was over.[112]

When oil prices declined and stabilized in the 1980s, the PURPA contracts became viewed as too expensive by consumers. In these circumstances, Congress passed the Energy Policy of Act of 1992 as a means of "deregulating" wholesale electricity markets and relieving state utility regulators of their role in setting prices for energy services. That responsibility would now go to a competitive market overseen by non-government regional transmission organizations (RTOs) and interconnection transmission organizations (ISOs) that often cross state lines, cover entire regions, and encompass a patchwork of areas. The Energy Policy Act also made it easier for non-utility companies to build and operate power plants ("merchant generators").

Deregulation of the U.S. power sector over the 1990s and 2000s turned utilities into intermediaries tasked with maintaining transmission lines to distribute electricity bought from wholesale suppliers. Large swathes of the country remain under a regulated utility model. The RTO-run "deregulated" markets include the PJM Interconnect, ISO New England and Midcontinent Interconnection System Organization. These regions buy and sell electricity as a commodity on various auctions, including "day-ahead" markets to meet fluctuating consumer demand.

Balancing a grid to ensure power supply meets consumer demand is critical; a mismatch between supply and demand could risk blackouts.

- The most expensive bid accepted is known as the market clearing price, the amount paid to any wholesale power supplier who offered to sell at or under that threshold. Any bid above that price is rejected as unnecessary.
- Increased interventions in the "markets" by state and federal policies include the flurry of subsidies and policy-directed contracts for renewables, nuclear, and wintertime stockpiling of fossil fuels along

[112] Blunt, Katherine. California Burning. Portfolio, Penguin Random House. 2022. p. 54-63.

with environmental directives aimed at curbing emissions and retiring fossil fuel-fired power plants. These policies have brought additional complications and strain on the power grid.
- Capacity markets help ensure grid reliability by providing long-term stability, but they can also increase consumer costs through capacity charges. Energy markets, on the other hand, can offer more competitive pricing but may result in price spikes during peak demand periods.

Dreams of a long-hoped-for nuclear “renaissance” for the U.S. in the 2000s and 2010s failed to materialize as the technological innovation of “fracking,” or the use of hydraulic fracturing to break open underground shale rock formations that hold natural methane gas and oil, suddenly turned the U.S. in the world leader in oil and gas. By 2018, the U.S. overtook Saudi Arabia and Russia as the world leader in petroleum production.[113]

After the 2000s, the deregulation of regional power pool markets across the country paved the way for major changes to American utilities. It became less expensive and more lucrative for investors to build natural gas power plants. The introduction of fracking for gas recovery accelerated this trend in the 2010s. The influx of inexpensive, fracked gas drove fuel costs down and, subsequently, lowered electricity prices.

Quick-to-build and affordable natural gas-fired generators became price-setters in power markets overseen by regional transmission organizations (RTOs). Nuclear power plants with higher operating costs could no longer compete in markets awash with cheap fracked gas. As a result, many nuclear power plants became uneconomic and faced premature closures, especially single-unit merchant plants in deregulated markets, while proposed new reactors were shelved or canceled.

The latest U.S. nuclear projects experienced escalating capital costs because of a lack of building experience. Nuclear opponents often argue that the delays and cost overruns of Vogtle Units 3 and 4 show why nuclear energy is uneconomical. Vogtle 3 and 4 final costs to build are nearly $35 billion, about $17 billion over its original budget.[114] Vogtle 3 reactor began producing power in 2023 followed by Vogtle 4 in 2024, seven years beyond their original projected startup dates. Westinghouse Electric Co. declared bankruptcy in 2017 after it was unable to absorb the price overruns from construction delays.[115]

Recommendations

Many local governments are interested in hosting new energy production, storage or disposal facilities and/or the resulting manufacturing industries. Expansion of the nuclear energy industry can bring economic opportunities in the form of a skilled workforce, high paying jobs and an expanded tax base. However, there is a burden for communities — from building support for new nuclear policies and facilities, to emergency

[113] Energy Information Agency, (September 12, 2018), https://www.eia.gov/todayinenergy/detail.php?id=37053.
[114] Associated Press,(May 25, 2023), https://apnews.com/article/nuclear-power-georgia-vogtle-reactors-8fbf41a3e04c656002a6ee8203988fad.
[115] Associated Press, (May 25, 2023), https://apnews.com/article/georgia-nuclear-power-plant-vogtle-rates-costs-75c7a413cda3935dd551be9115e88a64.

response and safety concerns, to ensuring the development of a disposal path for high-level nuclear waste that is generated during the nuclear processes.

Communities usually host a nuclear facility to obtain the benefits and economic growth created by the construction and operation of the facility. Each project is different, and the community must look beyond the economic projections and understand the actual number of jobs and other benefits that will be provided to the community.

To begin to assess the economic impact new projects may bring, consider:

Project Fundamentals

- Does the project align with long-term economic goals (revitalization, innovation, diversification)?
- Is the project co-located with industrial or energy infrastructure that boosts regional competitiveness?
- Does it support local grid reliability or anchor new industries (data centers, hydrogen, manufacturing)?
- What are the real economic benefits—and how certain are they?

Workforce

- Is there a plan to avoid creating a "boom-bust" labor cycle?
- What share of procurement will be local?
- Will local companies receive early notice and support to bid on contracts?
- Are supplier-development or capacity-building programs included?

Future Plans

- What happens if the project changes or scales up later?
- Will expansions require additional community consent?
- Will benefits automatically scale with the project size?
- Are there protections if the community accepts an initial proposal but rejects later changes or future activities?

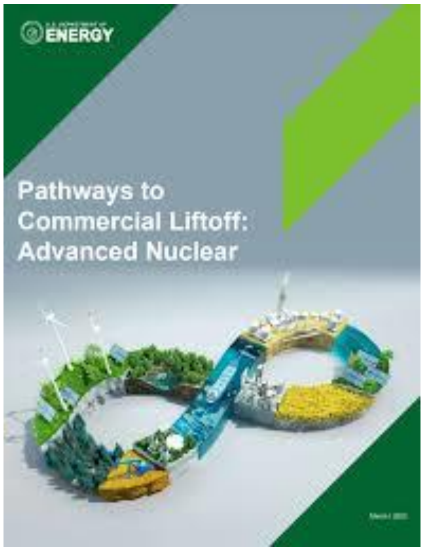
Value Beyond Electricity

Emerging nuclear technologies are poised to provide novel economic benefits.

New designs introduce new uses for nuclear reactors including saltwater desalination, industrial process heat, and district heating for homes and other buildings.

Some industrial sectors are especially difficult to decarbonize, so these new applications present enormous economic opportunities.

The global market for high-temperature heat for industry is one of the most economically promising applications for advanced nuclear reactors. Currently, fossil fuels produce all of the high-temperature process heat needed for industry and manufacturing. For example, reactor designs, such as X-energy's high-temperature gas reactor (HTGR) design, can produce heat up to 600 degrees Celsius. Producing heat at these temperatures reliably and cost-effectively would enable decarbonizing of a host of industrial applications that currently rely on burning coal and gas.



The most mature advanced nuclear reactors are currently in various stages of licensing and commercialization. The U.S. Department of Energy's *Pathways to Commercial Liftoff* report details the ways the U.S. industrial base must scale up to meet the supply chain needs of a brand-new set of technologies. The report defines full-scale industrialization of advanced nuclear power by 2050 as the construction and operation of 200 gigawatts of advanced nuclear capacity. According to the report, the nuclear manufacturing sector will need to scale up for specialized components and modular designs. The fuel supply chain will need to increase in capacity by 200-300 percent, including enrichment and fabrication. The U.S. would also need to employ an additional 375,000 workers with both technical and non-technical skillsets. Finally, component supply chain and licensing require their own advancements.[116]

[116] DOE Office of Nuclear Energy, (March 2023), https://liftoff.energy.gov/wp-content/uploads/2023/03/20230320-Liftoff-Advanced-Nuclear-vPUB.pdf.

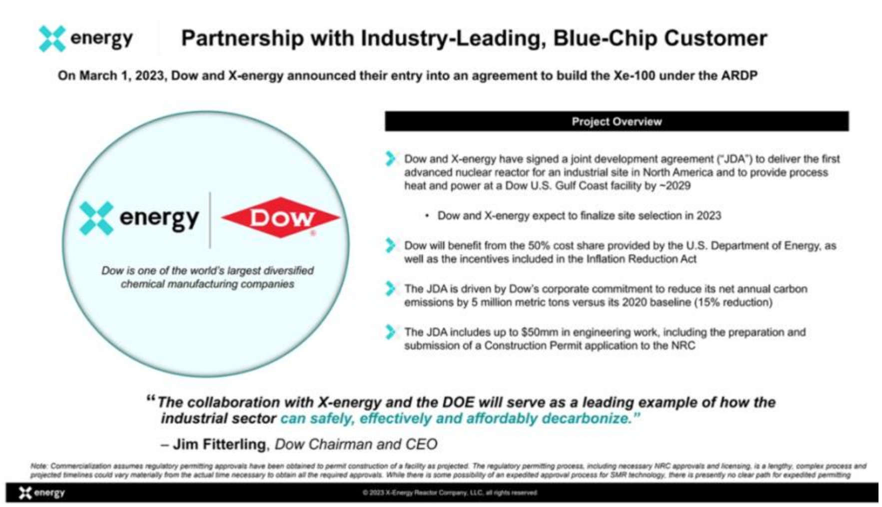
Case Study: Advanced Reactor Development Program (ARDP)

The most difficult economic aspect of commercializing a new nuclear reactor design to market is deploying a first-of-a-kind (FOAK) reactor. As with any technology, the first unit is risky and expensive compared to later units, when there has been learning-by-doing. FOAK costs derive from an unqualified supply chain, schedule overruns, and lack of experience building the technology.

DOE prioritizes assisting advanced reactor developers with demonstrating their reactor design for the first time. In 2020, DOE launched the Advanced Reactor Development Program (ARDP), which aims to help advanced reactor designers test, license, and build a FOAK commercial-scale advanced reactor. DOE issued a funding opportunity announcement (FOA) for the program that year, for which advanced reactor developers could apply. TerraPower and X-energy were selected for having the most mature technologies and were awarded the first $160 million cost-shared funding awards through ARDP, with more funding pledged throughout the program.[117] In total, DOE is supporting 10 U.S. reactor designs toward demonstration within 15 years and will invest a total of $3.2 billion to be spent over seven years.

TerraPower, headquartered in Bellevue, Washington, is developing its Natrium design, a liquid sodium-cooled reactor with built-in energy storage. Although the first unit will cost more, the company hopes to bring Natrium plants to market for under $1 billion, according to TerraPower's project director for the Natrium design (a standard LWR averages $5 billion). This cost equates to around $2,900 per kilowatt of installed capacity. DOE in its *Pathways to Commercial Liftoff* report states that "advanced nuclear overnight capital costs may need to reach $3,600 per kilowatt to unlock deployment at scale," which would make TerraPower's hoped-for outcome competitive.[118]

Rockville, Maryland-based X-energy is working to demonstrate a four-unit nuclear power plant using its Xe-100 high-temperature gas-cooled reactor (HTGR) design. SEC filings detail their partnership with DOW and the application of nuclear energy to process heat needs.



[117] DOE Office of Nuclear Energy, (October 13, 2020), https://www.energy.gov/ne/articles/us-department-energy-announces-160-million-first-awards-under-advanced-reactor

[118] DOE Office of Nuclear Energy, (March 2023), https://liftoff.energy.gov/wp-content/uploads/2023/03/20230320-Liftoff-Advanced-Nuclear-vPUB.pdf.

The company plans to deliver a "four-pack" of 80 MWe Xe-100 reactors, for a 320 MWe-total power plant, and a fuel production facility. Once the first Xe-100 power plant comes online with the help of ARDP, the reactor design promises to deliver several economic benefits. The Xe-100 HTGR can produce heat up to 600 degrees Celsius, which could help decarbonize industrial applications that currently rely on burning coal and gas. Components can also be manufactured and shipped to site using existing road and rail transport, cutting down on construction costs significantly. Additionally, Xe-100 can provide flexible electricity generation, ramping up or down, and the modular design will allow for a plant site to host four reactors or more, if needed.[119]

Case Study: Carbon Free Power Project

The DOE-funded Carbon Free Power Project (CFPP) was slated to become the first commercial SMR deployed in the U.S. The project set out to include four of NuScale's 77 MW SMRs, called NuScale Power Modules, for a total of 462 MW to be built at Idaho National Lab and come online by 2029.[120] DOE first announced funding for NuScale in 2013, as the winner of a competitive cost-sharing program for SMR development, to support the accelerated development of the NuScale Power Module™ technology.[121] The funding would assist in building a six- to 12-module (270MW-540MWE) plant to be located at a site like the Idaho National Laboratory.

In 2015, Utah Associated Municipal Power Systems (UAMPS), a collection of 50 municipal and regional utilities across seven states in the Western U.S., announced its plan to develop CFPP using NuScale's design. UAMPS participants signed a 2019 agreement to each purchase 200 MW of power from the reactors once they became operational. NuScale said it would require an 80 percent subscription level from the utility customers to continue toward deployment.[122] Since the initial award in 2013, the CFPP received significant funding from the Department of Energy.

The DOE Office of Nuclear Energy (DOE-NE) initiated the Advanced SMR R&D program in fiscal year 2019, through which DOE-NE partnered with NuScale Power and UAMPS on the CFPP. In 2020, DOE bestowed a $1.4 billion cost-sharing award to the CFPP, ultimately providing $232 million in DOE funds for the project.[123] In 2021, UAMPS participants elected to downsize to six reactors instead of 12, which would yield 426 MWe, or about 64 percent of the 720 MWe that could have been generated by the 12 reactors. NuScale raised its target price for power generation from $58/MWh to $89/MWh. A large driver of this increase was inflationary pressure on the energy supply chain, causing a 75 percent jump in the estimated construction cost of the project, which

[119] X-energy. https://x-energy.com/reactors/xe-100
[120] American Nuclear Society, (November 9, 2023), https://www.ans.org/news/article-5522/uamps-and-nuscale-drop-plans-to-build-smrs-at-inl/.
[121] NuScale, (December 12, 2013), https://www.nuscalepower.com/en/news/press-releases/2013/us-doe-awards-funding-for-nuscale-powers-smr-technology.
[122] NuScale, (November 9, 2023), https://www.utilitydive.com/news/nuscale-uamps-terminate-small-modular-nuclear-reactor-smr-project-idaho/699281/
[123] American Nuclear Society, (October 20, 2023), https://www.ans.org/news/article-2300/with-doe-funds-in-hand-uamps-preps-for-nuscale-smr-licensing-phase/

rose from $5.3 billion to $9.3 billion.[124] Several utility members of UAMPs then withdrew from the agreement, which contained a "no harm, no penalty" clause allowing members to exit the agreement if certain benchmarks were not achieved.[125] The remaining UAMPs participants unanimously withdrew from the project in 2023, yielding to concerns about FOAK uncertainties. NuScale announced that it agreed with UAMPS to terminate the Carbon Free Power Project. Today, NuScale continues to work to bring its design to market in North America, Europe, and the Middle East.[126]

Recommendations

Nuclear facilities represent vital sources for reliable, clean electricity, high-paying jobs, and significant tax revenue, yet unfinished projects or premature closures can quickly destabilize local economies. Recognizing the broad impacts early allows leaders to position nuclear as part of a long-term community development agenda.

To support positive outcomes, officials should prioritize tools that stabilize facility revenues and integrate nuclear into broad industrial strategies. Practical measures include:

- Advocating for long-term power purchase agreements
- Adopting low-carbon or nuclear portfolio standards
- Exploring energy pricing frameworks that value reliable, emissions-free generation.

In markets where merchant plants face revenue pressures, municipalities may also examine public or hybrid ownership models to secure local control and reinvest energy revenues in community priorities. Complementary strategies—such as operational cost reductions, participation in capacity markets, and structured penalties for project abandonment—can further protect local interests and maintain facility viability. Equally important is transparent engagement with stakeholders to ensure public confidence and long-term support. Leaders should initiate early hearings, involve neighboring communities and tribal governments, and leverage federal siting programs to address concerns about safety, waste management, and economic impacts. Combining these outreach efforts with targeted workforce development and economic incentives can position communities to maximize nuclear's benefits while managing risks.

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[124] Institute for Energy Economics and Financial Analysis, (January 11, 2023), https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor.
[125] U.S. Securities and Exchange Commission, (October 2022), https://www.sec.gov/Archives/edgar/data/1822966/000110465922056493/tm2213736d7_ex10-22.htm.
[126] Nuscale Power, https://www.nuscalepower.com/en/news/press-releases/2023/uamps-and-nuscale-power-agree-to-terminate-the-carbon-free-power-project.

Types of Nuclear Reactors

This chapter catalogs the wide range of nuclear power technologies and the diverse ways they are categorized by policy makers, nuclear developers, utilities and advocates. Local officials should understand the different types of nuclear reactors in today's market because reactor design directly affects community impacts, safety considerations, and economic opportunities. This information informs decision making with strategic questions to pose to developers, state and federal policy makers and partners.

Light Water Reactors

Currently, the fleet of nuclear reactors in the United States consists of light water reactors (LWRs). In LWRs, ordinary water, or "light water," is used to help moderate the chain reactions, to act as the cooling agent and to help remove the heat used to produce steam for turning the turbines of the electric generators. Like other thermal power plants, nuclear reactors generate heat, which boils water to produce steam that drives a turbine, generating electricity. These reactors release "fast" neutrons with high energy, which need a moderator to slow them down and control the chain reaction.[127]

[127] World Nuclear Association, (2015), https://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Nuclear_Information/Pocket%20Guide%20Reactors.pdf.

Between 1985 and 1996, 34 new commercial LWRs were put into service in the United States. The Watts Bar 2, Vogtle 3 and Vogtle 4 reactors came online in 2016, 2023 and 2024, consecutively, and are also LWRs.

LWRs can be divided into two categories: pressurized water reactors (PWRs) and boiling water reactors (BWRs). PWRs make up about 70% of the operable global nuclear fleet of 436 individual reactors.[128] Of the 366 light water reactors in operation today, 306 are pressurized water reactors (PWRs) and 60 are BWRs. Another 82 new PWR units and three new BWR units are forthcoming. The U.S. has a mix of both PWRs and BWRs. There are total of 94 operating nuclear reactors in the U.S., of which 62 are pressurized water reactors.

Pressurized Water Reactors (PWR)

These reactors have a primary cooling circuit that flows through the reactor core, and a secondary circuit that generates steam to turn the turbine that produces electricity. Water is pressurized within the first circuit in order not to boil and is under less pressure in the secondary circuit to boil in order to produce steam to turn the turbine.[129]

Boiling Water Reactors (BWR)

The remaining U.S. nuclear reactors are boiling water reactors. The second most common reactor type in the U.S. and worldwide, BWRs have only a single circuit that allows water to boil. The steam produced is separated from the remaining water in steam separators above the reactor core, and then fed directly to the turbine. Steam is then condensed and recycled. The U.S., Japan, Sweden, and Taiwan are the primary users of BWRs. [130]

Reactors Outside the U.S.

All U.S. reactors are LWRs, but a handful of other reactor designs are in use outside of the U.S. Another type of water-cooled reactor, called pressurized heavy water reactors (PHWR), use heavy water instead of normal water. Heavy water is a chemically different form of water that enables the use of naturally-occurring uranium for fuel rather than enriched uranium used in LWRs. PHWRs make up 11% of the global fleet and are most in use in Canada, as well as India, Romania, Argentina, Pakistan, and China.[131] Other reactor types currently operating around the world include nine individual gas-cooled reactor (GCR), 11 graphite-moderated reactors (LGR), and two liquid metal-cooled reactors (LMFBR).

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[128] World Nuclear Association, https://www.world-nuclear.org/nuclear-essentials/are-there-different-types-of-reactor.aspx
[129] World Nuclear Association, https://www.world-nuclear.org/nuclear-essentials/are-there-different-types-of-reactor.aspx
[130] World Nuclear Association (2015), https://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Nuclear_Information/Pocket%20Guide%20Reactors.pdf
[131] World Nuclear Association, https://www.world-nuclear.org/nuclear-essentials/are-there-different-types-of-reactor.aspx

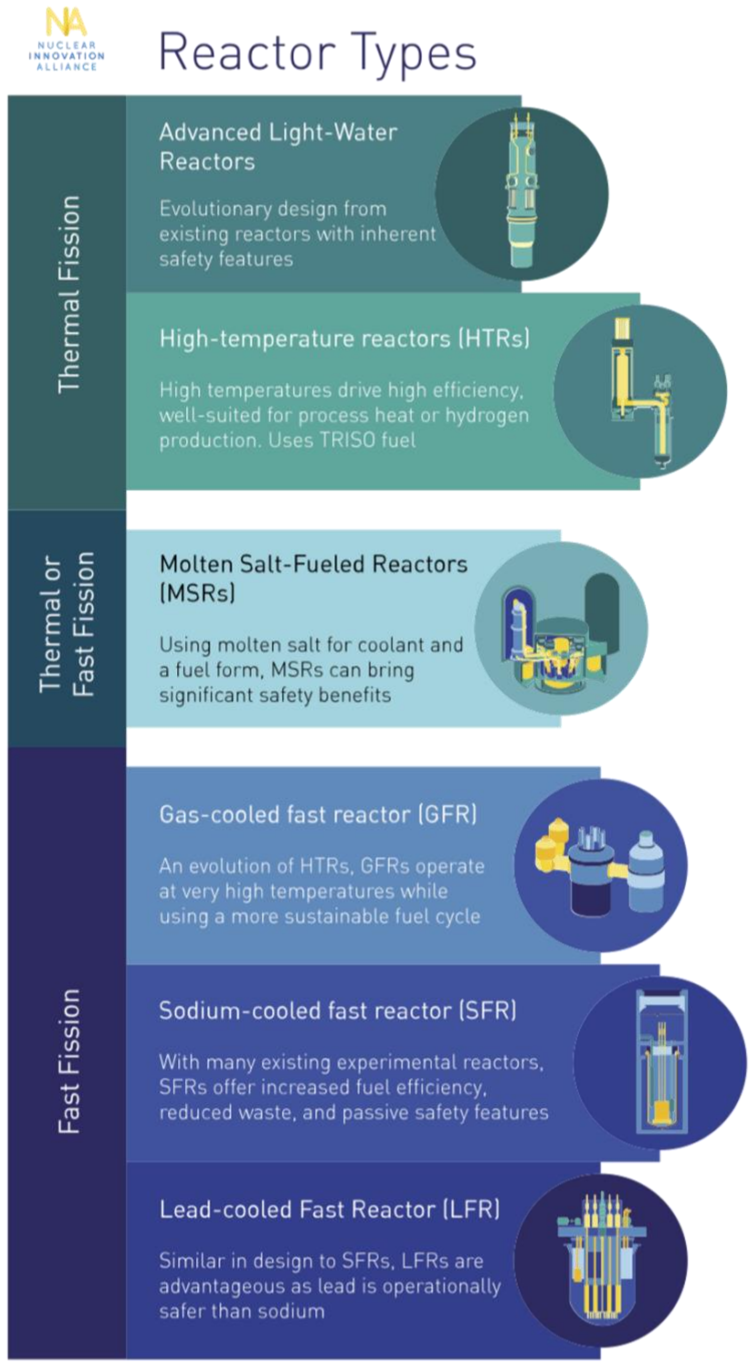
Advanced Reactors

Dozens of advanced reactor designs are currently under development in the U.S. Advanced reactors offer novel technological capabilities and economic benefits that make them a step ahead of conventional LWRs. Advanced reactors are either water-cooled or use a coolant other than water, such as liquid metal, gas, or molten salt. This next generation of nuclear reactors offers advanced safety systems and security features; they are also designed to use fuel more efficiently, minimizing the amount of fuel used per unit of energy produced.

Advanced reactors vary in size.

- **Full-size reactors** are similar in size to traditional reactors (generally 1,000 MW) and are considered full-size if they range from 300-1000 MW.
- **Small modular reactors** (SMRs) range from 20-300 MW; DOE defines SMRs as nuclear power plants with an output of less than 300 megawatts electric.
- **Microreactors** include reactors with an output ranging from 1-20 MW; these reactors are small enough to fit on a flatbed truck, making them easily mobile and deployable.[132]

The types of advanced reactors are currently at different stages of development in the United States.[133]



[132] DOE Office of Nuclear Energy, (May, 2020), https://www.energy.gov/sites/default/files/2020/05/f74/Advanced-Reactor-Types_Fact-Sheet_Draft_Hi-Res_R1.pdf.

[133] Nuclear Innovation Alliance graphic retrieved from https://nuclearinnovationalliance.org/use-cases-and-reactor-types

Small Modular or Medium-Sized Reactors

Known by the SMR acronym, small modular reactors, called small and medium-sized reactors by the International Atomic Energy Agency, represent a range of reactor designs that are approximately one-third the size of current nuclear plants. The smaller power output or physical size of SMRs can increase potential flexibility for utilities. The SMR concept provides for fewer upfront capital costs and offers new use cases for nuclear power. Plants may be manufactured in a modular way to avoid some on-site construction costs.

With the generation capacity similar to a typical coal-fired power plant, SMRs have been proposed to replace coal plants. For aging coal plants unable to meet modern pollution standards, SMRs offer an option to retire the coal plant while repurposing or repowering the energy facility with nuclear energy. This scenario takes advantage of the coal site's existing grid interconnection as well as its land footprint and skilled workforce and supply chains. SMRs concepts have also been proposed to potentially recycle used fuel or nuclear waste or to produce heat for a host of industrial applications.[134]

Some of the designs for SMRs (considered Generation III+) use little or no water for cooling, which would reduce their environmental impact. Through innovative concepts, advanced SMRs (considered Generation IV) would use non-light water reactor coolants such as liquid metal, helium or liquid salt that could potentially offer added functionality and affordability.

Accelerating the development of SMR designs is a high priority within DOE's Office of Nuclear Energy (DOE-NE), which is conducting research and development on advanced SMR concepts for use in the mid- to long term. DOE-NE formally began to support SMRs in April 2010, when it presented to Congress its *Nuclear Energy Research and Development Roadmap*. The DOE Office of Nuclear Energy's Small Modular Reactor Licensing Technical Support program started in 2012 with a mission to advance the licensing and commercialization of relatively mature domestic SMR designs. Specifically, the program supported certification and licensing requirements for U.S.-based SMR projects through cooperative agreements with industry partners, and by supporting the resolution of generic SMR issues. In 2018, the Department issued a multi-year, cost-shared funding opportunity to support the development of new reactor technologies, including SMRs.[135]

Advanced Small Modular Water-Cooled Reactor

Several U.S. companies are developing small modular water-cooled reactor designs, including GE-Hitachi Nuclear Energy, Holtec International, NuScale Power, and Westinghouse Electric Company. These reactors offer smaller versions of pressurized water reactor technology, which all modern LWRs currently use.

NuScale Power was the first developer with an SMR design licensed by the NRC. The company's 50 MW modular light water reactor design received NRC approval in 2020 and design certification in 2023.[136] The

[134] World Nuclear Association, https://www.world-nuclear.org/nuclear-essentials/are-there-different-types-of-reactor.aspx.
[135] DOE – Office of Nuclear Energy, https://www.energy.gov/ne/advanced-small-modular-reactors-smrs
[136] NuScale Power, (September 14, 2020), https://www.nuscalepower.com/en/news/press-releases/2020/us-nrc-issues-standard-design-approval-for-nuscales-smr-design

design is a smaller version of pressurized water reactor technology in use today. It boasts greater scalability as one NuScale power plant can house up to 12 individual reactor modules, alleviating the financial commitment associated with a large-sized power plant. In 2023, the NRC accepted NuScale's Standard Design Approval (SDA) application for formal review for its VOYGR-6 plant design featuring an uprated 77 MWe SMR.[137]

GE-Hitachi Nuclear Energy is developing the BWRX-300 reactor design, so-called because of its 300 MW power rating. The BWRX-300 is a smaller, water-cooled, water-moderated version of GE's boiling water reactor design. Unlike most other advanced designs, which require uranium fuel enriched over 5% (higher enriched fuels are not yet commercially available outside of Russia), the BWRX-300 uses a uranium oxide fuel already in production. Both the Tennessee Valley Authority and Ontario Power Generation plan to submit applications to license and build the design.[138]

Advanced Non-Water Cooled Reactors

Outside of light-water reactors (LWRs) commonly operated today, the majority of innovative commercial reactors fall into one of three categories: liquid metal-cooled fast reactors; high-temperature, gas-cooled reactors; and molten salt reactors.[139]

Liquid Metal-Cooled Fast Reactor

Liquid metal-cooled fast reactors (LMFRs) use metal (sodium or lead) as a coolant instead of water, allowing the coolant to operate at higher temperatures and pressures. Both uranium in metallic form and recycled nuclear waste like plutonium and actinides can fuel LMFRs.[140] These reactors are called fast reactors because their neutrons are not slowed down during the chain reaction unlike in conventional reactors, allowing for higher fuel burn-up. Fast reactors "consume" plutonium during the fission process and transform it into nuclear waste products that are not as useful for weapons. They can extract much more energy from the same amount of fuel than a typical LWR, reducing the amount of fuel required and the amount of spent fuel produced. Fast reactors can even reuse nuclear fuel, meaning they can produce more fuel than they consume.[141]

Westinghouse is currently developing a demonstration Lead-cooled Fast Reactor (LFR). Westinghouse's LFR is a medium-sized (450 MWe net) modular reactor that features innovative design elements that reduce capital

[137] NuScale Power, (August 1, 2023), https://www.nuscalepower.com/en/news/press-releases/2023/us-nuclear-regulatory-commission-accepts-nuscale-powers-standard-design-approval-application
[138] Wald, Matt. ANS Nuclear News (January 19, 2024), https://www.ans.org/news/article-5634/2024-the-state-of-advanced-reactors/
[139] Generation IV International Forum. (2020). *GIF Systems Research Plan: Technology Roadmap Update*. Retrieved from https://www.gen-4.org
[140] World Nuclear Association, https://www.world-nuclear.org/nuclear-essentials/are-there-different-types-of-reactor.aspx
[141] Mally Dean, Kristen, Argonne, National Laboratory, (November 13, 2023), https://www.anl.gov/article/fast-reactor-technology-is-an-american-clean-green-and-secure-energy-option.

cost and simplify the plant. Liquid lead has a boiling point of 1700 degrees Celsius, which allows the reactor to operate at high temperatures at atmospheric pressure without the coolant boiling off. [142]

Oklo Inc. is developing the Aurora Powerhouse, a compact sodium-cooled fast reactor employing metallic HALEU fuel and a fast-neutron spectrum. As of October 2025, the company has three project sites. The compact fast reactor design builds on the legacies of the Experimental Breeder Reactor-II and space reactor program.[143]

Seattle-based TerraPower LLC is currently partnering with GE-Hitachi Nuclear Energy – a Wilmington, North Carolina-based joint venture between General Electric and Hitachi – to deliver its 345-MW Natrium design, a liquid sodium-cooled reactor. The Natrium reactor design also includes a molten salt-based energy storage system which can boost the system's power output to 500 MWe for over five hours if needed to help meet added grid demand. The reactor's use of molten salt as a coolant instead of water allows for improved fuel utilization TerraPower aims to build its demonstration Natrium reactor at a retiring coal facility in Kemmerer, Wyoming, reusing the site's infrastructure and grid connections.[144] In 2024, TerraPower submitted its construction permit application to the NRC for the Natrium demonstration project.[145]

High-Temperature, Gas-Cooled Reactor

Gas-cooled reactors are cooled by flowing gas and designed to operate at high temperatures. The U.S. has only ever operated two high-temperature, gas-cooled reactors (HTGR): Peach Bottom from 1967 to 1988, and Fort Saint Vrain from 1979 to 1989. Three other HTGRs remain operational in Japan and China.[146]

Some advanced reactor developers are using the HTGR design to develop "fast" reactors. HTGRs can be used for electricity generation and are especially well-suited to providing process heat for industrial purposes, including hydrogen production. An HTGR could be used in the development of tar sands, oil shale and coal-to-liquids applications and would reduce the life-cycle carbon footprint of all these activities.[147]

X-energy's Xe-100 reactor design is a HTGR cooled with pressurized helium gas. The Xe-100 is suited to provide flexible power output and process heat for industrial applications, desalination, and hydrogen production. The reactor can provide highly flexible electricity as well as process heat up to 600 degrees Celsius for industrial and other applications. The Xe-100 is designed to use the company's proprietary TRISO-X fuel, a highly robust uranium fuel sealed into ceramic spheres that can allow the reactor to operate at temperatures much higher than LWRs can.[148]

[142] Westinghouse, https://www.westinghousenuclear.com/energy-systems/lead-cooled-fast-reactor/
[143] NRC, https://www.nrc.gov/reactors/new-reactors/large-lwr/col/aurora-oklo
[144] TerraPower https://natriumpower.com/
[145] TerraPower, (March 29, 2024) https://www.terrapower.com/terrapower-submits-cpa-nrc/
[146] Nuclear Energy Agency, (2022), https://www.oecd-nea.org/jcms/pl_20497/high-temperature-gas-cooled-reactors
[147] Nuclear Energy Agency, (2022), https://www.oecd-nea.org/jcms/pl_20497/high-temperature-gas-cooled-reactors
[148] X-energy, https://x-energy.com/reactors/xe-100

Under a joint development agreement (JDA) with Dow Chemical, X-energy plans to deliver four 80-MW Xe-100 reactors for a total of 320 MW at the power plant, proposed to be built at one of Dow's Gulf Coast facilities. [149]

Molten Salt Reactors

Molten salt reactors (MSRs) use molten fluoride or chloride salts as a coolant, at low pressure. The reactor's fuel is either in solid fuel rods, as in current reactors, or is dissolved in molten salt. MSRs were first used in the 1960s, when the U.S. developed the molten salt breeder reactor concept. A small 8 MW Molten Salt Reactor Experiment (MSRE) also operated at Oak Ridge National Laboratory from 1965 until 1969.[150]

Novel advanced MSR designs include unique capabilities like higher fuel burn-up. The use of salt as a coolant allows the reactor to operate at higher temperatures than conventional reactors, as the molten salt remains in liquid form up to 1400 degrees Celsius. MSRs can operate with a variety of fuels, such as uranium, plutonium, and actinides from thorium and nuclear waste. MSRs use epithermal or fast neutron spectrums.[151]

Kairos Power is developing its Fluoride Salt-Cooled High Temperature Reactor (KP-FHR), an MSR that uses a low-pressure fluoride salt coolant. The KP-FHR uses spherical ceramic fuel pellets called TRISO fuel pellets, which will float in the low-pressure fluoride salt, allowing for high temperatures and low pressures. Using a flexible steam cycle to convert heat from the fission process into electricity, the reactor can complement other energy sources like renewables by ramping up. [152]

Kairos plans to iterate its design using a series of test reactors near Oak Ridge, Tennessee. The first is the 35-MWthermal Hermes demonstration reactor, a scaled-down version of the KP-FHR, which the company anticipates will become operational by 2026.[153]

Microreactors

Microreactors are highly compact reactors that can generate up to 20 MW of thermal energy that can be converted to electricity or provide heat for industrial processes. Microreactors are a hundred or even thousand times smaller than conventional reactors. Their small size makes them ideal for generating power and heat in remote or rural locations, at military installations, or at natural disaster sites. They are also small enough that they can be built in a factory and transported to the build site by truck.[154]

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[149] X-energy, (March 1, 2023), https://x-energy.com/media/news-releases/dow-and-x-energy-advance-efforts-to-deploy-first-advanced-small-modular-nuclear-reactor-at-industrial-site-under-does-advanced-reactor-demonstration-program
[150] World Nuclear Association, (February, 2024), https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx
[151] World Nuclear Association, (September 10, 2024), https://world-nuclear.org/information-library/current-and-future-generation/molten-salt-reactors.aspx
[152] Kairos Power, https://kairospower.com/technology/
[153] American Nuclear Society, (July 16, 2021), https://www.ans.org/news/article-3077/kairos-power-is-building-toward-lowpower-demo-operations-in-2026/
[154] Idaho National Laboratory, https://inl.gov/trending-topics/microreactors/#:~:text=What%20are%20microreactors%3F,provide%20heat%20for%20industrial%20applications.

A team at the University of Illinois at Urbana-Champaign (UIUC) plans to construct a research reactor using Ultra Safe's MMR design. The university in 2021 submitted a letter of intent to the NRC to apply for a license to construct the project. The MMR would partially repower the university's Abbott coal power station, demonstrating the ability of small nuclear reactors to decarbonize existing fossil fuel fired infrastructure. [155]

INL leads the DOE Microreactor Program, funded through GAIN (Gateway for Accelerated Innovation in Nuclear), and works closely with companies and industrial colleagues developing microreactor designs. INL is developing DOE's MARVEL microreactor which will be the first new reactor at INL in over four decades. The MARVEL design is a sodium-potassium-cooled microreactor with 85 megawatts of thermal capacity. DOE's microreactor program completed MARVEL's final design review, the 90 percent design completion, a significant step in reactor deployment. The MARVEL microreactor is officially in the construction phase. [156]

INL developed a non-nuclear prototype known as the Primary Coolant Apparatus Test (PCAT) system to test that reactors will perform as designed, without using nuclear fuel. The prototype, which was fabricated in 2022, is a full-scale, non-nuclear replica of MARVEL powered by electricity. It will test the performance of the MARVEL cooling system and pave the way for the demonstration MARVEL reactor to be sited at INL's Transient Reactor Test (TREAT) facility.[157]

Apart from MARVEL, INL is helping industry partners accelerate innovation by carrying out testing in nuclear test beds and providing feedback. Two demonstration facilities are operational. The third facility, Hector, is currently in the design phase.

New Nuclear Operating Licenses

The NRC application review process for a combined operating license (COL) can take up to five years to complete. As part of the process, NRC staff reviews the COL applicant's qualifications, design safety, environmental impacts, operational programs, site safety, and verification of construction with Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) which are established by the regulator. The staff conducts its review in accordance with the Atomic Energy Act, NRC regulations, and the National Environmental Policy Act. All stakeholders (including the public) are given notice as to how and when they may participate in the regulatory process, which may include public meetings and opportunities to request a hearing on the issuance of a COL.

Under current licensing regulations, a company that seeks to build a new reactor can use already NRC-approved reactor designs. NRC's design certification is independent of their approval of applications to construct or operate new nuclear power plants. An applicant's use of an NRC-certified reactor design

[155] World Nuclear News, (June 29, 2021), ://world-nuclear-news.org/Articles/US-university-announces-plans-to-build-microreacto
[156] US Department of Energy, (October 12, 2023), https://www.energy.gov/ne/articles/marvel-microreactor-reaches-final-design-step
[157] Idaho National Laboratory, (January 13, 2022), https://inl.gov/nuclear-energy/forging-the-future-of-nuclear-power-inl-team-assembles-microreactor-prototype/

streamlines the process as all safety issues related to the design have been resolved, and the focus of the NRC's review is the quality of construction. Construction of a nuclear power plant may take five years or more.

Recommendations

Local elected officials considering hosting a nuclear facility will evaluate the potential environmental and economic benefits of a project along with the long-term obligations such a project will bring. The types of facilities proposed, the safety profile of the technologies involved, the regulatory requirements and the financial structure of the project will have lasting implications for the community. Asking the right questions early in the process helps ensure local officials negotiate from an informed position and proactively address concerns for constituents and neighboring jurisdictions.

A potential framework for evaluating new nuclear projects may include questions related to:

- **Technology and Design**
    - What type of facility is being proposed (large light-water, small modular reactor, microreactor, storage, disposal or manufacturing)?
    - How does its safety profile compare to current operating plants?
    - What are the specific fuel requirements, waste products, and storage needs?
    - What future expansion is anticipated?
    - What are the emergency planning and evacuation zone requirements?
    - How will the facility manage cooling water, emissions, and local environmental impacts?
    - What long-term waste handling or decommissioning commitments will the developer make?
- **Economic and Community Benefits**
    - What is the expected job creation (construction vs. operations)?
    - What skill levels are required?
    - How will local tax revenues, payments in lieu of taxes, or other benefits be structured?
    - Can the reactor provide additional benefits, such as district heating or industrial energy use?
- **Ownership, Financing, and Risk**
    - Who owns the facility, and what is the financial stability of the developer or utility?
    - What happens if the project is delayed, abandoned, or the operator exits the market?
    - Are there cost overrun protections or guarantees for the local community?
    - What federal and state licensing pathways does this technology follow, and how long will approvals take?

Relevant Nuclear Organizations

The following resources provide a more detailed look into the organizations that influence nuclear policy. The links include studies, statements of strategy, and homepages of relevant organizations and programs.

Government agencies, their roles and their advisory bodies

Department of Energy, Office of Nuclear Energy
www.energy.gov
The Department of Energy (DOE) Office of Nuclear Energy (NE) supports nuclear research and development in the U.S. by funding innovation and solving problems. In 2021, NE publicized a statement of its strategic vision for nuclear energy and the future of advanced nuclear reactors. Within the 35-page program, NE outlines five main goals: continue operating existing reactors, deploy advanced reactors, reform fuel cycles, maintain U.S. global nuclear leadership, and enable high performance within NE. They detail these goals with specific action items and a timeline designed to hold NE accountable to their mission to advance nuclear energy science and technology to build a secure, sustainable, and cost-effective energy supply.

For additional details, check out the Office of Nuclear Energy's Strategic Vision:

https://www.energy.gov/sites/prod/files/2021/01/f82/DOE-NE Strategic Vision -Web - 01.08.2021.pdf

Office of Nuclear Energy, Advanced Reactor Demonstration Program
https://www.energy.gov/ne/advanced-reactor-demonstration-program
In 2020, the Office of Nuclear Energy allocated $160 million in initial funding to accelerate developing and demonstrating new advanced reactor designs. Funding was disbursed to two companies, TerraPower and X-energy, for their designs. Both proposed reactors use alternative fuels and coolants, and the companies were

able to demonstrate that their designs would be viable for operation within seven years.[158] Since receiving support from the Office of NE, building sites have been selected and designs have been finalized for these reactors.

Nuclear Regulatory Commission

www.nrc.gov

Congress created NRC as an independent agency in 1974 from the Atomic Energy Commission (AEC). The NRC predecessor had the sole responsibility for the development and production of nuclear weapons and for the development and safety regulation of the civilian uses of nuclear materials under the Atomic Energy Act of 1954. The Energy Reorganization Act of 1974 abolished AEC and split the weapons and civilian functions between the Energy Research and Development Administration (now part of the Department of Energy) and NRC.[159] NRC is responsible for licensing facilities developed for the permanent disposal of high-level waste and spent nuclear fuel. NRC also regulates spent fuel pools and dry cask storage. NRC would be responsible for licensing any reprocessing facility for commercial spent nuclear fuel. NRC also regulates spent fuel pools and dry cask storage.

Defense Nuclear Facilities Safety Board

www.dnfsb.gov

Created by Congress in 1988, the Defense Nuclear Facilities Safety Board is responsible for independent oversight of all activities affecting nuclear safety within DOE's nuclear weapons complex.[160] Housed within the executive branch, the board may conduct investigations, issue subpoenas, hold public hearings, gather information, conduct studies and establish reporting requirements for DOE. It also is empowered to make recommendations to the Secretary of Energy.[161] The board is required by statute to report to Congress each year concerning its oversight activities, its recommendations to the Secretary of Energy and improvements in safety achieved at defense nuclear facilities as a result of its activities.[162]

Nuclear Waste Technical Review Board

www.nwtrb.gov

Congress created the Nuclear Waste Technical Review Board in 1987 to increase public confidence in DOE decision-making, to allay concerns over whether waste would be stored correctly, and to provide independent scientific and technical oversight of DOE's program. The board advises Congress and the Secretary of Energy on technical issues related to nuclear waste management, and it evaluates the technical validity of all

[158] DOE Office of Nuclear Energy (October 13, 2020), https://www.energy.gov/ne/articles/us-department-energy-announces-160-million-first-awards-under-advanced-reactor.
[159] "Energy Reorganization Act of 1974: Conference Report to Accompany H.R. 11510," bill, 1 § (1974).
[160] Defense Nuclear Facilities Safety Board, (August 2024), https://www.dnfsb.gov/.
[161] Defense Nuclear Facilities Safety Board, (October 2024), https://www.dnfsb.gov/about/mission.
[162] Defense Nuclear Facilities Safety Board, (August 2024), https://www.dnfsb.gov/.

activities undertaken by the Secretary of Energy related to DOE's continuing obligation to manage and develop an approach for the disposition of spent nuclear fuel and high-level radioactive waste.[163]

Environmental Protection Agency
www.epa.gov
EPA's regulatory role is to develop environmental standards and federal radiation protection guidance for offsite radiation due to the disposal of spent nuclear fuel, high-level waste and transuranic wastes. The standards limit (1) the amount of radioactivity entering the biosphere outside the boundaries of the facility, and (2) the radiation exposure to the public from management of spent fuel and waste prior to disposal. The guidance also establishes waste-disposal criteria. EPA environmental standards apply to DOE-operated and NRC-licensed facilities. NRC is responsible for implementing the standards developed by EPA and for determining that DOE can meet them.[164]

Department of Transportation (DOT)
www.transportation.gov
DOT regulates the packaging and carriage of all hazardous materials in the U.S., including high-level nuclear waste. Packaging must meet NRC regulations, and the package design must be reviewed and certified by NRC. DOT prescribes limits for external radiation levels and contamination and controls the mechanical condition of carrier equipment and qualifications of carrier personnel.[165]

Department of Interior (DOI)
www.doi.gov
DOI works with DOE to conduct laboratory and field geological investigations in support of waste disposal programs. Within DOI, the Bureau of Land Management manages certain public lands, and DOI can withdraw such public lands for limited use by DOE to study as potential radioactive waste storage or disposal sites. Development of a permanent waste repository other than Yucca Mountain would likely require congressional action to withdraw the land from public use.[166]

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[163] U.S. Nuclear Waste Technical Review Board, (August 2024), https://www.nwtrb.gov/about-us/mission.
[164] Nuclear Regulatory Commission, (January 26, 2024), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.
[165] Nuclear Regulatory Commission, (January 26, 2024), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.
[166] Nuclear Regulatory Commission, (January 26, 2024), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.

Oversight by and Input from State and Tribal Governments

States

Before 1992, the Nuclear Waste Policy Act (NWPA) gave states a limited role in regard to how nuclear waste from the federal government's weapons program was stored, treated or disposed of in their jurisdictions.[167] However, with the passage of the Federal Facility Compliance Act in 1992, affected states have worked jointly with DOE in shaping treatment and disposal plans for various waste categories (although states do not have regulatory authority over high-level waste), negotiating and enforcing cleanup milestone agreements, working with congressional delegations to ensure adequate funding levels, and providing oversight.[168]

Tribes

Affected tribes were also provided an oversight role by NWPA, but they wanted to be more engaged in decisions regarding the storage, treatment, and disposal of nuclear waste resulting from the federal government's weapons programs in their jurisdictions. Since 1989, tribes have participated in the Office of Environmental Management's State and Tribal Government Working Group (STGWG). In that capacity, members of affected tribes participate in the Office of Environmental Management's Five-Year Plan planning process which projects EM's planned strategies, funding and accomplishments over a given five-year period.[169]

In addition, through Executive Order 13175 of November 6, 2000, executive departments and agencies are required to recognize a "special relationship" with tribes by engaging in regular consultation and collaboration with tribal officials in the development of federal policies with tribal implications.[170]

[167] "The Nuclear Waste Policy Act of 1982," bill, 1 congress.gov § (1983).
[168] "Federal Facility Compliance Act of 1992," bill, 1 govinfo.gov § (1992).
[169] The White House, (November 5, 2009), https://obamawhitehouse.archives.gov/the-press-office/memorandum-Tribal-consultation-signed-president.
[170] The White House, (November 5, 2009), https://obamawhitehouse.archives.gov/the-press-office/memorandum-Tribal-consultation-signed-president.

Non-profit Organizations with Nuclear Focus

American Nuclear Society

www.ans.org/about

The American Nuclear Society (ANS) is an organization of scientists, engineers, and industry professionals which promotes the fields of nuclear energy and technology. ANS was formed in 1954 and has since grown to welcome more than 10,000 members from over 50 countries.[171] The Society boasts multiple publications, scholarships, and awards. ANS has local sections, professional divisions, and student groups across the country and around the world to educate members and steer policy toward safe and responsible applications of nuclear technology.[172]

Energy Communities Alliance

www.energyca.org

The Energy Communities Alliance (ECA) is the only non-profit, membership organization of local governments and communities that host, are adjacent to or impacted by nuclear facilities and U.S. Department of Energy (DOE) activities. The organization brings together local government officials to share information, establish policy positions, and promote community interests to address an increasingly complex set of constituent, environmental, regulatory, and economic development needs.

Generation IV International Forum

www.gen-4.org

Generation IV reactors exist primarily in the research and development stages. The Generation IV International Forum (GIF) was established in 2001 and consists of member countries, including the United States, Canada, France, Japan and others, as well as several international organizations.[173] The forum serves as a platform for member countries to share knowledge, expertise, and resources in nuclear technology research and development. In the U.S., the Department of Energy currently supports multiple demonstration projects to accelerate the commercialization of these technologies.

Health Physics Society

www.hps.org

The Health Physics Society (HPS) is a nonprofit scientific professional organization dedicated to promoting excellence in the science and practice of radiation safety. Established in 1955, HPS serves as a platform for professionals in radiation protection to collaborate, share knowledge, and advance the field. The Society offers a range of resources, including peer-reviewed publications and a member newsletter. HPS organizes annual and midyear meetings that provide opportunities for professional development, networking, and dissemination of the latest research and standards in radiation safety. Additionally, HPS maintains a public information website, Radiation Answers, dedicated to educating the public about radiation in an accessible

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[171] American Nuclear Society, (October 2024), https://www.ans.org/join/.
[172] American Nuclear Society, (October 2024), https://www.ans.org/communities/.
[173] GEN IV International Forum, (July 10, 2024), https://www.gen-4.org/.

format. Through these initiatives, HPS supports the professional growth of its members and promotes public understanding of radiation safety.

National Academies of Science

www.nationalacademies.org

The National Academies is a nonprofit, nongovernmental organization created to advise the nation about science and technology. Established in 1863 by an Act of Congress signed by President Lincoln, the private institution elects members for their outstanding contributions to research and invites them to advise the nation on issues related to science and technology. Congress and federal agencies often request and fund NAS activities, although the organization does not receive direct appropriations.[174]

Nuclear Energy Institute

www.nei.org

The Nuclear Energy Institute represents the commercial nuclear energy industry in the U.S. The trade group advocates for policies that support nuclear power, focusing on regulatory reform, financing for new reactors, and the role of nuclear energy in decarbonization. It is the leading U.S. policy and technical organization dedicated to all aspects of the commercial nuclear industry. Its members include utilities, reactor vendors, technology developers, stakeholders from every facet of the nuclear supply chain, clean energy buyers, national labs, labor unions, and universities.

Nuclear Innovation Alliance

www.nuclearinnovationalliance.org

The Nuclear Innovation Alliance (NIA) is a self-described "think-and-do" tank that advocates for expanding nuclear energy to mitigate climate change.[175] Within the brief, "Advanced Reactors 101," the NIA outlines the benefits of advanced nuclear technology and provides case studies of state leaders who have pioneered projects with emergent technologies. The expansion of nuclear power will reduce carbon emissions and air pollution while creating high-paying jobs and economic opportunities. Advanced reactors will be safer and more reliable than fossil fuels, especially in rural areas. The case studies provided in this report are currently being undertaken in Wyoming, Washington State, Utah, and Puerto Rico – the NIA hopes to inspire further advancements with these success stories.[176]

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[174] National Academies, (October 2024), https://www.nationalacademies.org/about/the-national-academies.
[175] Nuclear Innovation Alliance, (October 2024), https://www.nuclearinnovationalliance.org/our-mission.
[176] Nuclear Innovation Alliance, (October 2024), https://nuclearinnovationalliance.org/advanced-nuclear-0.

LIST OF ABBREVIATIONS

AEA: Atomic Energy Act

AEC: Atomic Energy Commission

AEO: Annual Energy Outlook

AFCI: Advanced Fuel Cycle Initiative

BIA: Bureau of Indian Affairs

BRC: Blue Ribbon Commission on America's Nuclear Future

BWR: Boiling Water Reactor

CO_2: Carbon Dioxide

DHLW: Defense High-Level Waste

DNFSB: Defense Nuclear Facilities Safety Board

DOE: Department of Energy

DOE-EM: Department of Energy-Office of Environmental Management

DOE-NE: Department of Energy-Office of Nuclear Energy

DOI: Department of Interior

DOT: Department of Transportation

ECA: Energy Communities Alliance

EDF: Électricité de France

EIA: Energy Information Administration

EPA: Environmental Protection Agency

EPRI: Electric Power Research Institute

FEMA: Federal Emergency Management Agency

FFHR: Fusion-Fission Hybrid Reactor

GAO: Government Accountability Office

HLW: High-Level Waste

IAEA: International Atomic Energy Agency

INL: Idaho National Laboratory

ISFSI: Independent spent fuel storage installation

JAEA: Japan's Atomic Energy Agency

kWh: Kilowatt Hour

LLW: Low-Level Waste **LWR**: Light Water Reactor

MDO: Waste management and disposal organization

MOX: Mixed Oxide

MRS: Monitored Retrievable Storage

NARUC: National Association of Regulatory Utility Consumers

NAS: National Academy of Sciences

NE: Nuclear Energy or Office of Nuclear Energy

NEI: Nuclear Energy Institute

NFS: Nuclear Fuel Services

NGO: Non-Governmental Organization

NIF: National Ignition Facility

NIMBY: Not in My Backyard

NNSA: National Nuclear Security Administration

NRC: Nuclear Regulatory Commission

NUMO: Nuclear Waste Management Organization of Japan

NWF: Nuclear Waste Fund

NWPA: Nuclear Waste Policy Act

NWTRB: National Waste Technical Review Board

ONSIR: Office of Nuclear Security and Incident Response

OPEC: Organization of the Petroleum Exporting Countries

PFS: Private Fuel Storage, LLC

MIT: Massachusetts Institute of Technology

PILT: Payment in Lieu of Taxes

PUREX: Plutonium-Uranium Extraction

PWR: Pressurized Water Reactor

R&D: Research and Development

RCRA: Resource Conservancy and Recovery Act

SFR: Sodium-Cooled Fast Reactor

SMR: Small Modular Reactor

SNF: Spent Nuclear Fuel

TEPCO: Tokyo Electric Power Company

TMI: Three Mile Island

TRU Waste: Transuranic Waste

UN: United Nations

UREX+: Uranium Reduction and Extraction

WANO: World Association of Nuclear Operators

WIPP: Waste Isolation Pilot Plant

WNA: World Nuclear Association

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