Congressional Research Service
Informing the legislative debate since 1914

Nuclear Energy: Overview of Congressional Issues

Updated January 8, 2024

Congressional Research Service
https://crsreports.congress.gov
R42853

CRS REPORT
Prepared for Members and
Committees of Congress

Congressional Research Service
Informing the legislative debate since 1914

SUMMARY

R42853

January 8, 2024

Mark Holt
Specialist in Energy Policy

Nuclear Energy: Overview of Congressional Issues

The policy debate over the role of nuclear power in the nation's energy mix is rooted in the technology's fundamental characteristics. Nuclear reactors can produce potentially vast amounts of useful energy with relatively low consumption of natural resources and emissions of greenhouse gases and other pollutants. However, facilities that produce nuclear fuel for civilian power reactors can also produce materials for nuclear weapons. In addition, the process of nuclear fission (splitting of atomic nuclei) to generate power produces radioactive material that can remain hazardous for thousands of years and must be contained. How to manage the weapons proliferation and safety risks of nuclear power, or whether the benefits of nuclear power are worth those risks, are issues that have long been debated in Congress.

The 93 licensed nuclear power reactors at 54 sites in the United States generate about 20% of the nation's electricity. One new reactor, in Georgia, began operation in June 2023 and a twin unit is scheduled to start up by early 2024. About a dozen more reactors of various designs are planned or proposed. Whether they eventually move forward will likely depend largely on their economic competitiveness with natural gas and renewable energy sources. Similar economic forces affect existing reactors. Thirteen U.S. reactors were permanently closed from 2013 through April 2022. However, several states have taken action to prevent reactor shutdowns, and Congress has enacted federal tax credits and other support for existing reactors.

The Department of Energy (DOE) and its predecessor agencies for decades have conducted research on "advanced" reactor technologies, such as fast neutron reactors, that would differ significantly from existing commercial nuclear plants and potentially be far smaller. Proponents of advanced reactors contend that they would be safer, more efficient, and less expensive to build and operate than today's conventional light water reactors. Detractors raise concerns regarding weapons-proliferation risks and cast doubt on their affordability and sustainability. DOE is providing support for several proposed advanced reactor demonstrations, which could indicate whether the anticipated benefits can be realized. Legislation supporting U.S. production of nuclear fuel was enacted by Congress on December 14, 2023, in the National Defense Authorization Act for FY2024 (Section 3131 of P.L. 118-31). Other advanced nuclear bills in the 118th Congress include S. 1111 and H.R. 6544.

Highly radioactive spent nuclear fuel that is regularly removed from nuclear reactors is currently stored primarily at power plant sites. Development of a permanent underground repository at Yucca Mountain, NV, was suspended by the Obama Administration. The Trump Administration requested funding for FY2018, FY2019, and FY2020 to revive the program, but it was not approved by Congress. No Yucca Mountain program funding has since been requested or provided.

The Obama Administration appointed the Blue Ribbon Commission on America's Nuclear Future to recommend an alternative approach to the Nuclear Waste Policy Act's focus on Yucca Mountain for permanent high-level waste disposal. The Commission's recommendations included selecting nuclear waste storage and disposal facilities through a "consent based" process. DOE awarded $26 million in grants to 13 consortia of universities and other organizations in June 2023 to develop consent-based siting approaches. In the meantime, Yucca Mountain remains the sole authorized candidate site for permanent disposal, despite its lack of funding. Nuclear waste bills in the 118th Congress include proposals to require state and local consent for siting a nuclear waste repository (H.R. 1051, S. 404).

The March 2011 disaster at the Fukushima Dai-ichi nuclear power plant in Japan increased attention to nuclear safety throughout the world. The Nuclear Regulatory Commission (NRC), which issues and enforces nuclear safety requirements, promulgated Fukushima-related regulations on March 12, 2012.

The level of security that must be provided at nuclear power plants has been a high-profile issue since the 9/11 terrorist attacks on the United States in 2001. Since those attacks, NRC issued a series of orders and regulations that substantially increased nuclear plant security requirements, although industry critics contend that those measures are still insufficient.

Encouraging exports of U.S. civilian nuclear products, services, and technology while making sure they are not used for foreign nuclear weapons programs has long been a fundamental goal of U.S. nuclear energy policy. Recent proposals to build reactors in several countries without nuclear power, including the Middle East, have prompted concerns about the effectiveness of international controls. Current bills to encourage nuclear exports include S. 1928 and H.R. 806.

Contents

Tables

Contacts

Synthesis of Key Issues

The long-running policy debate over the future of nuclear energy is rooted in the technology's inherent characteristics. Initially developed for its unprecedented destructive power during World War II, nuclear energy seemed to hold equal promise after the war as a way of providing limitless energy to all humanity. International diplomacy has focused ever since on finding institutional mechanisms for spreading the perceived benefits of nuclear energy throughout the world while preventing the technology from being used for the proliferation of nuclear weapons. Much of this international effort is focused on key nuclear fuel cycle facilities—plants for enriching uranium in the fissile isotope U-235 and for separating plutonium from irradiated nuclear fuel. Such plants can be used to produce civilian nuclear reactor fuel as well as fissile material for nuclear warheads.

Yet even the use of nuclear power solely for peaceful energy production has proven intrinsically controversial. The harnessing of nuclear fission in a reactor creates highly radioactive materials that must be kept from overheating and escaping from the reactor building, as occurred during the accidents at Fukushima in Japan, Chernobyl in the Soviet Union, and, to a lesser extent, Three Mile Island in Pennsylvania. Spent nuclear fuel that is regularly removed from reactors during refueling must be isolated from the environment for up to 1 million years. Proposed commercial technologies to reduce long-lived nuclear waste through recycling usually involve separating plutonium that possibly could be used for nuclear weapons, although technologies designed to reduce proliferation risks are also the subject of worldwide research and development efforts. All nuclear energy technologies, even with recycling, would still leave substantial amounts of radioactive waste to be stored and disposed of. Central storage and disposal sites for nuclear waste have proven difficult to develop throughout the world, as illustrated by the long-running controversy over the proposed U.S. waste repository at Yucca Mountain, NV, and proposed consolidated interim storage facilities in New Mexico and Texas.

The March 2011 disaster at Japan's Fukushima Dai-ichi nuclear power plant, which forced the evacuation of areas as far as 30 miles away, slowed nuclear power expansion plans around the world, particularly in Japan and Western Europe. Nevertheless, dozens of new reactors are still being planned and built in China, India, Russia, and elsewhere.[1] In these areas, nuclear power's initial promise of generating large amounts of electricity without the need for often-imported fossil fuels, along with the more recent desire to reduce greenhouse gas emissions, remains a compelling motivation.

With 93 licensed reactors, the United States has the largest nuclear power industry in the world. But U.S. nuclear power growth has been largely stagnant for the past two decades, as natural gas and renewable energy have captured most of the market for new electric generating capacity and improvements in energy efficiency have slowed electricity demand growth.[2] Congress enacted incentives for new nuclear plants in the Energy Policy Act of 2005 (P.L. 109-58), including production tax credits, loan guarantees, and insurance against regulatory delays. Those incentives, combined with rising natural gas prices and concerns about federal restrictions on carbon dioxide emissions, prompted announcements by late 2009 of up to 30 new nuclear power reactors in the

[1] World Nuclear Association, "World Nuclear Power Reactors and Uranium Requirements," November 2023, http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx.

[2] Energy Information Administration, *Annual Energy Outlook 2023*, March 16, 2023, https://www.eia.gov/outlooks/aeo/narrative/index.php#TheElectricityMixinth.

United States.[3] However, subsequent declines in natural gas prices and uncertainty about carbon dioxide controls put most of those projects on hold.

Some of those projects began construction, with mixed results. A new reactor in Georgia began commercial operation in July 2023 and a twin unit is scheduled to start up by early 2024. A planned advanced nuclear plant in Idaho was terminated by its developers in November 2023 after experiencing numerous delays and cost overruns. Two identical reactors under construction in South Carolina were canceled in July 2017. The Georgia and South Carolina projects both experienced large cost overruns and schedule delays. An older reactor, Watts Bar 2 in Tennessee, received an NRC operating license on October 22, 2015, after construction had been suspended for two decades and then completed.

Existing U.S. nuclear power plants are continuing to face difficult competition from natural gas and renewable energy. Thirteen U.S. reactors were permanently closed from 2013 through April 2022. Three of those units closed because of the need for expensive repairs, three were retired under agreements with state utility regulators, and seven could not compete in their regional wholesale electricity markets. All 13 units had substantial time remaining on their initial 40-year operating licenses or had received or planned to apply for 20-year license extensions from the Nuclear Regulatory Commission (NRC). (See **Table 2**.) The shutdowns prompted widespread discussion about the future of other aging U.S. reactors and proposals for federal assistance. Action taken by states has forestalled the announced shutdowns of 20 other U.S. reactors during the past several years. Congress has also enacted federal tax credits and other support for existing and new nuclear power plants.

The extent to which the growth of nuclear power should be encouraged in the United States and around the world will continue to be a major component of the U.S. energy policy debate. Questions for Congress could include the implementation of policies to encourage or discourage nuclear power, post-Fukushima safety standards, development of new nuclear power and fuel cycle technologies, and nuclear waste management strategies.

Basic Facts and Statistics

The 93 licensed nuclear power reactors at 54 sites in the United States generate about 20% of the nation's electricity. The oldest of today's operating reactors were licensed in 1969, and the most recent to begin commercial operation was Vogtle 3 in Georgia in July 2023.[4] Before that, the most recent reactors to start up were Watts Bar 2 in 2015 and its twin unit, Watts Bar 1, in 1996 in Tennessee.[5] All U.S. reactors were initially licensed to operate for 40 years, but nearly all of them have received or applied for 20-year license renewals by NRC.[6] NRC issued its first "subsequent license renewals," which allow operation for up to 80 years, to the Turkey Point 1 and 2 reactors in Florida in December 2019. Four more renewals to 80 years, for Peach Bottom 2 and 3 in Pennsylvania and Surry 1 and 2 in Virginia, were issued in March 2020 and May 2021. Subsequent license renewal applications for another 10 reactors are currently under review, one application is being reviewed for acceptance, and eight others are anticipated during the next two

[3] Nuclear Regulatory Commission, "Expected New Nuclear Power Plant Applications," updated March 28, 2008, https://www.nirs.org/wp-content/uploads/nukerelapse/industry/expectednewrxapplications32808.pdf.

[4] Georgia Power, "Vogtle Unit 3 goes into operation," news release, July 31, 2023, https://www.georgiapower.com/company/news-center/2023-articles/vogtle-unit-3-goes-into-operation.html.

[5] Nuclear Regulatory Commission, *Information Digest, 2020-2021*, NUREG-1350, vol. 34, Appendix A,https://www.nrc.gov/docs/ML2304/ML23047A378.pdf.

[6] Nuclear Regulatory Commission, "Status of Initial License Renewal Applications and Industry Initiatives," October 13, 2023, https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html.

years.[7] Under the current mixture of 40- and 60- and 80-year licenses, all of today's operating reactors would shut down by 2055. If newer reactors, such as Vogtle 3, eventually were to receive license renewals to 80 years, the shutdown date for the existing fleet could be pushed back by two decades or more.

Whether new reactors will be constructed to replace the existing fleet or even to expand nuclear power's market share will depend largely on costs. The cost of building and operating a new nuclear power plant in the United States is generally estimated to be significantly higher than natural gas combined-cycle plants (which use both combustion and steam turbines to generate electricity) and higher than wind and solar as well. For example, the Energy Information Administration (EIA) estimates that, for plants coming on line in 2028, the average cost of electricity generation from a nuclear power plant would be 7.1 cents per kilowatt-hour (kwh), including tax credits, while advanced combined-cycle gas-fired generation would cost 4.3 cents/kwh and an ultracritical coal plant would cost 8.9 cents/kwh. EIA estimates that electricity from onshore wind would cost 3.1 cents/kwh, solar photovoltaics 2.3 cents/kwh, and geothermal 3.7 cents/kwh.[8] Such estimates depend on a wide range of variables, such as future fuel costs, regional solar and wind availability, current and future tax incentives, and environmental regulations and mandates. The specific attributes of each generating technology, such as the intermittent nature of solar and wind, are also important considerations in power plant construction decisions.

The two new U.S. reactors at the Vogtle nuclear plant site in Georgia experienced considerable construction delays and cost overruns.[9] As noted above, construction of two new units in South Carolina has been terminated. Licenses to build and operate 10 additional reactors have been issued by NRC. However, applications for 14 other new reactors have been withdrawn or suspended. An application for a license to build a 1.5 megawatt microreactor at Idaho National Laboratory was submitted to NRC on March 11, 2020.[10] Aside from the 2 new Vogtle units, the 10 other planned reactors with issued licenses do not have specific schedules for moving toward construction.

Much of the U.S. interest in new nuclear power plants is focused on "advanced" reactors, using different technology from that of existing light water reactors, which use ordinary (light) water as a coolant and moderator to slow the neutrons in the nuclear chain reaction. There is also considerable interest in "small modular reactors," which would be smaller than today's commercial reactors and could use a variety of technologies. In addition to the microreactor noted above, NRC is conducting licensing reviews or pre-application activities for several advanced reactors.[11]

Throughout the world, 436 reactors are currently in service or operable, and 62 more are under construction. France is the most heavily nuclear-reliant country in the world, with 56 reactors

[7] Nuclear Regulatory Commission, "Status of Subsequent License Renewal Applications," September 6, 2023, https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html.

[8] Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2023," p. 8, April 2023, https://www.eia.gov/outlooks/aeo/electricity_generation/pdf/AEO2023_LCOE_report.pdf. Levelized costs include capital costs averaged over the life of the plant, plus fuel and maintenance costs and tax credits, in 2022 dollars.

[9] Darrell Proctor, "Another Delay for New Unit at Vogtle Nuclear Plant," *Power*, June 17, 2023, https://www.powermag.com/another-delay-for-new-unit-at-vogtle-nuclear-plant.

[10] Nuclear Regulatory Commission, "Combined License Applications for New Reactors," July 3, 2023, https://www.nrc.gov/reactors/new-reactors/col.html.

[11] Nuclear Regulatory Commission, "Licensing Activities for Advanced Reactors," March 31, 2022, https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities.html.

generating 63% of the country's electricity in 2022. Thirty-two countries in 2022 (plus Taiwan) generated at least some of their electricity from nuclear power.[12]

After the Fukushima accident, Germany, which had previously generated about 30% of its electricity with nuclear power, began phasing out its 17 power reactors through early 2023. Japan, which had also generated about 30% of its electricity with nuclear power and had planned to raise that level to 50%, now is planning for about 20% by 2030. All Japanese reactors were closed within a year after the 2011 earthquake and tsunami, and 11 of Japan's 33 operable reactors are currently in commercial service. In addition to the 11 currently approved to operate, 14 Japanese reactors have applied for restart, which involves safety upgrades to meet new regulatory requirements. It is not clear how many of Japan's operable reactors will ultimately resume operation.[13] France had planned to reduce nuclear power to 50% of the country's total generation by 2025, although that goal was pushed back in 2019 and then rescinded altogether in 2023.[14]

Major Nuclear Energy Issues

Advanced Nuclear Technology

Existing commercial nuclear power plants in the United States are based on light water reactor (LWR) technology, in which ordinary (light) water is used to cool the reactor and to moderate, or slow, the neutrons in a nuclear chain reaction. In the chain reaction, neutrons cause the nuclei of uranium and other heavy atoms to fission (split), releasing large amounts of energy and additional neutrons to maintain the reaction. The federal government developed LWRs for naval propulsion in the 1950s and funded the commercialization of the technology for electricity generation. DOE and its predecessor agencies for decades have also conducted research on "advanced" reactor technologies that use different coolants and moderators, as well as fast neutron reactors that have no moderator.

The term "advanced nuclear reactor" is defined by the Energy Act of 2020 (P.L. 116-260, Division Z) as a fission reactor that has "significant improvements" over existing commercial reactors, and any fusion reactor. Areas of improvement can include safety, waste generation, performance, resistance to weapons proliferation, "modular sizes," and integration of electric and non-electric applications (such as heat and hydrogen production). That definition encompasses small modular reactors (SMRs) of any type. Supporters of advanced reactors contend that their potentially lower cost and other advantages over existing commercial reactors could make them highly competitive with other low-emission energy sources and create a vast export market. Several demonstrations of advanced reactor designs are currently planned, which could provide an indication of their commercial viability.

To produce less long-lived radioactive waste than existing reactors, some advanced reactor concepts would involve the reprocessing of spent nuclear fuel to separate uranium, plutonium,

[12] World Nuclear Association, "Nuclear Share Figures, 2012-2022," August 2023, http://www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx; World Nuclear Association, "World Nuclear Power Reactors and Uranium Requirements," op. cit.

[13] World Nuclear Association, "Nuclear Power in Japan," August 2023, http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx.

[14] World Nuclear Association, "Nuclear Power in France," August 2023, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx.

and other long-lived radioisotopes to make new fuel for fast reactors.[15] Such reprocessing, or recycling, would also reduce the need for newly mined uranium to fuel a potentially growing worldwide reactor fleet, according to proponents. However, the separation of plutonium from spent nuclear fuel also raises significant concerns about nuclear weapons proliferation.

SMRs would be smaller than today's commercial LWRs, which generally have about 1,000 megawatts (MW) of electric generating capacity or more.[16] Supporters of SMRs contend that they would be small enough to be assembled in factories and shipped to reactor sites to reduce construction costs. In addition, SMRs could reduce the financial risks of building a new nuclear power plant, because each module would cost less than today's large reactors and revenues could begin when the first module was complete, rather than after completion of a much larger unit. However, some analysts contend that SMRs would be too small to achieve the economies of scale needed for economic viability.[17] None of the currently proposed U.S. designs for SMRs have been constructed, so actual costs and construction times have yet to be demonstrated.[18]

Very small SMRs are often called "microreactors," defined by DOE as having thermal energy capacity below 20 MW. They could provide heat or electric power at remote locations. Self-contained microreactor power units would be assembled in a factory, transported to a site in a shipping container, and set up to generate power within a week, according to DOE. Microreactors would be "self regulating," in that their designs are intended to prevent overheating even without operator intervention.[19]

Recent Events

DOE's Advanced Reactor Demonstration Program (ARDP) supports demonstration plants using advanced nuclear technology and the development of technologies for possible future demonstration.[20] The program was initially funded with $230 million by the Further Consolidated

[15] Radioisotopes are radioactive isotopes; isotopes are forms of an element that have different numbers of neutrons. Different radioisotopes of the same element will behave the same chemically but have different half-lives and other radioactive characteristics. Long-lived radioisotopes separated from spent fuel could in principle be fissioned or transmuted in a fast reactor into shorter-lived radioisotopes for disposal.

[16] A DOE fact sheet says SMRs can "represent a variety of sizes, technology options, capabilities, and deployment scenarios" and are "envisioned to vary in size from tens of megawatts up to hundreds of megawatts." DOE Office of Nuclear Energy, "Advanced Small Modular Reactors (SMRs)," https://www.energy.gov/ne/advanced-small-modular-reactors-smrs. The Infrastructure Investment and Jobs Act (P.L. 117-58, Section 40321) and the James M. Inhofe National Defense Authorization Act (NDAA) for Fiscal Year 2023 (P.L. 117-263, Section 320, amending P.L. 117-81, NDAA for FY2022) define SMRs as having generating capacity of less than 300 MW. The 300 MW limit is also used by the Atomic Energy Act in setting reactor liability limits for public damages (42 U.S.C. 2210(b)(5)). The International Atomic Energy Agency (IAEA) defines SMRs as having electrical capacity of up to 300 MW. IAEA, "Small Modular Reactor (SMR) Regulators' Forum," https://www.iaea.org/topics/small-modular-reactors/smr-regulators-forum.

[17] Deign, Jason, "Interest in Small Modular Nuclear Reactors Is Growing. So Are Fears They Aren't Viable," Greentech Media, March 14, 2018, https://www.greentechmedia.com/articles/read/interest-in-small-modular-nuclear-grows#gs.ph5LRao.

[18] A high-temperature gas-cooled SMR began commercial operation in China in December 2023. The 210 MW (electric) plant took 11 years to construct at a cost that was not announced. See "China's Demonstration HTR-PM Enters Commercial Operation, *World Nuclear News*, December 6, 2023, https://www.world-nuclear-news.org/Articles/Chinese-HTR-PM-Demo-begins-commercial-operation.

[19] DOE Office of Nuclear Energy, "What Is a Nuclear Microreactor?," February 26, 2021, https://www.energy.gov/ne/articles/what-nuclear-microreactor. Electrical output of a reactor can range from about 34%-39% of its thermal output. World Nuclear Association, "Is the Cooling of Power Plants a Constraint on the Future of Nuclear Power?," p. 3, https://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/WNA_Position_Statements/PS-cooling.pdf.

[20] DOE, "Advanced Reactor Demonstration Program," https://www.energy.gov/ne/advanced-reactor-demonstration-program.

Appropriations Act, 2020 (P.L. 116-94) and was authorized by the Energy Act for funding through FY2025.

The Infrastructure Investment and Jobs Act (IIJA, P.L. 117-58), enacted in 2021, appropriated $2.477 billion through FY2025 for ARDP, in addition to annual appropriations. DOE selected two demonstration projects in October 2020 to receive a total of $3.2 billion from the program over seven years, with the project sponsors matching that amount. Five potential future reactor demonstration projects received 80% cost-share awards under ARDP in December 2020, totaling $600 million of DOE funding over seven years.

In addition to the ARDP projects, DOE announced a cost-shared award of up to $1.4 billion under an earlier program in October 2020 to demonstrate the NuScale water-cooled SMR at Idaho National Laboratory. However, that project was terminated on November 8, 2023, by NuScale and the intended owner of the plant, Utah Associated Municipal Power Systems (UAMPS). According to a statement by the companies, UAMPS members (mostly small municipal power systems) did not commit to purchasing enough of the SMR plant's planned 462 megawatts of electric generation to make the project economically viable.[21] The project had experienced a number of delays and cost overruns before being terminated.[22]

Tax credits for advanced nuclear reactors and other new zero-carbon power plants were included in the law commonly referred to as the Inflation Reduction Act of 2022 (IRA, P.L. 117-169). Qualifying plants can receive a 10-year electricity production tax credit of up to 2.6 cents/kilowatt-hour (as adjusted for inflation[23]) or a 30% investment tax credit. IRA also includes $700 million for DOE to develop supplies of high-assay low enriched uranium (HALEU), needed for some advanced reactor designs, including the two non-LWR demonstration plants that DOE is supporting. HALEU, not currently available commercially, is uranium enriched in the fissile isotope U-235 above the 3%-5% level used by existing commercial reactors but below the 20% threshold for highly enriched uranium. DOE's HALEU program was authorized by the Energy Act of 2020. The Nuclear Energy Innovation Capabilities Act of 2017 (NEICA, P.L. 115-248) authorizes the construction of demonstration reactors funded by the private sector at DOE sites and authorizes grants to help pay for advanced reactor licensing. The Nuclear Energy Innovation and Modernization Act (P.L. 115-439), enacted in 2019, requires NRC to develop a new licensing framework for advanced nuclear technology. Proponents of the law contend that NRC's existing licensing system is too focused on LWR technology and would potentially cause delays in non-LWR applications.

NRC is currently reviewing a design certification application for the NuScale SMR plant, which would consist of six 77 MW (electric) reactors in a large pool of water.[24] NRC is also reviewing construction permit applications by Kairos Power and Abilene Christian University.[25] Under

[21] NuScale, UAMPS, "Utah Associated Municipal Power Systems (UAMPS) and NuScale Power Agree to Terminate the Carbon Free Power Project (CFPP)," news release, November 8, 2023, https://www.cfppllc.com/file/44ac923c-86d2-43de-a87b-2c6e336a0db5.

[22] Zach Bright, "NuScale Cancels First-of-a-Kind Nucler Project as Costs Surge," *Energywire*, November 9, 2023, https://www.eenews.net/articles/nuscale-cancels-first-of-a-kind-nuclear-project-as-costs-surge.

[23] The base renewable energy production tax credit of 1.5 cents/kwh, amended by IRA, was established in 1992 and is annually adjusted for inflation.

[24] NRC, "NuScale US460 Standard Design Approval Application Review," August 1, 2023, https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/current-licensing-reviews/nuscale-us460.html. The first planned NuScale power plant, at Idaho National Laboratory, was canceled November 8, 2023, but the design review is continuing for other potential projects.

[25] NRC, "Current Licensing Reviews of Advanced Reactors," July 31, 2023, https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/current-licensing-reviews.html.

ARDP, one of the award recipients, TerraPower, is proposing to build its demonstration plant on the site of a closed coal-fired power plant in Wyoming,[26] while the other, X-energy, is proposing to build a four-unit demonstration plant at a Dow Chemical plant in Texas.[27]

Table 1. Planned Advanced Reactor Demonstration Plants

Selected Projects with DOE Funding or NRC License Applications

Reactor Designer	Tech-nology	Reactor Power (electric)	Plant Owner	DOE Funding	DOE Cost Share	Plant Location	NRC Licensing Status
Terra Power	Sodium-cooled fast reactor	345 MW	PacificCorp	Up to $1.6 billion	50%	Kemmerer, WY	Pre-application activities
X-energy	High-temperature gas-cooled reactor	80 MW	Energy Northwest	Up to $1.2 billion	50%	Seadrift, TX	Pre-application activities
Kairos	Fluoride-salt-cooled high-temperature reactor	35 MW	Kairos	Up to $303 million	48%	Oak Ridge, TN	Construction permit approved 12/12/2023
Abilene Christian University	Molten salt research reactor	1 MW	Abilene Christian University	None for demonstra-tion	0%	Abilene, TX	Construction permit application submitted 8/12/2022
Previously funded project terminated							
NuScale	Light water SMR	77 MW	Utah Associated Municipal Power Systems (UAMPS)	Up to $1.4 billion	50%	Idaho Falls, ID (Idaho National Laboratory)	Standard Design Approval application submitted 1/1/2023

Sources: DOE, NRC, 2023.

Note: NuScale/UAMPS project terminated by sponsors November 8, 2023. See news release at https://www.cfpplc.com/file/44ac923c-86d2-43de-a87b-2c6e336a0db5.

The Department of Defense (DOD) awarded a contract in 2022 to BWX Technologies to build a prototype mobile microreactor. An award to develop a second prototype design went to X-energy in 2023. According to DOD's Strategic Capabilities Office (SCO), "By nurturing and developing multiple micro reactor designs, SCO will not just provide options for the military Services, but will also help jumpstart a truly competitive commercial marketplace for micro reactors."[28]

[26] DOE Office of Nuclear Energy, "Next-Gen Nuclear Plant and Jobs Are Coming to Wyoming," June 7, 2021, https://www.energy.gov/ne/articles/next-gen-nuclear-plant-and-jobs-are-coming-wyoming.

[27] X-energy, "Energy Northwest and X-energy Sign Joint Development Agreement for Xe-100 Advanced Small Modular Reactor Project," July 19, 2023, https://x-energy.com/media/news-releases/energy-northwest-x-energy-joint-development-agreement-xe-100.

[28] DOD, "DOD Exercises Option on Second Micro Nuclear Reactor Design," September 13, 2023, (continued...)

DOE's nuclear energy research and development program includes reactor modeling and simulation, experimental processing of spent nuclear fuel, development of advanced reactor concepts, and testing of "accident tolerant fuels" for existing LWRs. The Energy and Water Development and Related Agencies Appropriations Act, 2023 (P.L. 117-328, Division D) included $1.473 billion for DOE nuclear energy programs. The enacted funding measure provided $85 million for the Advanced Reactor Demonstration Program and $114 million for accident-tolerant fuels. An additional $300 million was appropriated under Division M of P.L. 117-328 for advanced nuclear reactor demonstrations and fuel availability.

For FY2024, the Biden Administration requested $1.563 billion for nuclear energy programs, while the House approved $1.783 billion (H.R. 4394, H.Rept. 118-126) and the Senate Appropriations Committee recommended $1.551 billion (S. 2443, S.Rept. 118-72).

Selected Congressional Action—118th Congress

Hearing to Examine the Nuclear Fuel Cycle, Senate Committee on Energy and Natural Resources

Topics included the supply of HALEU for advanced reactors, domestic nuclear fuel production, and nuclear waste storage and disposal. Held March 9, 2023, https://www.energy.senate.gov/hearings/2023/3/full-committee-hearing-to-examine-the-nuclear-fuel-cycle.

Hearing on American Nuclear Energy Expansion: Powering a Clean and Secure Future, House Committee on Energy and Commerce, Subcommittee on Energy, Climate, and Grid Security

Topics included conditions needed for deployment of nuclear technologies, domestic nuclear infrastructure and workforce, regulatory issues, and competition in international markets. Held April 18, 2023, https://energycommerce.house.gov/events/energy-climate-and-grid-security-subcommittee-hearing-american-nuclear-energy-expansion-powering-a-clean-and-secure-future.

Hearing on From Theory to Reality: The Limitless Potential of Fusion Energy, House Committee on Science, Space, and Technology, Subcommittee on Energy

Topics included the status of DOE fusion research and the growth of private-sector companies pursuing commercial fusion. Held June 13, 2023, https://science.house.gov/hearings?ID=1A693FA1-B7A9-4408-BE83-6253FFB7787D.

National Defense Authorization Act for Fiscal Year 2023 (P.L. 118-31, H.R. 2670, Rogers)

Section 3131, the Nuclear Fuel Security Act of 2023, requires DOE to establish a Nuclear Fuel Security Program to increase the supply of HALEU for advanced reactors and, if necessary, domestically produced low-enriched uranium. DOE must enter into at least two contracts to begin acquiring at least 20 metric tons per year of HALEU by the end of 2027 or the earliest feasible date, subject to available funding. The program must use only uranium produced and processed in the United States or, if necessary, by U.S. allies or partners. Revenues from the sale and transfer

https://www.defense.gov/News/Releases/Release/Article/3524458/dod-exercises-option-on-second-micro-nuclear-reactor-design.

of enriched uranium acquired for the program are to be deposited into a revolving fund to be used for further acquisitions. Introduced April 18, 2023; conference report passed by the Senate on December 13, 2023, and by the House on December 14, 2023; signed by the President on December 22, 2030.

Atomic Energy Advancement Act (H.R. 6544, Duncan)

Among other provisions, would remove requirements for NRC to recover costs for reviewing applications and conducting pre-application for early site permits for advanced reactors. Would require NRC to develop risk-informed and performance-based strategies and guidance for microreactor licensing. Would authorize a pilot program for DOE long-term power purchases from a new commercial nuclear power plant. Would require an interagency study of the global nuclear energy industry and global supply chains. Would require NRC to coordinate reactor import and export licensing activities and authorizes an NRC International Nuclear Reactor Export and Innovation Branch. Would extend authority for new reactors to be included in the Price-Anderson Act nuclear accident liability system through 2065. Would authorize the Secretary of Energy to award prizes for the first advanced reactor to receive an NRC operating license and for other licensing categories. Introduced December 1, 2023; ordered to be reported December 5, 2023, by House Committee on Energy and Commerce.

Advanced Reactor Fee Reduction Act (H.R. 6326, Bucshon)

Would limit the hourly rates charged by NRC for reviewing pre-application materials for advanced reactor licenses and for reviewing advanced reactor license applications. Introduced November 9, 2023; referred to Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered to be reported by House Committee on Energy and Commerce December 5, 2023.

Strengthening American Nuclear Competitiveness Act (H.R. 6303, Bill Johnson)

Would require the Secretary of Energy to report to Congress on U.S. nuclear energy industry competitiveness and to review and update the process for granting general authorization to countries for the transfer of civilian nuclear technology. Would establish exceptions to the current prohibition on foreign ownership or control of U.S. nuclear power plants. Would extend the deadline for new reactors to be included in the Price-Anderson Act nuclear liability and compensation system from 2025 to 2065. Introduced November 8, 2023; referred to Committee on Energy and Commerce, and in addition the Committee on Foreign Affairs for provisions under its jurisdiction.

Advanced Nuclear Reactor Prize Act (H.R. 6253, Curtis)

Would authorize the Secretary of Energy to make awards to cover regulatory costs relating to licensing certain first-of-a-kind advanced nuclear reactors. Introduced November 7, 2023; referred to the House Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered to be reported by House Committee on Energy and Commerce December 5, 2023.

Green Nuclear Fertilizer Act (H.R. 5750, Donalds)

Would require the secretaries of Energy and Agriculture and NRC to submit a report to Congress on the feasibility of producing hydrogen from advanced nuclear reactors to make “green nuclear

fertilizer." Introduced September 27, 2023; referred to Committee on Agriculture, and to the Committee on Energy and Commerce for provisions under its jurisdiction.

Nuclear Fuel Security Act of 2023 (H.R. 5718, Latta/S. 452, Manchin)

Would require DOE to ensure supplies of domestic nuclear fuel, at all stages of production, and would set a goal of providing at least 10 metric tons of HALEU for advanced reactors by June 30, 2026. H.R. 5718 introduced September 26, 2023; referred to Committees on Energy and Commerce, and Science, Space, and Technology. Ordered to be reported by House Committee on Energy and Commerce December 5, 2023. S. 442 introduced February 15, 2023; referred to Committee on Energy and Natural Resources and reported with an amendment July 11, 2023 (S.Rept. 118-52). Provisions included as Section 3144 of the National Defense Authorization Act for Fiscal Year 2024 (S. 2226), passed by the Senate July 27, 2023. Similar to provisions enacted as Section 3131 of P.L. 118-31 above.

U.S. Capitol Power Plant Retrofit Act (H.R. 5706, Donalds)

Would require the Architect of the Capitol, in consultation with DOE and NRC, to study the feasibility of "retrofitting the Capitol Power Plant to incorporate an advanced nuclear reactor." Introduced September 26, 2023; referred to Committee on Transportation and Infrastructure.

Expressing the sense of the Senate and House that advanced nuclear power should be encouraged (S.Res. 321, Budd/H.Res. 124, Donalds)

Expresses the sense of the Senate and House that nuclear power should be promoted as clean, reliable, and secure, that advanced nuclear reactors could be a U.S. export opportunity, and that the necessary supply chain, fuel, and workforce should be established. Senate resolution introduced July 27, 2023; referred to Committee on Energy and Natural Resources; House resolution introduced February 14, 2023; referred to Committee on Energy and Commerce, and to the Committee on Armed Services for provisions under its jurisdiction.

Provide Logistical Aid to airports via advanced Nuclear Energy (PLANE) Act (H.R. 4678, Donalds)

Would require NRC, the Federal Aviation Administration, and DOE to establish procedures to deploy microreactors at airports. Introduced July 17, 2023; referred to Committee on Transportation and Infrastructure.

Leverage Obligated appropriations for Advanced Nuclear (LOAN) Act (H.R. 4677, Donalds)

Would make DOE advanced reactor demonstration projects eligible for DOE innovative technology loan guarantees. Introduced July 17, 2023; referred to Committee on Energy and Commerce, and also the Committee on Science, Space, and Technology for provisions under its jurisdiction.

Advanced Nuclear Feasibility Act (H.R. 4674, Donalds)

Would require DOE to establish a grant program for feasibility studies for the deployment of advanced nuclear reactors. Introduced July 17, 2023; referred to Committee on Energy and Commerce.

Civil Nuclear Export Act of 2023 (S. 1928, Manchin)

Would allow for Export-Import (EXIM) Bank financing of fast breeder reactors and spent nuclear fuel reprocessing plants if they are otherwise permitted by law, add nuclear facilities to the EXIM Bank Program on China and Transformational Exports, and establish EXIM Bank liability limits for damages caused by nuclear projects financed by the bank. Introduced June 12, 2023; referred to Committee on Banking, Housing, and Urban Affairs.

21st Century American Atomic Energy Age Act (H.R. 3553, Wittman)

Would require NRC to provide technical assistance to SMR license applicants, among other provisions. Introduced May 18, 2023; referred to Committee on Energy and Commerce, and to the Committees on Homeland Security and Armed Services for provisions under their jurisdiction.

Advanced Nuclear Support Act (H.R. 3487, Donalds)

Would provide financial support for "commercial planning for, and licensing and construction of, advanced nuclear reactors, and supply chain infrastructure associated with advanced nuclear reactors." Introduced May 18, 2023; referred to Committee on Energy and Commerce, and to Committee on Science, Space, and Technology for provisions under its jurisdiction.

Recoup American Nuclear Global Leadership Act (H.R. 3486, Donalds)

Would establish Nuclear Exports Working Group composed of senior officials from DOE, EXIM Bank, NRC, Department of Commerce, and other relevant agencies. Introduced May 18, 2023; referred to Committee on Foreign Affairs.

To amend the Internal Revenue Code of 1986 to make advanced nuclear facilities eligible for the qualifying advanced energy project credit (H.R. 2488, Donalds)

Would make advanced nuclear facilities eligible for the qualifying advanced energy project tax credit. Introduced April 6, 2023; referred to Committee on Ways and Means.

Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act of 2023 (S. 1111, Capito)

Would authorize NRC to establish an International Nuclear Reactor Export and Innovation Branch, restrict possession of nuclear fuel assemblies manufactured in Russia or China, restrict nuclear exports to countries lacking specified international safeguards, limit NRC fees for advanced reactor license applications, authorize prizes for the first advanced reactor licenses, and exclude NRC costs for reviewing advanced reactors at DOE sites from annual fees, among other provisions. Introduced March 30, 2023; reported with an amendment in the nature of a substitute by Environment and Natural Resources Committee July 10, 2023. Text included as Section 8141 of the National Defense Authorization Act (NDAA) for Fiscal Year 2024 (S. 2226), passed by the Senate July 27, 2023. Not included in FY2024 NDAA as enacted (P.L. 118-31).

International Nuclear Energy Act of 2023 (S. 826, Manchin/H.R. 2938, Donalds)

Would require the Secretary of State, in coordination with the Secretaries of Energy and Commerce, to conduct meetings with allied and partner nations to pursue collaboration on

research, development, licensing, and deployment of advanced nuclear reactor technologies; and includes other provisions to encourage international civil nuclear cooperation and exports. Senate bill introduced March 15, 2023; referred to Committee on Foreign Relations. House bill introduced April 28, 2023; referred to Committees on Foreign Affairs, Energy and Commerce, and Ways and Means.

National Strategy to Utilize Microreactors for Natural Disaster Response Efforts Act (H.R. 1009, Donalds)

Would require the President, in consultation with relevant federal agencies, to develop a national strategy to utilize microreactors to assist with natural disaster response efforts. Introduced February 14, 2023; referred to Committee on Transportation and Infrastructure, and to the Committees on Energy and Commerce, and Armed Services, for provisions under their jurisdiction.

Nuclear Assistance for America's Small Businesses Act (H.R. 1007, Donalds)

Would delay collection of a portion of NRC fees related to advanced reactor license applications and pre-application activities. Introduced February 14, 2023; referred to Committee on Energy and Commerce.

Global Nuclear Energy Assessment and Cooperation Act (H.R. 995, Carter of Georgia)

Would require NRC to support "the consideration of international technical standards to assist the design, licensing, and construction of advanced nuclear systems" and establish an NRC International Nuclear Reactor Export and Innovation Branch to carry out such activities, among other provisions. Introduced February 14, 2023; approved by Committee on Energy and Commerce Subcommittee on Energy, Climate, and Grid Security October 24, 2023. Also referred to Committee on Foreign Affairs for provisions under its jurisdiction. Similar provisions included in H.R. 6544, ordered to be reported by House Committee on Energy and Commerce December 5, 2023.

International Nuclear Energy Financing Act of 2023, (H.R. 806, McHenry)

Would require the Secretary of the Treasury to instruct the United States Executive Director at the World Bank and other international financial institutions to support assistance for nuclear energy. Introduced February 2, 2023; referred to Committee on Financial Services.

CRS Reports

CRS Report R45706, *Advanced Nuclear Reactors: Technology Overview and Current Issues*, by Mark Holt

Additional References

Gateway for Accelerated Innovation in Nuclear (GAIN), DOE website, https://gain.inl.gov/SitePages/Home.aspx

Pathways to Commercial Liftoff: Advanced Nuclear, DOE, March 2023, https://liftoff.energy.gov/advanced-nuclear

Laying the Foundation for New and Advanced Nuclear Reactors in the United States, National Academy of Engineering, 2023, https://www.nationalacademies.org/our-work/laying-the-foundation-for-new-and-advanced-nuclear-reactors-in-the-united-states

Proposed U.S. Army Mobile Nuclear Reactors: Costs and Risks Outweigh Benefits, Alan J. Kuperman, University of Texas at Austin, LBJ School of Public Affairs, Nuclear Proliferation Prevention Project, April 22, 2021, http://mail01.tinyletterapp.com/NPPP/2-reports-army-reactors-space-reactors/19288238-sites.utexas.edu/nppp/files/2021/04/army-reactor-report-nppp-2021-april.pdf

Small Modular Reactors: Challenges and Opportunities, Organisation for Economic Co-operation and Development Nuclear Energy Agency, April 7, 2021, https://www.oecd.org/publications/small-modular-reactors-18fbb76c-en.htm

A Comparison of Advanced Nuclear Technologies, Andrew C. Kadak, Columbia University Center on Global Energy Policy, March 2021, https://energypolicy.columbia.edu/sites/default/files/A%20Comparison%20of%20Nuclear%20Technologies%20033017.pdf

"Advanced" Isn't Always Better: Assessing the Safety, Security, and Environmental Impacts of Non-Light-Water Nuclear Reactors, Edwin Lyman, Union of Concerned Scientists, March 2021, https://www.ucsusa.org/resources/advanced-isnt-always-better

U.S. Advanced Nuclear Energy Strategy for Domestic Prosperity, Climate Protection, National Security, and Global Leadership, Nuclear Innovation Alliance and Partnership for Global Security, February 2021, https://partnershipforglobalsecurity.org/wp-content/uploads/2021/02/US-Advanced-Nuclear-Energy-Strategy-NIA-PGS-02-16-2021-1.pdf

Metric and Method for Comparing Investments to Decarbonize the Electricity System, Rocky Mountain Institute, September 24, 2019, https://rmi.org/insight/decarbonizing-the-electricity-system

Uranium and Fuel Supply

The nuclear fuel supply chain begins with the mining of uranium, which is found in geological deposits with widely varying concentrations throughout the world. Mined natural uranium is concentrated to the form of an oxide, U_3O_8, known as yellowcake. About 0.7% of the uranium in yellowcake consists of the fissile isotope U-235, while the remaining 99.3% is non-fissile U-238. To make nuclear fuel appropriate for commercial light water fission reactors, the yellowcake must be chemically converted to uranium hexafluoride (UF_6) in a conversion plant. The UF_6 is then sent to a uranium enrichment plant where, in a gaseous state, it is spun in large cylindrical centrifuges to separate U-235 from the slightly more massive U-238. As a result, some of the UF_6 (toward the center of the centrifuge) gains an increased concentration, or enrichment, of U-235. To make fuel for existing commercial light water reactors, the UF_6 is fed into a series of centrifuges until the U-235 enrichment reaches between 3% and 5%. Additional centrifuges and energy would be needed to reach higher enrichment levels, such as the nearly 20% required for HALEU. Enriched uranium is transported to fuel fabrication plants to be made into fuel assemblies—bundles of long metal tubes filled with uranium—to be loaded into reactors to produce energy.

Russia's full-scale invasion of Ukraine in February 2022 led to broad sanctions on Russian exports, including those in the energy sector. However, sanctions have not been imposed on

Russian uranium exports, because of substantial reliance on those exports by the United States and Europe, particularly exports of enriched uranium.[29]

The world's largest uranium-mining countries, in order, are Kazakhstan, Canada, Namibia, Australia, Uzbekistan, Russia, Niger, and China, which together accounted for 98% of world production of uranium concentrate in 2022. U.S. uranium concentrate production in 2022 accounted for 0.15%.[30] Canada was the largest supplier of uranium to U.S. nuclear power plants in 2022, accounting for 27%, followed by Kazakhstan at 25% and Russia at 12%. Most U.S. uranium mines halted production after 2018, primarily because of low prices. [31] Following a sharp increase in uranium prices and expectations of further rising demand, several U.S. mines restarted operations in 2022 and 2023, with more reopenings planned.[32]

The only U.S. uranium conversion plant, in Metropolis, IL, halted operation in 2017 because of low prices and oversupply. Nuclear reactors in the United States at that point became dependent on conversion plants in Canada and France, conversion conducted in Russia to prepare uranium for enrichment and subsequent export, and secondary supplies from inventories. The Metropolis plant restarted in mid-2023, following a doubling of conversion prices.[33] Production is to be increased at the Canadian conversion plant in 2024, and the owners of a closed conversion plant in the United Kingdom are reportedly considering restart.[34]

Russia dominates world uranium enrichment capacity, with about 45%. The United States has one enrichment plant, owned by the European consortium Urenco, with about 8% of the world's capacity. Other enrichment plants are located in France, Germany, the Netherlands, and the United Kingdom.[35] In 2022, Russia supplied 24% of uranium enrichment services purchased by U.S. nuclear power plants, while the U.S. enrichment plant provided 27% and Western European plants provided 49%.

Russian uranium imports to the United States are subject to annual import limits established under the terms of the 1992 Russian Suspension Agreement, asamended, between the U.S. Department of Commerce and the Russian Federation's State Atomic Energy Corporation, ROSATOM. Since that time, the Russian Suspension Agreement has been amended five times to extend and modify the limits, including the most recent amendment finalized between Commerce and ROSATOM on October 5, 2020.[36] Congress codified the amendment to the suspension

[29] For a European perspective, see Ashutosh Pandey, "Why EU Sanctions Don't Include Russian Nuclear Industry, July 19, 2023," *Deutsche Welle*, https://www.dw.com/en/russia-nuclear-industry-eu/a-66275352.

[30] World Nuclear Association, "Word Uranium Mining Production," August 2023, https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx.

[31] Energy Information Administration, "U.S. Uranium Production up in 2022 After Reaching Record Lows in 2021," August 17, 2023, https://www.eia.gov/todayinenergy/detail.php?id=60160.

[32] Energy Information Administration, "Domestic Uranium Production Report—Annual," May 31, 2023, https://www.eia.gov/uranium/production/annual; and "Production Begins at Three U.S. Uranium Mines," *World Nuclear News*, December 22, 2023, https://www.world-nuclear-news.org/Articles/Production-begins-at-three-US-uranium-mines; Mining.com, "Uranium Price Makes Fresh Decade High as Forecasts Grow (Even) Rosier," September 12, 2023, https://www.mining.com/uranium-price-makes-fresh-decade-high-as-forecasts-grow-even-rosier.

[33] William Freebairn, "Conversion, Enrichment Suppliers Worried About Future Oversupply," *Platts NuclearFuel*, October 27, 2023.

[34] "Uranium Conversion at UK's Springfields Site Could Resume Under Right Conditions: Official," *Platts Nuclear News Flashes*, December 20, 2023.

[35] World Nuclear Association, "Uranium Enrichment," October 2022, https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx.

[36] Enforcement and Compliance, International Trade Administration, Department of Commerce, "2020 Amendment to the Agreement Suspending the Antidumping Investigation on Uranium From the Russian Federation," *Federal*
(continued...)

agreement with Section 2007 of the Consolidated Appropriations Act, 2021 (P.L. 116-260), which amended 42 U.S.C. 2297h-10a by establishing additional import limits through 2040.

The fuel fabrication stage, in which enriched uranium is made into finished reactor fuel assemblies, does not rely on Russian capacity. Capacity at three U.S. fuel fabrication plants is more than sufficient to supply all U.S. commercial reactors. Western European reactors also do not need Russian fuel fabrication. However, some Eastern European countries with Soviet-designed reactors use fuel fabricated in Russia.[37]

Recent Events

Urenco announced July 6, 2023, that it would expand the capacity of its U.S. enrichment plant in New Mexico by 15%, starting in 2025. "New commitments from U.S. customers for non-Russian fuel underpin this investment," according to a company statement.[38] Another 15% capacity increase was announced by Urenco for its Netherlands plant on December 14, 2023, along with an unspecified increase at its plant in Germany, with both increases tied to increased customer commitments.[39] French nuclear fuel firm Orano announced October 26, 2023, that it would expand its enrichment plant by 30% by 2028, which could include production of HALEU "as driven by demand."[40] The U.S. firm Centrus delivered the initial 20 kilograms of HALEU to DOE in November 2023 under a contract that calls for 900 kilograms in 2024 "with options to produce more in the future," according to DOE.[41]

In line with those announcements, leaders from the United States, Canada, France, Japan, and the United Kingdom pledged on December 7, 2023, that they would "pursue at least USD $4.2 billion in government-led and private investment in our five nations' collective enrichment and conversion capacity over the next three years" that would be "free from Russian material." The agreement was reached at the Net Zero Nuclear Summit on the sidelines of the United Nations Framework Convention on Climate Change's 28th Conference of the Parties (COP28).[42]

The House passed a bill (H.R. 1042) on December 11, 2023, to prohibit imports of enriched uranium from Russia. If no alternative supplies were available, the Secretary of Energy could grant waivers to the prohibition through 2027, up to specified annual limits. The Congressional Budget Office estimated that the bill would increase the price of nuclear fuel by 13% by prompting "a gradual replacement of Russian suppliers with higher-cost sources of enrichment

Register, October 9, 2020. The finalized amendment dates were March 11, 1994; October 3, 1996; May 7, 1997; February 1, 2008; and October 5, 2020.

[37] World Nuclear Association, "Nuclear Fuel and Its Fabrication," October 2021, https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/fuel-fabrication.aspx.

[38] Urenco, "Urenco's First Capacity Expansion to Be at Its U.S. Site," news release, July 6, 2023, https://www.urenco.com/news/global/2023/urencos-first-capacity-expansion-to-be-at-its-us-site.

[39] Urenco, "Urenco Announces Major Netherlands Expansion to Strengthen Energy Security, news release, December 14, 2023, https://www.urenco.com/news/global/2023/urenco-announces-major-expansion-in-the-netherlands-to-strengthen-energy-security.

[40] Orano, "Orano Announces 30% Increase in Uranium Enrichment Capacity by 2028," news release, October 26, 2023, https://www.orano.group/usa/en/our-news/news-releases/2023/orano-announces-30-increase-in-uranium-enrichment-capacity-by-2028.

[41] DOE Office of Nuclear Energy, "Centrus Produces Nation's First Amounts of HALEU," November 7, 2023, https://www.energy.gov/ne/articles/centrus-produces-nations-first-amounts-haleu.

[42] DOE, "At COP28, U.S., Canada, France, Japan, and UK Announce Plans to Mobilize $4.2 Billion for Reliable Global Nuclear Energy Supply Chain," December 7, 2023, https://www.energy.gov/articles/cop28-us-canada-france-japan-and-uk-announce-plans-mobilize-42-billion-reliable-global.

services under the bill's waiver provisions."[43] In a March 9, 2023, hearing in the Senate Committee on Energy and Natural Resources, the president of the largest U.S. nuclear plant operator, Constellation Energy, testified that "while Western suppliers have said that new capacity could be available as early as 2028, that date could easily slip if legislation to support new capacity is not enacted soon."[44]

Recent Congressional Action—118th Congress

Hearing to Examine the Nuclear Fuel Cycle, Senate Committee on Energy and Natural Resources

Topics included domestic nuclear fuel production, the supply of HALEU for advanced reactors, and nuclear waste storage and disposal. Held March 9, 2023, https://www.energy.senate.gov/hearings/2023/3/full-committee-hearing-to-examine-the-nuclear-fuel-cycle.

National Defense Authorization Act for Fiscal Year 2023 (P.L. 118-31, H.R. 2670, Rogers)

Section 3131 of P.L. 118-31, which is cited as the Nuclear Fuel Security Act of 2023, requires DOE to establish a Nuclear Fuel Security Program to increase the supply of HALEU for advanced reactors and, if necessary, domestically produced low-enriched uranium. DOE must enter into at least two contracts to begin acquiring at least 20 metric tons per year of HALEU by the end of 2027 or the earliest feasible date, subject to available funding. The program must use only uranium produced and processed in the United States or, if necessary, by U.S. allies or partners. Revenues from the sale and transfer of enriched uranium acquired for the program are to be deposited into a revolving fund to be used for further acquisitions. Introduced April 18, 2023; conference report passed by the Senate on December 13, 2023, and by the House on December 14, 2023; signed by the President on December 22, 2030.

Nuclear Fuel Security Act of 2023 (H.R. 5718, Latta/S. 452, Manchin)

Would require DOE to ensure supplies of domestic nuclear fuel, at all stages of production, and would set a goal of providing at least 10 metric tons of HALEU for advanced reactors by June 30, 2026. H.R. 5718 introduced September 26, 2023; referred to Committees on Energy and Commerce, and Science, Space, and Technology. Ordered to be reported by House Committee on Energy and Commerce December 5, 2023. S. 452 introduced February 15, 2023; referred to Committee on Energy and Natural Resources and reported with an amendment July 11, 2023 (S.Rept. 118-52). Provisions included as Section 3144 of the National Defense Authorization Act for Fiscal Year 2024 (S. 2226), passed by the Senate July 27, 2023. Similar to provisions enacted as Section 3131 of P.L. 118-31 above.

[43] Congressional Budget Office, Cost Estimate, H.R. 1042, Prohibiting Russian Uranium Imports Act, as reported by the House Committee on Energy and Commerce, December 5, 2023, https://www.cbo.gov/system/files/2023-12/hr1042.pdf.

[44] Testimony of Joseph Dominguez, President and Chief Executive Officer, Constellation Energy, before the Senate Committee on Energy and Natural Resources, March 9, 2023, https://www.energy.senate.gov/services/files/0E076807-6F7F-4C0A-8D21-8E7E0A7ACF25.

Prohibiting Russian Uranium Imports Act (H.R. 1042, Rodgers)/Reduce Russian Uranium Imports Act (S. 763, Barrasso)

Would prohibit imports of enriched uranium from Russia. If no alternative supplies were available, the Secretary of Energy could grant waivers to the prohibition through 2027, up to specified annual limits. House bill introduced February 14, 2023; reported by the House Committee on Energy and Commerce December 1, 2023 (H.Rept. 118-296). Passed House December 11, 2023. Senate bill introduced March 9, 2023; referred to Committee on Energy and Natural Resources.

CRS Reports

CRS Report R45753, *The Front End of the Nuclear Fuel Cycle: Current Issues*, by Lance N. Larson

Additional References

Uranium Enrichment, World Nuclear Association, October 2022, https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx

Radioactive Waste

After several years in a nuclear reactor, nuclear fuel (primarily uranium) can no longer economically sustain a nuclear chain reaction and becomes highly radioactive and thermally hot. Such spent nuclear fuel must be periodically removed from operating reactors and stored in adjacent pools of water, which prevents overheating and provides radiation shielding. After several years of cooling, the spent fuel can be placed in dry casks for storage elsewhere on the plant site.

When existing U.S. reactors were built, spent fuel had been expected to be taken away for reprocessing (separation of plutonium and uranium to make new fuel) or permanent disposal. However, reprocessing has not become commercialized in the United States, for economic and nonproliferation reasons, and central waste storage and disposal facilities have proven difficult to site. As a result, the vast majority of U.S. commercial spent fuel remains at the nuclear plants where it was generated—estimated at 90,000 metric tons at the end of 2022 and increasing at the rate of about 2,200 metric tons per year.[45]

The Nuclear Waste Policy Act of 1982 (P.L. 97-425, NWPA), as amended in 1987, named Yucca Mountain, NV, as the nation's sole candidate site for a permanent high-level nuclear waste repository. NWPA required the DOE to study the site and seek a license from NRC to build a repository there.

Citing opposition from the State of Nevada, the Obama Administration halted the Yucca Mountain project. No new funding has been appropriated for it since FY2010. The Obama Administration appointed the Blue Ribbon Commission on America's Nuclear Future to develop an alternative nuclear waste policy, and its final report was issued in January 2012. DOE largely adopted the Commission's recommendations in a January 2013 waste strategy that called for a "consent-based" process to select nuclear waste storage and disposal sites and for a surface

[45] DOE, Resource Portal for DOE Nuclear Waste Management Information, interactive map, viewed October 24, 2023, https://curie.pnnl.gov/map.

storage pilot facility to open by 2021.[46] DOE issued a *Draft Consent-Based Siting Process* shortly before the end of the Obama Administration.[47]

A federal appeals court on August 13, 2013, ordered NRC to continue the Yucca Mountain licensing process with previously appropriated funds.[48] In response, NRC issued the final volumes of the Yucca Mountain Safety Evaluation Report (SER), which provided the NRC staff's determination that the repository would meet all applicable standards. However, the staff said upon completing the SER that NRC should not authorize construction of the repository until all land and water rights requirements were met and a supplement to DOE's environmental impact statement (EIS) was completed.[49] NRC completed the supplemental EIS in May 2016 and made its database of Yucca Mountain licensing documents publicly available, using nearly all the remaining previously appropriated licensing funds.[50]

Recent Events

The Trump Administration largely halted the consent-based siting process and included funding to restart Yucca Mountain licensing in its FY2018, FY2019, and FY2020 budget submissions to Congress, but the requests were not funded by Congress. The Trump Administration did not seek Yucca Mountain repository funding for FY2021, but only funds for interim storage planning, which were appropriated by Congress. The Biden Administration also requested nuclear waste funds only for planning in FY2022, FY2023, and FY2024 (with those amounts enacted in FY2022 and FY2023).

The Biden Administration resumed the consent-based siting process in December 2021 with a request for information about the design of such a program and issued an updated report on consent-based siting in April 2023.[51] Under the updated process, DOE awarded grants on July 9, 2023, to 13 consortia made up of academic, nonprofit, and private-sector institutions to "work with communities interested in DOE's community-centered approach to storing and disposing of spent nuclear fuel."[52]

With no spent fuel disposal or storage facilities currently under development by DOE, two private-sector storage facilities in New Mexico and Texas have been proposed. NRC issued licenses to the Texas facility on September 13, 2021, and to the New Mexico facility on May 9, 2023. These near-surface Consolidated Interim Storage Facilities are intended to hold spent fuel

[46] DOE, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, January 2013, http://energy.gov/sites/prod/files/2013%201-15%20Nuclear_Waste_Report.pdf.

[47] DOE, *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste*, January 12, 2017, https://energy.gov/sites/prod/files/2017/01/f34/Draft%20Consent-Based%20Siting%20Process%20and%20Siting%20Considerations.pdf.

[48] U.S. Court of Appeals for the District of Columbia Circuit, *In re: Aiken County et al*., No. 11-1271, writ of mandamus, August 13, 2013, http://www.cadc.uscourts.gov/internet/opinions.nsf/BAE0CF34F762EBD985257BC6004DEB18/$file/11-1271-1451347.pdf.

[49] NRC, "NRC Publishes Final Two Volumes of Yucca Mountain Safety Evaluation," news release 15-005, January 29. 2015, http://www.nrc.gov/reading-rm/doc-collections/news/2015/.

[50] NRC, *Supplement to the U.S. Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, NUREG-2184, Final Report, May 2016, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2184/; "NRC Staff Issues Volume 3 of Yucca Mountain Safety Evaluation Report," news release 14-069, October 16, 2014, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1949/v3/.

[51] DOE, *Consent-Based Siting Process for Federal Consolidated Interim Storage of Spent Nuclear Fuel*, April 2023, https://www.energy.gov/sites/default/files/2023-05/Consent-Based%20Siting%20Process%20Report-0424%203.pdf.

[52] DOE, "DOE Awards $26 Million to Support Consent-Based Siting for Spent Nuclear Fuel," June 9, 2023, https://www.energy.gov/articles/doe-awards-26-million-support-consent-based-siting-spent-nuclear-fuel.

from nuclear power plants around the country until a permanent underground repository is available.[53] However, they are facing strong opposition from the two proposed host states. New Mexico filed a lawsuit against NRC on March 29, 2021, and the Texas governor signed a law banning new spent fuel storage facilities in the state on August 9, 2021.[54] In a lawsuit filed by Texas, the Fifth Circuit Court of Appeals on August 25, 2023, vacated the license for the Texas site on the grounds that NRC lacks authority to license nuclear waste storage facilities other than those specified by NWPA.[55] NRC petitioned for review by the full circuit court on October 24, 2023.[56]

Canadian plans for nuclear waste disposal have also generated congressional controversy, because some proposed sites are near the Great Lakes. In 2019, Canada's Nuclear Waste Management Organization narrowed its search for a spent nuclear fuel repository to two sites in Ontario, one located near Lake Huron.[57]

Recent Congressional Action—118th Congress

Hearing to Examine the Nuclear Fuel Cycle, Senate Committee on Energy and Natural Resources

Topics included nuclear waste storage and disposal, the supply of HALEU for advanced reactors, and domestic nuclear fuel production. Held March 9, 2023, https://www.energy.senate.gov/hearings/2023/3/full-committee-hearing-to-examine-the-nuclear-fuel-cycle.

Increasing Nuclear Safety Protocols for Extended Canister Transfers (INSPECT) Act (H.R. 5115, Levin)

Would require NRC to assign a resident inspector to each commercial nuclear power plant that has permanently ceased operation. Would require the inspector to conduct inspections of decommissioning activities and spent nuclear fuel transfer activities, and remain at the plant until all fuel is transferred from its spent fuel pools to dry storage. Introduced August 1, 2023; referred to Committee on Energy and Commerce.

[53] NRC, "Consolidated Interim Storage Facility (CISF)," December 8, 2020, https://www.nrc.gov/waste/spent-fuel-storage/cis.html; NRC, "NRC Issues License to Interim Storage Partners for Consolidated Spent Nuclear Fuel Interim Storage Facility in Texas," news release 21-036, September 13, 2021, https://www.nrc.gov/docs/ML2125/ML21257A091.pdf; NRC, "NRC Issues License to Holtec International for Consolidated Spent Nuclear Fuel Interim Storage Facility in New Mexico," news release 23-031, May 9, 2023, https://www.nrc.gov/cdn/doc-collection-news/2023/23-031.pdf.

[54] Texas Governor Greg Abbott, "Interim Storage Partners (ISP) Consolidated Interim Storage Facility Project, Docket ID NRC-2016-0231," November 3, 2020, https://www.nrc.gov/docs/ML2030/ML20309B061.pdf; Texas Legislature Online, Actions, HB7, https://capitol.texas.gov/BillLookup/Actions.aspx?LegSess=872&Bill=HB7; and New Mexico Governor Michelle Lujan Grisham, "Comments from Governor Michelle Lujan Grisham on Docket ID NRC-2018-0052," September 22, 2020, https://www.nrc.gov/docs/ML2026/ML20269A025.pdf.

[55] State of Texas v. NRC, U.S. Court of Appeals for the Fifth Circuit, August 25, 2023, https://www.ca5.uscourts.gov/opinions/pub/21/21-60743-CV0.pdf.

[56] NRC Petition for Review of Action, U.S. Court of Appeals for the Fifth Circuit, October 24, 2023, https://www.exchangemonitor.com/wp-content/up.

[57] Canadian Nuclear Waste Management Organization, "About the Site Selection Process," viewed December 7, 2023, https://www.nwmo.ca/Site-selection.

Spent Fuel Prioritization Act of 2023 (H.R. 3862, Levin)

Would require that, in determining the order in which spent nuclear fuel will be taken by DOE from nuclear plant sites under NWPA, highest priority shall be given to plants that are permanently closed and are located in the highest-population areas, earthquake zones, and areas that pose national security concerns. Introduced June 6, 2023; referred to Committee on Energy and Commerce.

Expressing the sense of the Senate and the House of Representatives that the President and the Secretary of State should ensure that the Government of Canada does not permanently store nuclear waste in the Great Lakes Basin (S.Res. 117, Stabenow; H.Res. 243, Kildee)

Expresses the sense of the House and Senate that Canada should not allow construction of a nuclear waste repository within the Great Lakes Basin, and that the President and the Department of State should work with Canada to prevent such construction and craft a long-term solution for nuclear waste storage that does not threaten the Great Lakes. Senate resolution introduced March 22, 2023; referred to Committee on Foreign Relations. House resolution introduced March 22, 2023; referred to Committee on Foreign Affairs.

Nuclear Waste Informed Consent Act (H.R. 1051, Titus/S. 404, Cortez Masto)

Would require the Secretary of Energy to obtain the consent of affected state, local, and tribal governments before making expenditures from the Nuclear Waste Fund for a nuclear waste repository. Both bills introduced February 14, 2023. House bill referred to Committee on Energy and Commerce; Senate bill referred to Committee on Environment and Public Works.

CRS Reports

CRS In Focus IF11201, *Nuclear Waste Storage Sites in the United States*, by Lance N. Larson

Additional References

CURIE Resource Portal for DOE Nuclear Waste Management Information, DOE Office of Nuclear Energy, https://curie.pnnl.gov

Disposal of High-Level Nuclear Waste, Government Accountability Office, Key Issues website, https://www.gao.gov/key_issues/disposal_of_highlevel_nuclear_waste/issue_summary

Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors, National Academies of Sciences, Engineering, and Medicine, 2023, https://nap.nationalacademies.org/catalog/26500/merits-and-viability-of-different-nuclear-fuel-cycles-and-technology-options-and-the-waste-aspects-of-advanced-nuclear-reactors

Commercial Spent Nuclear Fuel, Nuclear Waste Technical Review Board, January 2022, https://www.nwtrb.gov/our-work/fact-sheets/commercial-spent-nuclear-fuel.Commercial *Spent Fuel: Congressional Action Needed to Break Impasse and Develop a Permanent Disposal Solution*, Government Accountability Office, September 2021, https://www.gao.gov/products/gao-21-603.

Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward, Nuclear Waste Technical Review Board, April 2021, https://www.nwtrb.gov/

our-work/reports/six-overarching-recommendations-for-how-to-move-the-nation-s-nuclear-waste-management-program-forward-(april-2020)

Forging a Path Forward on US Nuclear Waste Management: Options for Policy Makers, Matt Bowen, Columbia University Center on Global Energy Policy, January 2021, https://www.energypolicy.columbia.edu/research/report/forging-path-forward-us-nuclear-waste-management-options-policy-makers

Preparing for Nuclear Waste Transportation, Nuclear Waste Technical Review Board, September 2019, https://www.nwtrb.gov/our-work/reports/preparing-for-nuclear-waste-transportation-(september-2019)

Reset of America's Nuclear Waste Management: Strategy and Policy, Stanford University Center for International Security and Cooperation and George Washington University Elliott School of International Affairs, October 15, 2018, https://fsi-live.s3.us-west-1.amazonaws.com/s3fs-public/reset_report_2018_final.pdf

Report to the Secretary of Energy, Blue Ribbon Commission on America's Nuclear Future, January 2012, http://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov

Nuclear Plant Economic Viability

U.S. nuclear power plants have faced severe financial pressure caused primarily by competition from low-cost natural gas, growing supplies of renewable energy, and stagnant electricity demand. Thirteen U.S. reactors were permanently closed from 2013 through April 2022 (**Table 2**). Plans for up to 30 new U.S. reactors announced during the past 15 years have largely been put on hold, with 1 completed, 1 currently under construction, and 2 canceled in 2017 after construction had begun.

In light of that situation, Congress and several states have taken action to keep the existing nuclear fleet operating and to encourage the construction of new reactors. A key element of that debate is the appropriate role of nuclear power, if any, in meeting national energy and environmental goals. Nuclear power supporters generally point to the technology as crucial for providing a secure, domestic source of energy with low greenhouse gas and other emissions. Supporters also see a viable and growing domestic nuclear power industry as crucial in providing a technology base for naval nuclear reactors and other defense nuclear programs, and in providing a base for nuclear power plant exports to counter reactor exports being pursued by Russia and China for geopolitical purposes. Opponents generally counter that safety and proliferation risks, nuclear waste hazards, and high costs outweigh those benefits.

Government support for nuclear power can include loan guarantees, tax credits, clean energy mandates, emissions credits, and electricity market regulations.

The two new reactors at the Vogtle plant have received loan guarantees from DOE totaling $12 billion, as authorized by Title 17 of the Energy Policy Act of 2005 (P.L. 109-58). Energy Secretary Ernest Moniz announced the issuance of $6.5 billion in loan guarantees on February 19, 2014, to two of the three utility partners in the project, Georgia Power and Oglethorpe Power. Another $1.8 billion loan guarantee for another partner, Municipal Electric Authority of Georgia, was issued June 24, 2015. Energy Secretary Rick Perry announced the finalization of an additional $3.7 billion in loan guarantees to the three partners in the Vogtle project on March 22,

2019.[58] No other proposed nuclear plants have received any commitments for DOE loan guarantees.

Federal tax credits for electricity production from new nuclear plants were extended by the Bipartisan Budget Act of 2018 (P.L. 115-123). Before the extension, new nuclear plants had been required to begin operation before January 1, 2021, to qualify for the production tax credit, which is limited to 6,000 megawatts of total generating capacity. The extension allows new reactors to use the credit after that date if the capacity limit has not been reached. Along with the extension, the tax credit was modified to allow non-taxpaying partners in a nuclear project, such as public power agencies, to transfer their credits to a project's taxpaying partners. The two new Vogtle reactors total about 2,300 megawatts of capacity, well within the limit. As noted above, construction delays pushed the startup of the first of the new reactors (Vogtle 3) to July 2023 and the planned completion date of Vogtle 4 to early 2024, well beyond the previous 2021 deadline, and the production tax credits are widely considered crucial for their financial viability.

Table 2. U.S. Commercial Reactor Shutdowns Since 2012

Reactor	State	Shutdown Date	Net Summer Generating Capacity (Megawatts)	Start-Up Year	Major Factors Contributing to Shutdown
Crystal River 3	Florida	February 2013	860	1977	Cost of major repairs to reactor containment
Kewaunee	Wisconsin	May 2013	566	1974	Operating losses
San Onofre 2	California	June 2013	1,070	1983	Cost of replacing new steam generators
San Onofre 3	California	June 2013	1,080	1984	Cost of replacing new steam generators
Vermont Yankee	Vermont	December 2014	620	1972	Operating losses
Fort Calhoun	Nebraska	October 2016	479	1973	Operating losses
Oyster Creek	New Jersey	September 2018	614	1969	Agreement with state to avoid building cooling towers
Pilgrim	Massachusetts	May 2019	685	1972	Operating losses, rising capital expenditures
Three Mile Island 1	Pennsylvania	October 2019	803	1974	Operating losses
Indian Point 2	New York	April 30, 2020	1,020	1974	Low electricity prices; settlement with state
Duane Arnold	Iowa	August 2020	601	1975	Lower-cost alternative power

[58] Department of Energy, "Secretary Perry Announces Financial Close on Additional Loan Guarantees During Trip to Vogtle Advanced Nuclear Energy Project," news release, March 22, 2019, https://www.energy.gov/articles/secretary-perry-announces-financial-close-additional-loan-guarantees-during-trip-vogtle.

Reactor	State	Shutdown Date	Net Summer Generating Capacity (Megawatts)	Start-Up Year	Major Factors Contributing to Shutdown
Indian Point 3	New York	April 30, 2021	1,035	1976	Low electricity prices; settlement with state
Palisades	Michigan	April 2022	784	1971	Operating losses, end of power purchase agreement; plant owner now attempting to restart with state and federal support

Source: Information from company news releases and DOE on the status of reactor shutdowns since 2012.

Recent Events

Congress took a major step to improve the economics of existing nuclear plants by establishing a tax credit in IRA Section 13105. The credit provides up to 1.5 cents per kilowatt-hour, adjusted for inflation, for electricity generated in 2024 through 2032. IRA Section 13701 makes new nuclear reactors eligible for a similar 10-year clean electricity production credit that is available for facilities placed into service after 2024. IRA Section 13707 allows nuclear reactors to qualify for a clean electricity investment tax credit of up to 30% if they do not take the clean electricity production credit.

IIJA created a Civil Nuclear Credit Program to provide direct financial support to nuclear power plants at risk of closure for economic reasons. Reactors certified by the Secretary of Energy as being at risk of closure can submit bids to receive credits for four years, specifying an amount per megawatt-hour of electricity generated that would be paid for each credit. DOE announced a final Civil Nuclear Credit award totaling up to $1.1 billion to the two-unit Diablo Canyon plant in California on January 2, 2024.[59] The Diablo Canyon credit award, the only one issued by the program to date, is intended to prevent the planned permanent shutdown of the plant in 2025.

The one-unit Palisades nuclear power plant in Michigan ceased operation in April 2022. The plant's owner, Holtec, had purchased the plant with the intention of decommissioning it, but decided after the shutdown to try to resume operation. Holtec announced the filing of a restart application with NRC on October 6, 2023, and has applied for a DOE loan guarantee. No permanently closed reactors in the United States have ever restarted.[60]

Several states also have taken action to prevent nuclear plant closures. An Illinois law signed September 15, 2021, provides "carbon mitigation credits" to nuclear plants at risk of closure for

[59] DOE, "Record of Decision for the Final Environmental Impact Statement for the Civil Nuclear Credit Program Proposed Award of Credits to Pacific Gas and Electric Company for Diablo Canyon Power Plant," *Federal Register*, January 2, 2024, https://www.federalregister.gov/documents/2024/01/02/2023-28808/record-of-decision-for-the-final-environmental-impact-statement-for-the-civil-nuclear-credit-program; DOE, "Biden-Harris Administration Announces Major Investment to Preserve America's Clean Nuclear Energy Infrastructure," November 21, 2022, https://www.energy.gov/articles/biden-harris-administration-announces-major-investment-preserve-americas-clean-nuclear.

[60] Holtec International, "Holtec Formally Initiates Process with NRC to Reauthorize Operations at Palisades Power Plant," October 6, 2023, https://holtecinternational.com/2023/10/06/holtec-formally-initiates-process-with-nrc-to-reauthorize-operations-at-palisades-power-plant.

economic reasons, averting the planned shutdown of two plants with four operating reactors.[61] New York and Illinois provided "zero emission credits" to seven reactors that had been at risk of retirement by 2018.[62] Connecticut enacted legislation in 2017 to make nuclear reactors eligible for a state procurement process for zero-emission electricity sources, upon certification of financial need. New Jersey enacted zero-emission credits for nuclear power in 2018.[63] Ohio enacted subsidies in July 2019 that prompted the owner of the state's two commercial reactors, Davis-Besse and Perry, to rescind the units' previously planned retirements, although the assistance was repealed in March 2021.[64] The planned retirement of the two-unit Beaver Valley nuclear plant in western Pennsylvania was rescinded in March 2020, after Pennsylvania joined the Regional Greenhouse Gas Initiative (RGGI). The plant's owner, Energy Harbor, said RGGI would provide emissions credits "which will begin to help level the playing field for our carbon-free nuclear generators."[65] Michigan enacted legislation on July 31, 2023, to provide $150 million toward restarting the closed Palisades plant.[66]

DOE's Light Water Reactor Sustainability Program manages cost-shared research projects "to solve significant highest priority cost and technical problems threatening existing plants."[67] The program includes research on materials used in nuclear plants, modeling of plant aging, and plant upgrades. The Consolidated Appropriations Act, 2023 (P.L. 117-328) included $45 million for the sustainability program, nearly the same as in FY2022. For FY2024, the Biden Administration requested $35 million for the program, while the House approved $45 million (H.R. 4394) and the Senate Appropriations Committee recommended $35 million (S. 2443).

Federal policy on carbon dioxide emissions could also have a significant impact on the expansion of nuclear power and the economic viability of existing reactors. The Biden Administration has set a goal of eliminating carbon emissions for the U.S. power sector by 2035.[68]

---

[61] Illinois General Assembly, Energy Transition Act (Nuclear Plant Assistance), Public Act 102-0662, https://ilga.gov/legislation/publicacts/102/102-0662.htm.

[62] *Zero-Emission Credits*, Nuclear Energy Institute, April 2018, https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/zero-emission-credits-201804.pdf.

[63] *Solutions for Maintaining the Existing Nuclear Fleet*, Center for Climate and Energy Solutions, May 2018, https://www.c2es.org/site/assets/uploads/2018/05/solutions-for-maintaining-existing-nuclear-fleet.pdf.

[64] "FirstEnergy Solutions Rescinds Deactivation Notices for Competitive Generating Plants in Ohio," *PR Newswire*, July 26, 2019, https://www.prnewswire.com/news-releases/firstenergy-solutions-rescinds-deactivation-notices-for-competitive-generating-plants-in-ohio-300891786.html. A bill repealing the Ohio nuclear plant assistance was signed by the governor on March 31, 2021. See Mike DeWine, Governor of Ohio, "Governor DeWine Signs Ohio Transportation Budget," news release, March 31, 2021, https://governor.ohio.gov/wps/portal/gov/governor/media/news-and-media/transportation-budget-signed-03312021.

[65] Energy Harbor, "Energy Harbor Corp Rescinds Deactivation Notice for Nuclear Generating Plant in Pennsylvania," news release, March 13, 2020, https://energyharbor.com/en/about/news-and-information/energy-harbor-corp-rescinds-deactivation-notice-for-nuclear-gene.

[66] David Dalton, "Michigan Budget Includes $150 Million to Support Nuclear Reactor Restart," *NucNet*, July 3, 2023, https://www.nucnet.org/news/michigan-budget-includes-usd150-million-to-support-nuclear-reactor-restart-7-1-2023.

[67] Department of Energy, "Reactor Technology Program Overview," presentation by R. Shane Johnson, Deputy Assistant Secretary for Nuclear Technology Demonstration and Deployment, to the Nuclear Energy Advisory Committee, July 9, 2018, https://www.energy.gov/sites/prod/files/2018/07/f53/RSJ%20Brief%20to%20NEAC%20-%20July%209%202018_0.pdf.

[68] White House, "President Biden to Catalyze Global Climate Action Through the Major Economies Forum on Energy and Climate," fact sheet, April 20, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2023/04/20/fact-sheet-president-biden-to-catalyze-global-climate-action-through-the-major-economies-forum-on-energy-and-climate.

Selected Congressional Action—118th Congress

Expressing the sense of Congress relating to nuclear power being a necessary clean baseload energy source to achieve a reliable, secure, and green electric grid (H.Con.Res. 26, Donalds)

Expresses the sense of Congress that "in order to achieve geopolitical energy leadership, reduce carbon emissions, and secure American energy independence, Congress is committed to embracing and accepting nuclear power as a clean baseload energy source that is easily compatible with other intermittent energy sources and necessary to achieve a reliable, secure, and green electric grid." Introduced March 17, 2003; referred to Committee on Energy and Commerce.

CRS Reports

CRS Report R46820, *U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns*, by Mark Holt and Phillip Brown

Additional References

Nuclear Costs in Context, Nuclear Energy Institute, December 2023, https://www.nei.org/resources/reports-briefs/nuclear-costs-in-context

Overnight Capital Cost of the Next AP1000, Koroush Shirvan, Massachusetts Institute of Technology, March 2022, https://web.mit.edu/kshirvan/www/research/ANP193%20TR%20CANES.pdf

World Nuclear Industry Status Report 2022, Mycle Schneider and Antony Froggatt, October 2022, https://www.worldnuclearreport.org/

Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders, Organisation for Economic Co-operation and Development Nuclear Energy Agency, July 2020, http://www.oecd-nea.org/ndd/pubs/2020/7530-reducing-cost-nuclear-construction.pdf

Strategy to Restore American Nuclear Energy Leadership, Department of Energy Nuclear Fuel Working Group, April 23, 2020, https://www.energy.gov/articles/secretary-brouillette-announces-nuclear-fuel-working-groups-strategy-restore-american

The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China, Center for Strategic and International Studies, March 12, 2020, https://www.csis.org/analysis/changing-geopolitics-nuclear-energy-look-united-states-russia-and-china

U.S. Nuclear Energy Leadership: Innovation and the Strategic Global Challenge, Atlantic Council, May 20, 2019, https://www.atlanticcouncil.org/in-depth-research-reports/report/us-nuclear-energy-leadership-innovation-and-the-strategic-global-challenge-2

The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions, Union of Concerned Scientists, November 2018, https://www.ucsusa.org/sites/default/files/attach/2018/11/Nuclear-Power-Dilemma-full-report.pdf

Promising Market and Federal Solutions for Existing Nuclear Power, Center for Climate and Energy Solutions, October 2018, https://www.c2es.org/document/promising-market-and-federal-solutions-for-existing-nuclear-power/

Economic and Market Challenges Facing the U.S. Nuclear Commercial Fleet—Cost and Revenue Study, Idaho National Laboratory, September 2017, https://gain.inl.gov/SiteAssets/Teresa/Market%20Challenges%20for%20Nuclear%20Fleet-ESSAI%20Study%20Sept2017.pdf

Safety and Regulation

The 2011 Fukushima Dai-ichi nuclear plant disaster in Japan, triggered by a 9.0-magnitude earthquake and 45-foot tsunami, greatly increased concerns about safety in the nuclear policy debate. The accident clearly demonstrated the potential consequences of a total loss of power (or "station blackout") at today's commercial nuclear plants. Even when the nuclear reaction shuts down as designed, as at the Fukushima plant after the initial earthquake, residual radioactivity in the reactor core continues to generate "decay heat" that must be removed, typically by electrically driven or controlled cooling systems.

When the tsunami knocked out power at the three Fukushima Dai-ichi reactors that had been operating when the earthquake struck, the buildup of heat and pressure from residual radioactivity became so great that it melted the reactors' nuclear fuel and exceeded the limits of their containment structures. The decay heat also caused steam to chemically react with the nuclear fuel cladding in the reactor cores, generating additional heat along with hydrogen that escaped into the upper part of the reactor buildings and exploded. Cooling was also lost in Fukushima's spent fuel storage pools, causing concern that they could overheat, although later examination indicated that they did not.

Safety requirements for nuclear power plants are established and enforced in the United States by NRC, an independent regulatory agency. The Atomic Energy Act of 1954 requires NRC to ensure that licensed nuclear facilities "provide adequate protection to the health and safety of the public" (42 U.S.C. 2232). NRC may issue safety requirements that exceed the statutory "adequate protection" standard if their benefits are found to exceed their costs.

NRC safety regulations address the effects of external events such as earthquakes and floods, equipment failure such as breaks in coolant pipes, and other problems that could lead to radioactive releases into the environment. Critics of nuclear power contend that NRC is often reluctant to impose necessary safety requirements that would be costly or disruptive to the nuclear industry. However, the industry has frequently contended that costly safety proposals are unnecessary and would not significantly increase large existing safety margins.

Following the Fukushima disaster, NRC established a task force to identify lessons applicable to U.S. reactors and recommend safety improvements. The task force's report led to NRC's first Fukushima-related regulatory requirements, on March 12, 2012. NRC ordered all reactors to develop strategies to maintain cooling and containment integrity during external events, such as floods and earthquakes, that were more severe than anticipated by the plants' designs ("beyond design basis"). In addition, NRC required that U.S. reactors of similar design to the Fukushima reactors have "reliable hardened vents" to remove excess pressure from their primary containments, and that better instrumentation be installed to monitor the condition of spent fuel pools during accidents.[69]

The NRC commissioners on March 19, 2013, required NRC staff to study whether to require the newly mandated containment vents to include filters or other means to reduce the release of radioactive material if the vents have to be used. The idea of requiring filters had drawn praise

[69] Nuclear Regulatory Commission, "Actions in Response to the Japan Nuclear Accident: March 12, 2012," updated May 30, 2012, http://www.nrc.gov/reactors/operating/ops-experience/japan/timeline/03122012.html.

from nuclear critics but opposition from the industry on cost grounds.[70] NRC voted on August 19, 2015, not to proceed with rulemaking on filtered vents.[71]

Congressional controversy was generated by NRC's final rule for Mitigation of Beyond-Design-Basis Events (MBDBE), announced January 24, 2019.[72] The MBDBE regulation requires nuclear power plants to implement strategies to maintain reactor core cooling when electric power is lost, as occurred during the Fukushima accident. The MBDBE proposed rule, published November 13, 2015,[73] and the draft final rule, released by NRC on January 5, 2017,[74] would have required the equipment used in those strategies to be able to withstand newly evaluated flooding and seismic risks, and that regular drills and exercises be conducted. The final rule excluded those requirements, among other changes.[75] In supporting those exclusions, the Commission majority asserted that the deleted requirements did not meet NRC's cost-benefit standards.[76] NRC is continuing to monitor the implementation of all post-Fukushima regulations and orders.[77]

Recent Events

NRC published new emergency planning regulations for SMRs and other new nuclear technologies on November 16, 2023. The new rules allow SMRs and other new technologies (other than conventional large LWRs) to calculate emergency planning zones (EPZs) based on smaller inventories of radioactive materials, lower frequencies of release, and other safety improvements over existing reactors. For existing reactors, the EPZ for direct radioactive exposure (the "plume exposure pathway"), in which planning for evacuations and other protective actions is required, includes the area within about 10 miles from each reactor. Under the calculations specified by the new rules, an EPZ might not extend beyond the boundary of a nuclear plant site. In its explanation of the new rules, NRC said, "In cases where a plume exposure pathway EPZ does not extend beyond the site boundary, even in the absence of NRC requirements for offsite radiological emergency planning, the responsible OROs [offsite response organizations] would continue to take actions to protect the health and safety of the public."[78] The

[70] NRC, "Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I and Mark II Containments," staff requirements memorandum, SECY-12-0157, March 19, 2013, http://www.nrc.gov/reading-rm/doc-collections/commission/srm/2012/2012-0157srm.pdf; Freebairn, William, "NRC Staff Recommends Ordering Filtered Vents for 31 Power Reactors," *Inside NRC*, November 5, 2012, p. 1.

[71] NRC, "Hardened Vents and Filtration (for Boiling Water Reactors with Mark I and Mark II containment designs)," http://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard/hardened-vents.html.

[72] NRC, "NRC To Issue Final Rule for Mitigating Severe Events at U.S. Reactors," news release, January 24, 2019, https://www.nrc.gov/reading-rm/doc-collections/news/2019/19-005.pdf; Letter from Senators Tom Carper and Sheldon Whitehouse to NRC Chairman Kristine Svinicki, April 1, 2019, https://www.carper.senate.gov/newsroom/press-releases/carper-whitehouse-request-details-surrounding-nrc-s-weakening-of-post-fukushima-rule.

[73] NRC, "Mitigation of Beyond-Design-Basis Events," Proposed Rule, *Federal Register*, November 13, 2015, Vol. 80, No. 219, p. 70610, https://www.govinfo.gov/content/pkg/FR-2015-11-13/pdf/2015-28589.pdf.

[74] NRC, Final Rule: Mitigation of Beyond-Design-Basis Events, SECY-16-0142, Enclosure 1, January 5, 2017, https://www.nrc.gov/docs/ML1630/ML16301A005.html.

[75] NRC, "Staff Requirements—Affirmation Session," SRM-M190124A, Enclosure 1, January 24, 2019, https://www.nrc.gov/docs/ML1902/ML19023A038.html.

[76] Ibid., "Views of the Commission."

[77] NRC, "Plant-Specific Japan Lessons-Learned Activities," December 7, 2021, https://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard/japan-plants.html.

[78] NRC, "Emergency Preparedness for Small Modular Reactors and Other New Technologies," final rule and guidance, *Federal Register*, November 16, 2023, https://www.federalregister.gov/documents/2023/11/16/2023-25163/emergency-preparedness-for-small-modular-reactors-and-other-new-technologies.

new rules were long supported by the nuclear industry but criticized by groups skeptical about the nuclear industry's safety and security record.[79]

The 10th anniversary of the Fukushima disaster in March 2021 was noted around the world with retrospectives, status reports, and commentary. "An important lesson of Fukushima is that regulators must be strong, independent and adequately resourced," the International Atomic Energy Agency said in marking the occasion.[80] The Japan Atomic Industrial Forum issued a statement declaring, "We in the nuclear industry must reflect on the Fukushima Daiichi accident and learn its lessons thoroughly as we firmly pledge never to allow it to recur, through our unwavering efforts to improve safety."[81]

Selected Congressional Action—118th Congress

Hearing on the Nomination of Jeffery Martin Baran to Be a Member of the Nuclear Regulatory Commission, Senate Committee on Environment and Public Works

Hearing focused on the nominee's record as an NRC Commissioner and whether his actions were appropriate to ensure adequate safety or imposed unnecessary burdens on the nuclear industry. Held May 10, 2023, https://www.epw.senate.gov/public/index.cfm/2023/5/hearing-on-the-nomination-of-jeffery-martin-baran-to-be-a-member-of-the-nuclear-regulatory-commission.

Hearing on the Nuclear Regulatory Commission's Proposed Fiscal Year 2024 Budget, Senate Committee on Environment and Public Works

Topics included whether NRC has sufficient budget and staffing to ensure adequate nuclear safety, progress on developing a regulatory framework for advanced reactors, and whether the agency is operating efficiently. Held April 19, 2023, https://www.epw.senate.gov/public/index.cfm/2023/4/the-nuclear-regulatory-commission-s-proposed-fiscal-year-2024-budget.

Atomic Energy Advancement Act (H.R. 6544, Duncan)

Title I would require NRC to update its mission statement to include that licensing and regulation should be efficient and not unnecessarily limit the growth and benefits of nuclear power, while remaining consistent with Atomic Energy Act safety standards. Would require NRC to implement procedures for "efficient, timely, and predictable" licensing reviews and make other improvements in licensing efficiency. Would authorize direct hiring and higher compensation if needed to address NRC workforce shortages. Would reduce and restrict fees charged to specified nuclear license applicants. Introduced December 1, 2023, and ordered to be reported by House Committee on Energy and Commerce December 5, 2023.

---

[79] See, for example, "NRC's Risky Rule Change Ignores History. More Nuclear Emergency Planning Needed, Not Less. Statement by Dr. Edwin Lyman at the Union of Concerned Scientists," August 14, 2023, https://www.ucsusa.org/about/news/nrcs-risky-rule-change-ignores-history-more-nuclear-emergency-planning-needed-not-less; and Nuclear Energy Instititute, "NRC Staff Agrees Small Modular Reactors Won't Need Large-Scale Emergency Zones," August 22, 2018, https://www.nei.org/news/2018/nrc-staff-agrees-smrs-wont-need-large-epzs.

[80] International Atomic Energy Agency, "Ten-Year Anniversary of the Fukushima Daiichi Nuclear Power Plant Accident: A Decade of Improving Nuclear Safety," March 10, 2021, https://www.iaea.org/newscenter/statements/ten-year-anniversary-of-the-fukushima-daiichi-nuclear-power-plant-accident-a-decade-of-improving-nuclear-safety.

[81] Japan Atomic Industrial Forum President Shiro Arai, "Marking the Tenth Anniversary of the Fukushima Daiichi Accident," February 26, 2021, https://www.jaif.or.jp/en/presidents-comments/4976 .

Efficient Nuclear Licensing Hearings Act (H.R. 6464, Griffith)

Would allow NRC to issue licenses and permits without holding the currently required mandatory hearing if such a hearing is not requested and allow for use of informal adjudicatory procedures. Introduced November 21, 2023; referred to the House Committee on Energy and Commerce.

Advancing Nuclear Regulatory Oversight Act (H.R. 6346, Lesko)

Would require NRC to submit reports to Congress on regulatory changes adopted during the COVID-19 health emergency, possible oversight and inspection improvements, and potential reductions in NRC's costs for office space and facilities. Introduced November 9, 2023; referred to the House Committee on Energy and Commerce.

Nuclear for Brownfield Site Preparation Act (H.R. 6268, Guthrie)

Would require NRC to submit a report to Congress and initiate a rulemaking on timely licensing reviews for nuclear facilities at retired fossil fuel sites or brownfield sites. Introduced November 7, 2023; referred to the House Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered to be reported by the House Committee on Energy and Commerce December 5, 2023.

NRC Mission Alignment Act (H.R. 6265, Duncan)

Would require NRC to update its mission statement, while conforming to the Atomic Energy Act of 1954, to include that licensing of nuclear facilities should be efficient and not unnecessarily limit the potential benefits of nuclear energy. Introduced November 7, 2023; referred to the House Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered to be reported by the House Committee on Energy and Commerce December 5, 2023.

Modernize Nuclear Reactor Environmental Reviews Act (H.R. 6252, Weber)

Would direct the Nuclear Regulatory Commission to submit a report and conduct a rulemaking on facilitating efficient, timely environmental reviews of nuclear reactor applications. Introduced November 6, 2023; referred to the House Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered to be reported by the House Committee on Energy and Commerce December 5, 2023.

Nuclear Licensing Efficiency Act (H.R. 6236, Allen)

Would tighten timelines for NRC licensing reviews and require NRC, in reviewing applications for nuclear facilities at currently licensed sites, to use information previously used to license that site, to the maximum extent practicable. Introduced November 6, 2023; referred to the House Committee on Energy and Commerce. Similar provisions included in H.R. 6544, ordered t be reported by the House Committee on Energy and Commerce December 5, 2023.

Nuclear Red Tape Reduction Act (H.R. 4676, Donalds)

Would establish deadlines for interested parties to request that NRC hold hearings on applications for reactor construction permits and license applications, allow for hearings to be waived in specified circumstances, and require NRC to report to Congress on reactor license renewal periods. Introduced July 17, 2023; referred to Committee on Energy and Commerce.

NRC Office of Public Engagement and Participation Act of 2023 (H.R. 4530, Levin)

Would establish an Office of Public Engagement and Participation within NRC to support, coordinate, and assist public participation in NRC proceedings and advocate for the public interest within NRC. Introduced July 11, 2023; referred to Committee on Energy and Commerce.

Strengthening the NRC Workforce Act of 2023 (H.R. 4528, DeGette)

Would authorize the NRC Chairman, upon certifying a critical hiring need or shortage of candidates, to "directly appoint highly qualified individuals into the competitive service." Also would establish procedures for temporarily setting higher compensation levels for certain categories of employees. Introduced July 11, 2023. Related NRC workforce provisions included in the National Defense Authorization Act for FY2024 as passed by the Senate (S. 2226, Section 8141(u)). Similar provisions included in H.R. 6544, ordered to be reported by the House Committee on Energy and Commerce December 5, 2023.

Hydrogen Permitting Simplification Act (H.R. 2962, Lesko)

Would exempt certain major federal actions, including actions that produce hydrogen from nuclear reactors, from requirements under the National Environmental Policy Act of 1969. Introduced April 27, 2023; referred to Committee on Energy and Commerce, and to the Committee on Natural Resources for provisions under its jurisdiction.

Department of Energy and Nuclear Regulatory Commission Whistleblower Protection Act (S. 1112, Duckworth)

Would specify that DOE and NRC employees are included in protections against management retaliation under the Energy Reorganization Act (42 U.S.C. 5851) for raising nuclear safety concerns. Introduced March 30, 2023; referred to Committee on Energy and Natural Resources. Reintroduced from 116th Congress (S. 2962).

Nuclear Regulatory Commission Survey Act (H.R. 1006, Donalds)

Would require the NRC inspector general to distribute optional and anonymous surveys about NRC's efficiency and effectiveness to NRC employees and, if feasible, to stakeholders in the nuclear industry. Introduced February 14, 2023; referred to Committee on Energy and Commerce.

Additional References

Improving the Efficiency of NRC Power Reactor Licensing: The 1957 Mandatory Hearing Reconsidered, Columbia University Center on Global Energy Policy, November 21, 2023, https://www.energypolicy.columbia.edu/publications/improving-the-efficiency-of-nrc-power-reactor-licensing-the-1957-mandatory-hearing-reconsidered

Plant-Specific Safety Enhancements After Fukushima, Nuclear Regulatory Commission, web page, reviewed/updated January 8, 2024, https://www.nrc.gov/reactors/operating/ops-experience/post-fukushima-safety-enhancements.html

Safety of Nuclear Power Reactors, World Nuclear Association, March 2022, https://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx

Nuclear Power 101, Natural Resources Defense Council, January 5, 2022, https://www.nrdc.org/stories/nuclear-power-101

Nuclear Safety: Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident, Report to the Chairman, Subcommittee on Transportation and Infrastructure, Committee on Environment and Public Works, U.S. Senate, Government Accountability Office, GAO-14-109, March 2014, http://www.gao.gov/products/GAO-14-109

State-of-the-Art Reactor Consequence Analyses (SOARCA) Report, Nuclear Regulatory Commission, NUREG-1935, November 2012, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1935

Security and Emergency Response

The level of security that must be provided at nuclear power plants became a high-profile issue after the 9/11 terrorist attacks on the United States in 2001. Since those attacks, NRC issued a series of orders and regulations that substantially increased nuclear plant security requirements, although industry critics contend that those measures are still insufficient. Key measures include an increase in the level of attacks that nuclear plant security forces must be able to repel, requirements for mitigating the effects of large fires and explosions, and a requirement that new reactors be capable of withstanding aircraft crashes without releasing radioactive material. NRC also modified its planning requirements for evacuations and other emergency responses after the 9/11 attacks, and the Fukushima disaster illustrated the importance of emergency response to radioactive releases from any cause.

NRC issued wide-ranging revisions to its emergency preparedness regulations on November 1, 2011, dealing with duties of emergency personnel and the inclusion of hostile actions in emergency planning drills.[82] In response to Fukushima, NRC staff recommended that nuclear emergency plans be required to address events affecting multiple reactors and prolonged station blackout. NRC told nuclear power plants on March 12, 2012, to provide specific information and analysis on those issues.[83]

The NRC Cyber Security Directorate was established in June 2013 to coordinate rulemaking, guidance, and oversight of cybersecurity at nuclear power plants and other regulated nuclear facilities. As part of the Directorate, NRC's Cyber Assessment Team responds to cybersecurity events at NRC-licensed facilities and coordinates threat assessments with other federal agencies.[84]

Recent Events

NRC issued a final rule March 14, 2023, on "Enhanced Weapons, Firearms Background Checks, and Security Event Notifications."[85] The rule establishes procedures for nuclear power plants and other licensed nuclear facilities to apply for NRC authorization to arm their security personnel

[82] NRC, "Enhancements to Emergency Preparedness Regulations," final rule, *Federal Register*, November 23, 2011, p. 72560.

[83] NRC, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," March 12, 2012, http://pbadupws.nrc.gov/docs/ML1205/ML12053A340.pdf.

[84] NRC, "Backgrounder on Cyber Security," July 2021, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/cyber-security-bg.html.

[85] NRC, "Enhanced Weapons, Firearms Background Checks, and Security Event Notifications," final rule, March 14, 2023, https://www.federalregister.gov/documents/2023/03/14/2023-03944/enhanced-weapons-firearms-background-checks-and-security-event-notifications.

with "enhanced" weapons, such as semiautomatic assault weapons and machine guns, despite any state laws prohibiting such weapons. NRC is authorized to preempt state laws for this purpose under Atomic Energy Act Section 161A, enacted by the Energy Policy Act of 2005 (P.L. 109-58). The rule also modifies NRC requirements for nuclear power plants and other licensed facilities to report events related to physical security and would add requirements for reporting suspicious activities.

Concerns about international nuclear plant security have been raised by Russia's ongoing military occupation of Ukraine's six-reactor Zaporizhzhia nuclear power plant (ZNPP)—the largest in Europe. Russian forces captured the plant on March 4, 2022, and it has since lost offsite power several times, increasing the risk of damage to the plant's nuclear fuel and radioactive releases to the environment. The International Atomic Energy Agency (IAEA) issued a report on September 5, 2022, that called for "establishment of a nuclear safety and security protection zone" around the plant, but the proposal has not been implemented.[86]

Selected Congressional Action—118th Congress

Sanction Russian Nuclear Safety Violators Act of 2023 (H.R. 3246, Meeks)

Would require the President to impose specified sanctions on any foreign person who has endangered the integrity, safety, or undermined Ukrainian operational control of the Zaporizhzhia Nuclear Power Station. Introduced May 11, 2023; referred to Committee on Foreign Affairs and the Committee on the Judiciary for provisions under its jurisdiction.

To require reports on the dangers posed by nuclear reactors in areas that might experience armed conflict (S. 571, Markey)

Would require the Secretary of Defense and the Administrator for Nuclear Security to submit a report to Congress assessing the dangers posed by nuclear reactors in regions that have experienced armed conflict within the past 25 years or may experience armed conflict under specified scenarios. Introduced February 28, 2023; referred to Committee on Armed Services.

CRS Reports

CRS Insight IN11883, *Russian Military Actions at Ukraine's Nuclear Power Plants*, by Mark Holt and Mary Beth D. Nikitin

CRS In Focus IF10821, *Price-Anderson Act: Nuclear Power Industry Liability Limits and Compensation to the Public After Radioactive Releases*, by Mark Holt

Additional References

Security Aspects of Nuclear Facilities, International Atomic Energy Agency, website, https://www.iaea.org/topics/security-aspects

Update on Radiological Emergency Preparedness Enhancement Activities Resulting from Lessons Learned Following September 11, 2001, and Other Recent Natural Disasters, Nuclear Regulatory Commission, July 19, 2019, https://www.nrc.gov/docs/ML1911/ML19116A159.pdf

[86] IAEA, *Nuclear Safety, Security, and Safeguards in Ukraine*, September 5, 2022, https://www.iaea.org/sites/default/files/22/09/ukraine-2ndsummaryreport_sept2022.pdf.

Backgrounder on Nuclear Security, Nuclear Regulatory Commission, web page, last reviewed/updated May 31, 2019, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/security-enhancements.html

Nuclear Plant Security, Union of Concerned Scientists, web page, updated February 25, 2016, https://www.ucsusa.org/nuclear-power/nuclear-plant-security#.W2RtxtJKiUk

Protecting Our Nation, Nuclear Regulatory Commission, NUREG/BR-0314, Rev. 4, August 2015, https://www.nrc.gov/docs/ML1523/ML15232A263.pdf

Nuclear Weapons Nonproliferation

Encouraging exports of U.S. civilian nuclear products, services, and technology while making sure they are not used for foreign nuclear weapons programs has long been a fundamental goal of U.S. nuclear energy policy. Section 123 of the Atomic Energy Act requires that any country receiving U.S. nuclear technology, equipment, or materials implement a peaceful nuclear cooperation agreement with the United States. These so-called 123 agreements are intended to ensure that U.S. nuclear cooperation with other countries does not result in the production of weapons materials or otherwise encourage the proliferation of nuclear weapons. Section 123 allows nuclear cooperation agreements to take effect after 90 days of continuous congressional session if they adhere to specified criteria.

International controls and inspections are intended to ensure the peaceful use of civilian nuclear facilities and prevent the proliferation of nuclear weapons. However, recent plans or proposals to build nuclear power plants in countries[87] that have not previously used nuclear energy, including several in the Middle East and countries without nuclear experience, have prompted concerns that international controls may prove inadequate. Numerous recommendations have been made in the United States and elsewhere to create new incentives for nations to forgo the development of uranium enrichment and spent nuclear fuel reprocessing facilities that could produce weapons materials as well as civilian nuclear fuel.

Iran's nuclear energy program is a major example of the tension between peaceful and weapons uses of nuclear technology. Long-standing world concern had focused on the Iranian uranium enrichment program, which Iran contended was solely for peaceful purposes but which the United States and other countries suspected was for producing weapons material. The U.N. Security Council had imposed sanctions and passed several resolutions calling on Iran to suspend its enrichment program and other sensitive nuclear activities. Iran finalized the Joint Comprehensive Plan of Action (JCPOA) on July 14, 2015, with the United States (which ceased participating in 2018[88]) and the other four permanent members of the U.N. Security Council plus Germany to lift the U.N. sanctions in return for specified Iranian actions to preclude nuclear weapons development.

[87] World Nuclear Association, "World Nuclear Power Reactors and Uranium Requirements," October 2021, http://www.world-nuclear.org/info/reactors.html.

[88] The White House, "President Donald J. Trump Is Ending United States Participation in an Unacceptable Iran Deal," May 8, 2018, https://trumpwhitehouse.archives.gov/briefings-statements/president-donald-j-trump-ending-united-states-participation-unacceptable-iran-deal.

Recent Events

President Trump announced on May 8, 2018, that his Administration would cease implementing the JCPOA and reimpose sanctions. Other parties to the JCPOA have not followed the U.S. lead.[89] Nevertheless, beginning in July 2019, the IAEA verified that some of Iran's nuclear activities were exceeding JCPOA-mandated limits; Iran has since increased the number of activities that violate JCPOA restrictions. The Biden Administration, in April 2021, participated in indirect talks with Iran through other JCPOA participants about potentially returning to compliance if Iran did as well.[90] A United Kingdom Parliament fact sheet issued in October 2023 says the JCPOA talks have stalled and may "now be derailed by wider geopolitical developments in the Middle East."[91]

An extension of the U.S. peaceful nuclear cooperation agreement with South Korea generated controversy but no congressional action to block it. During negotiations on the U.S.-South Korea nuclear cooperation extension, which entered into force November 25, 2015, South Korea had sought advance U.S. consent for spent fuel reprocessing and uranium enrichment. The United States did not provide such consent, on general nonproliferation grounds and because such consent could affect other ongoing issues on the Korean peninsula. The new agreement did, however, establish a bilateral "high level commission" to further consider those issues. The high-level commission's deliberations are to be informed by the results of a 10-year Joint Fuel Cycle Study by scientists from the two countries that was scheduled to be completed in April 2021. However, according to DOE, some aspects of the study have not been completed and discussions on how to move forward are continuing.[92]

Japan's long-standing nuclear cooperation agreement with the United States automatically renewed on July 17, 2018, and will remain in force indefinitely unless terminated by either side.[93] The agreement allows Japan to reprocess spent nuclear fuel from its U.S.-designed reactors, separating plutonium and uranium for use in new fuel. A long-delayed commercial reprocessing plant at Rokkasho is scheduled to be completed in 2024 at the earliest.[94] Some nuclear nonproliferation groups had urged the United States to use the renewal of the U.S.-Japan nuclear cooperation agreement as an opportunity to urge Japan not to begin its reprocessing program. They noted that Japan already has substantial stockpiles of previously separated plutonium that

[89] European Union, "Joint Statement on the Re-imposition of U.S. Sanctions Due to Its Withdrawal from the Joint Comprehensive Plan of Action (JCPOA)," June 8, 2018, https://eeas.europa.eu/headquarters/headquarters-homepage/49141/joint-statement-re-imposition-us-sanctions-due-its-withdrawal-joint-comprehensive-plan-action_en.

[90] U.S. Department of State, "Briefing with Senior State Department Official on Recent U.S. Engagement in Vienna Regarding the JCPOA," April 9, 2021, https://www.state.gov/briefing-with-senior-state-department-official-on-recent-u-s-engagement-in-vienna-regarding-the-jcpoa.

[91] UK Parliament, House of Commons Library, "What Is the Status of the Iran Nuclear Deal?," October 13, 2023, https://commonslibrary.parliament.uk/research-briefings/cbp-9870.

[92] Emails from John Krohn, DOE Office of Congressional and Intergovernmental Affairs, March 31, 2021, and June 28, 2021. The March email says that "the US and ROK are continuing to talk to determine how to 'finalize' the study, as well as potential continued work in this area." An article in the Bulletin of the Atomic Scientists quoted an unnamed senior U.S. official as saying that "at least three or four more years will be necessary for the two governments to be in a position to draw any actual conclusions related to the technical and economic feasibility and nonproliferation acceptability of pyroprocessing on the Korean Peninsula." Frank N. von Hippel and Jungmin Kang, "Why Joint U.S.-South Korean Research on Plutonium Separation Raises Nuclear Proliferation Danger," *Bulletin of the Atomic Scientists*, January 13, 2022, https://thebulletin.org/2022/01/why-joint-us-south-korean-research-on-plutonium-separation-raises-nuclear-proliferation-danger.

[93] DOE, National Nuclear Security Administration, "123 Agreements for Peaceful Cooperation," December 7, 2022, https://www.energy.gov/nnsa/123-agreements-peaceful-cooperation.

[94] Japan Nuclear Fuel Limited, "Reprocessing," viewed Novermber 2, 2023, https://www.jnfl.co.jp/en/business/reprocessing.

could potentially be used for weapons as well as reactor fuel.[95] Japan approved a Strategic Energy Plan July 3, 2018, that includes a pledge to reduce Japanese plutonium inventories, reportedly following pressure from the United States and other countries.[96]

Discussions between the United States and Saudi Arabia toward drafting a peaceful nuclear cooperation agreement have prompted substantial controversy. The U.S. nuclear industry strongly supports an agreement so that it could supply reactors and other nuclear technology to Saudi Arabia.[97] However, nuclear nonproliferation groups want any nuclear cooperation agreement to include a binding commitment from Saudi Arabia to forswear uranium enrichment and spent fuel reprocessing on its territory.[98] Then-Secretary of State Mike Pompeo testified to the Senate Foreign Relations Committee May 24, 2018, that the United States was insisting that Saudi Arabia accept such a commitment as part of any 123 agreement, despite Saudi arguments that the country has a right to enrich and reprocess under international inspections.[99] Then-Energy Secretary Rick Perry told reporters at a meeting in September 2019 that the United States also would condition any U.S.-Saudi 123 Agreement on Saudi acceptance of the Additional Protocol, which allows strengthened international safeguards on nuclear facilities.[100] The Biden Administration has included U.S.-Saudi nuclear cooperation as a potential element of a larger diplomatic normalization agreement between Saudi Arabia and Israel, an effort that has been suspended but reportedly not necessarily abandoned after the October 7, 2023, attack on Israel by Hamas.[101]

Congress prohibited the use of FY2023 funds for Export-Import Bank support for nuclear exports to Saudi Arabia until the kingdom has a 123 agreement in effect that commits to renouncing uranium enrichment and reprocessing and has signed an Additional Protocol with the IAEA (Section 7041(i) of Division K, P.L. 117-328). The same provision was included for appropriation in FY2022 (P.L. 117-103), FY2021 (P.L. 116-260) and FY2020 (P.L. 116-94).

Selected Congressional Action—118th Congress

Iran Nuclear Verification Act (H.R. 6057, McClain)

Would prohibit the United States from becoming a party to the JCPOA or any other nuclear agreement with Iran until the President certifies that United Nations inspectors are allowed full

[95] Nonproliferation Policy Education Center, "Tokyo and Washington Have Another Nuclear Problem," August 17, 2017, http://npolicy.org/article.php?aid=1341&rid=2.

[96] Reuters, "Japan Pledges to Cut Plutonium Stockpile Amid Growing Concern by Neighbours," July 31, 2018, https://www.reuters.com/article/us-japan-nuclear-plutonium/japan-pledges-to-cut-plutonium-stockpile-amid-growing-concern-by-neighbors-idUSKBN1KL0I4.

[97] Nuclear Energy Institute, "As Saudi Arabia Considers New Reactors, NEI Conducts Trade Mission," April 26, 2018, https://www.nei.org/news/2018/saudi-arabia-considers-new-reactors.

[98] Nonproliferation Policy Education Center, "Letter to Congress on Nuclear Cooperation with Saudi Arabia," May 24, 2018, http://npolicy.org/article.php?aid=1395&rtid=4.

[99] Mufson, Steven, "Pompeo: Saudis Must Not Enrich Uranium If It Seeks Civilian Nuclear Cooperation," May 24, 2018, https://www.washingtonpost.com/business/economy/pompeo-saudis-must-not-enrich-uranium-if-it-seeks-civilian-nuclear-cooperation/2018/05/24/714c5e30-5f92-11e8-a4a4-c070ef53f315_story.html.

[100] Natter, Ari, "U.S. Says Saudis Must Forgo Enrichment for Nuclear Sharing Deal," *Bloomberg*, September 18, 2019, https://www.bloomberg.com/news/articles/2019-09-19/u-s-says-saudis-must-forgo-enrichment-for-nuclear-sharing-deal.

[101] Samuel Hickey, "Amid Gaza War, a Beefed up Saudi Nuke Program Is Still on the Table," Quincy Institute for Responsible Statecraft, October 26, 2023, https://responsiblestatecraft.org/saudi-arabia-nuclear-israel.

access to all Iranian nuclear facilities and have completed a comprehensive report on those facilities. Introduced October 25, 2023; referred to Committee on Foreign Affairs.

Expressing support of the International Atomic Energy Agency's nuclear security role (S.Res. 429, Lujan/H.Res. 641, Foster)

Resolves that the Senate and House maintain that IAEA "plays an indispensable role in strengthening nuclear security and safety around the globe" and encourage the United States and other nations to ensure that IAEA has sufficient resources to carry out its duties. Senate resolution introduced October 25, 2023; referred to Committee on Foreign Relations. House resolution introduced August 1, 2023; referred to Committee on Foreign Affairs.

Solidify Iran Sanctions Act of 2023 (S. 1390, Scott/H.R. 3033, Steel)

Would strike the sunset provision in the Iran Sanctions Act of 1996 (P.L. 104-172), which imposes various sanctions on Iran for its programs to develop nuclear weapons and other weapons of mass destruction. Senate bill introduced May 1, 2023; referred to Committee on Banking, Housing, and Urban Affairs. House bill introduced April 28, 2023; ordered to be reported by Committee on Foreign Affairs June 21, 2023.

Iran Nuclear Treaty Act (S. 472, Johnson)

Would declare that any agreement reached by the President regarding Iran's nuclear program shall be a treaty subject to Senate advice and consent. Introduced February 16, 2023; referred to Committee on Foreign Relations.

To terminate certain waivers of sanctions with respect to Iran issued in connection with the Joint Comprehensive Plan of Action (S. 256, Cruz)

Would revoke certain waivers of sanctions relating to Iran's nuclear activities and prohibit the President from issuing a new waiver relating to such activities. Introduced February 2, 2023; referred to Committee on Banking, Housing, and Urban Affairs.

CRS Reports

CRS Report R41910, *Nuclear Energy Cooperation with Foreign Countries: Issues for Congress*, by Paul K. Kerr, Mary Beth D. Nikitin, and Mark Holt

CRS Report RS22937, *Nuclear Cooperation with Other Countries: A Primer*, by Paul K. Kerr and Mary Beth D. Nikitin

CRS Report RL33192, *U.S.-China Nuclear Cooperation Agreement*, by Mark Holt, Mary Beth D. Nikitin, and Paul K. Kerr

CRS Report R40094, *Iran's Nuclear Program: Tehran's Compliance with International Obligations*, by Paul K. Kerr

CRS In Focus IF12106, *Iran and Nuclear Weapons Production*, by Paul K. Kerr

CRS Report R44942, *U.S. Decision to Cease Implementing the Iran Nuclear Agreement*, by Kenneth Katzman, Paul K. Kerr, and Valerie Heitshusen

CRS In Focus IF10799, *Prospects for U.S.-Saudi Nuclear Energy Cooperation*, by Christopher M. Blanchard and Paul K. Kerr

Other References

Nuclear Nonproliferation, Government Accountability Office, Key Issues website, https://www.gao.gov/key_issues/nuclear_nonproliferation/issue_summary

Nuclear Cooperation Agreements, Nuclear Energy Institute website, https://www.nei.org/advocacy/compete-globally/nuclear-cooperation-agreements

Nuclear Non-Proliferation … If You Can Keep It, Henry D. Sokolski for the American Bar Association, January 6, 2023, https://www.americanbar.org/groups/law_national_security/publications/aba-standing-committee-on-law-and-national-security-60-th-anniversary-an-anthology/nuclear-non-proliferation-if-you-can-keep-it

The Nonproliferation Gold Standard: The New Normal?, Arms Control Association, October 2019, https://www.armscontrol.org/act/2019-10/features/nonproliferation-gold-standard-new-normal

Blocking the Gateways to Nuclear Disorder in the Middle East, Nonproliferation Policy Education Center, Working Paper 2202, September 2022, https://npolicy.org/blocking-the-gateways-to-nuclear-disorder-in-the-middle-east-occasional-paper-2202

The Case for a Pause in Reprocessing in East Asia: Economic Aspects, Nuclear Threat Initiative, August 9, 2016, http://www.nti.org/analysis/reports/case-pause-reprocessing-east-asiaeconomic-aspects/.

Author Information

Mark Holt
Specialist in Energy Policy

Disclaimer