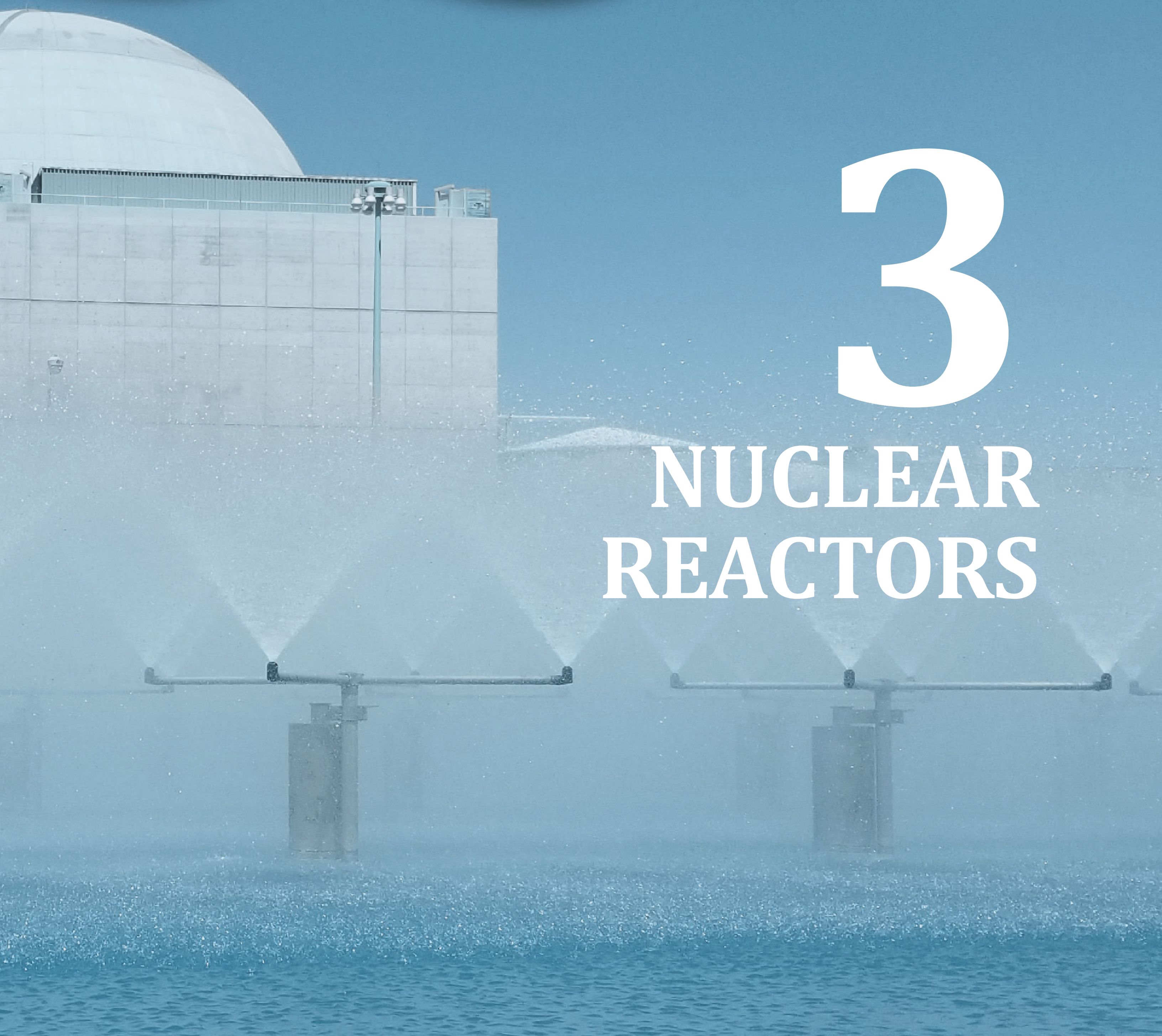
3
NUCLEAR REACTORS



U.S. ELECTRICITY GENERATED BY COMMERCIAL NUCLEAR POWER

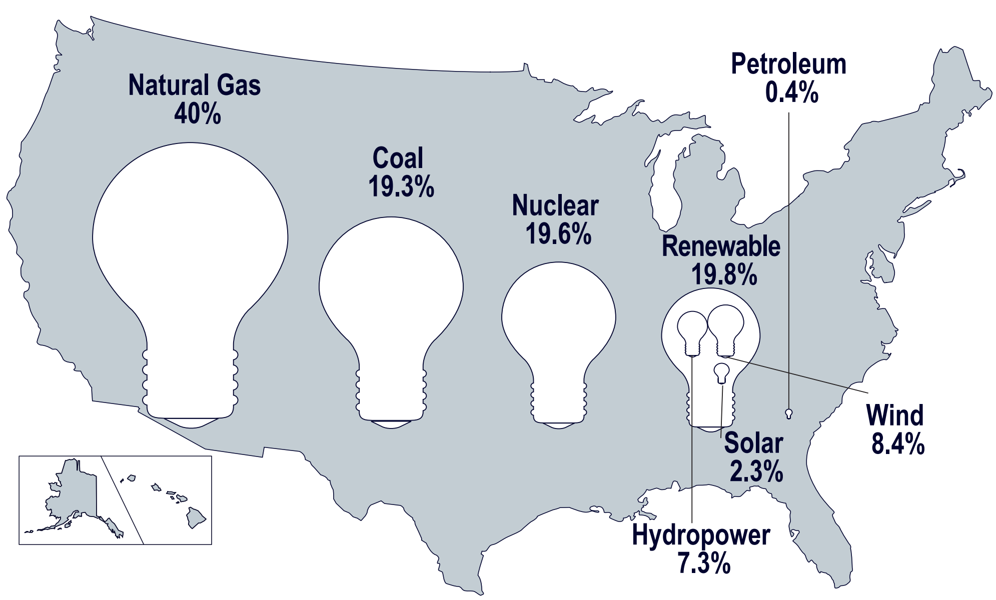
According to the U.S. Energy Information Administration (EIA), in 2020, preliminary estimates show that 4,009 billion kilowatt-hours (kWh) (or 4 trillion kWh) of electricity were generated at utility-scale electricity generation facilities in the United States. About 60.3 percent of this electricity generation was from fossil fuels (coal, natural gas, petroleum, and other gases). Nuclear energy provided 19.7 percent (790 billion kWh), and about 19.8 percent came from renewable energy sources (see Figure 9. U.S. Gross Electricity Share by Energy Source, 2020, and Figure 10. U.S. Electricity Generation by Energy Source, 2015–2020).

Since the 1970s, the Nation's utilities have asked permission to generate more electricity from existing nuclear plants. The NRC regulates how much heat a commercial nuclear reactor may generate. This heat, or power level, is used with other data in many analyses that demonstrate the safety of the nuclear power plant. Because this power level is included in the plant's license and technical specifications, the NRC must review and approve any licensee's requested change to it, as it would for any license or technical specification change. Increasing a commercial nuclear power plant's maximum operational power level is called a "power uprate."

The NRC has approved power uprates that have collectively added the equivalent of seven new reactors' worth of electrical generation to the power grid. See the Glossary for information on the electric power grid.

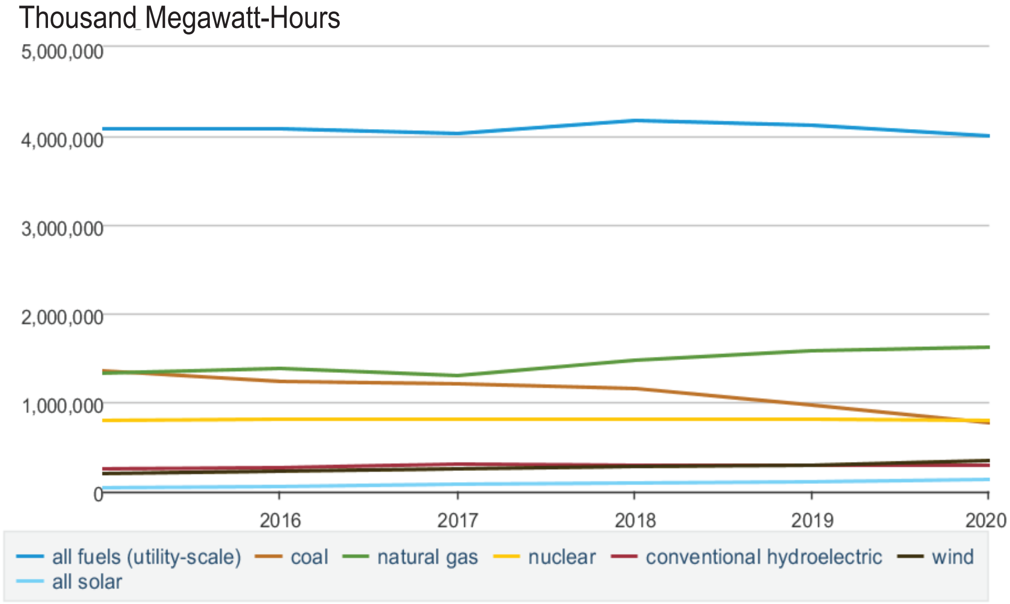
According to the EIA, in 2019, each of the following States generated more than 40,000 megawatt-hours of electricity from nuclear power: Illinois, Pennsylvania, South Carolina, New York, Alabama, North Carolina, and Texas. Illinois ranked first in the Nation in both generating capacity and net electricity generation from nuclear power. Illinois nuclear power plants accounted for 12 percent of the Nation's nuclear power generation. The 2019 data cited reflect the total net electricity generation from nuclear sources in each of these States. See Figure 11. Gross Electricity Generated in Each State by Nuclear Power. In 2019, 30 of the 50 States generated electricity from nuclear power plants.

Figure 9. U.S. Gross Electricity Share by Energy Source, 2020



Note: Figures are preliminary and rounded.
Source: DOE/EIA at https://www.eia.gov—Table 7.2a Electricity Net Generation: Total (All Sectors) data released as of June 24, 2021, annual total for 2020.

Figure 10. U.S. Electricity Generation by Energy Source, 2015–2020



***2020 data are preliminary. Note: Figures are rounded.**
Source: DOE/EIA, https://www.eia.gov—Electricity Data Browser; —Electricity Net Generation: Total (All Sectors—Annually 2015–2020) released as of June 2021 for 2020 data.

U.S. COMMERCIAL NUCLEAR POWER REACTORS

Power plants convert heat into electricity using steam. At nuclear power plants, the heat to boil water into steam is created when atoms split apart in a process called "fission." When the process is repeated over and over, it is called a chain reaction. The reaction's heat creates steam to turn a turbine. As the turbine spins, the generator turns, and its magnetic field produces electricity.

Nuclear power plants are very complex. There are many buildings at the site and many different systems. Some of the systems work directly to make electricity, while others keep the plant working correctly and safely. All nuclear power plants have a containment structure with reinforced concrete about 4 feet (1.2 meters) thick that houses the reactor. To keep reactors performing efficiently, operators remove about one-third of the fuel every year or two and replace it with fresh fuel. Used fuel is stored and cooled in deep pools of water located on site. The process of removing used fuel and adding fresh fuel is known as refueling.

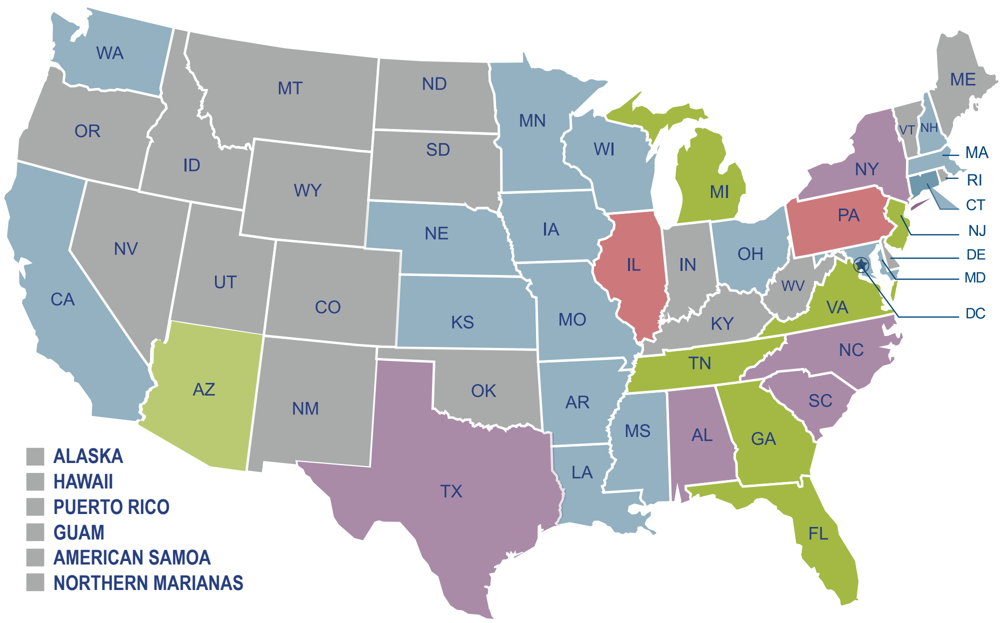
See Appendix E for a list of parent companies of U.S. commercial operating nuclear power reactors, Appendix A for a list of reactors and their general licensing information, Appendix T for Native American Reservations and Trust lands near nuclear power plants, and Appendix J for radiation doses and regulatory limits.

APPENDIX

The United States has two types of commercial nuclear reactors. Pressurized-water reactors are known as PWRs. They keep water in the reactor under pressure, so it heats to over 500 degrees Fahrenheit (260 degrees Celsius) but does not boil. Water from the reactor and the water that is turned into steam are in separate pipes and never mix. In boiling-water reactors,called BWRs, the water heated in the reactor actually boils and turns into steam, which then turns a turbine generator to produce electricity. In both types of plants, the steam is turned back into water and reused.

The NRC regulates commercial nuclear power plants that generate electricity. There are several operating companies and vendors and many different types of reactor designs. Of these designs, only PWRs and BWRs are currently in commercial operation in the United States. See Glossary for typical PWR and BWR designs. Although commercial U.S. reactors have many similarities, each one is considered unique (see Figure 12. U.S. Operating Commercial Nuclear Power Reactors).

Figure 11. Gross Electricity Generated in Each State by Nuclear Power



Total Nuclear Power Generated (in thousand megawatt-hours)

None	< less than 20,000	20,001 to 40,000	40,001 to 60,000	> more than 60,001+
0 States	16 States	8 States	4 States	2 States

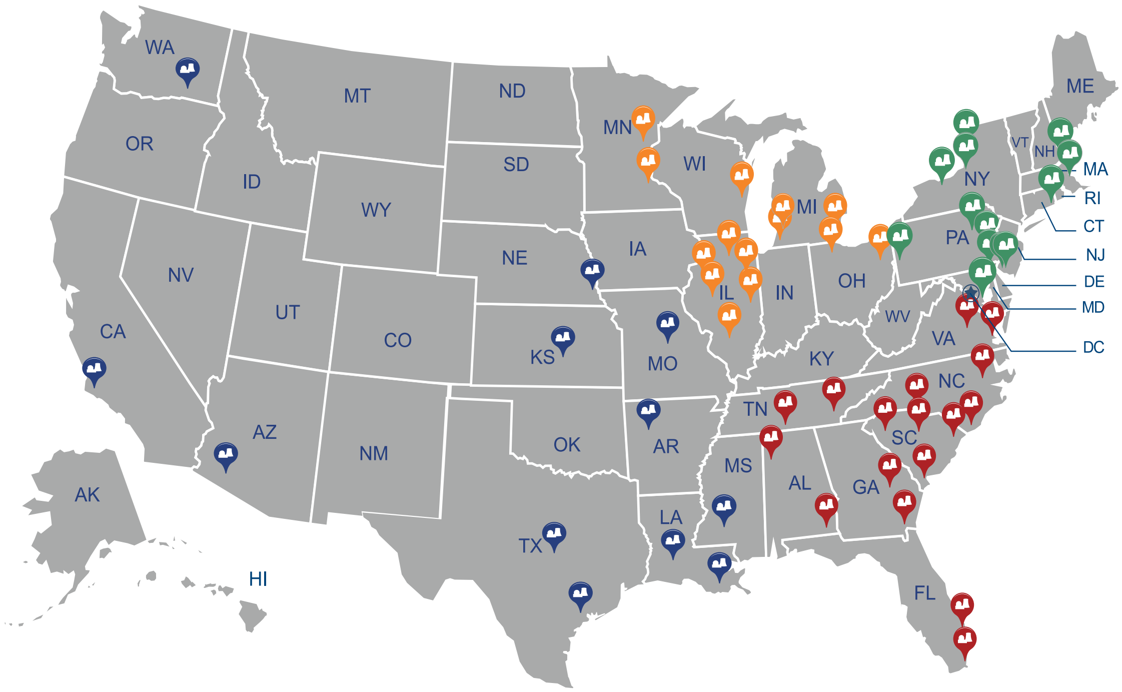
Total Nuclear Power Generated by State (in megawatt-hours)

State	Total Nuclear Generated	% of Nuclear Electricity
Illinois	98,735,488	53%
Pennsylvania	83,229,652	36%
S. Carolina	56,103,043	56%
New York	44,865,018	34%
Alabama	43,656,862	30%
N. Carolina	41,915,605	32%
Texas	41,298,007	8%
Tennessee	35,720,405	43%
Georgia	33,591,181	26%
Michigan	32,909,275	28%
Arizona	31,920,368	28%
Virginia	29,497,516	30%
Florida	29,108,066	12%
New Jersey	26,637,324	37%
Ohio	17,010,561	14%

State	Total Nuclear Generated	% of Nuclear Electricity
California	16,165,384	8%
Connecticut	16,733,398	42%
Maryland	15,012,922	38%
Minnesota	14,104,547	24%
Louisiana	13,981,335	14%
Arkansas	13,574,947	21%
Mississippi	11,032,514	17%
New Hampshire	10,906,923	60%
Wisconsin	10,030,305	16%
Kansas	9,247,734	18%
Missouri	9,189,863	12%
Washington	8,866,499	8%
Nebraska	6,951,600	19%
Iowa	5,235,716	8%
Massachusetts	2,177,204	10%

Source: DOE/EIA, State Historical Tables for 2019, Released September 2020, Revised February 2021, https://eia.gov/state.

Figure 12. U.S. Operating Commercial Nuclear Power Reactors



REGION I

CONNECTICUT
Millstone 2 and 3

MARYLAND
Calvert Cliffs 1 and 2

NEW HAMPSHIRE
Seabrook

NEW JERSEY
Hope Creek
Salem 1 and 2

NEW YORK
FitzPatrick
Ginna
Nine Mile Point 1 and 2

PENNSYLVANIA
Beaver Valley 1 and 2
Limerick 1 and 2
Peach Bottom 2 and 3
Susquehanna 1 and 2

REGION II

ALABAMA
Browns Ferry 1, 2, and 3
Farley 1 and 2

FLORIDA
St. Lucie 1 and 2
Turkey Point 3 and 4

GEORGIA
Hatch 1 and 2
Vogtle 1 and 2

NORTH CAROLINA
Brunswick 1 and 2
McGuire 1 and 2
Harris 1

SOUTH CAROLINA
Catawba 1 and 2
Oconee 1, 2, and 3
Robinson 2
Summer

TENNESSEE
Sequoyah 1 and 2
Watts Bar 1 and 2

VIRGINIA
North Anna 1 and 2
Surry 1 and 2

REGION III

ILLINOIS
Braidwood 1 and 2
Byron 1 and 2
Clinton
Dresden 2 and 3
LaSalle 1 and 2
Quad Cities 1 and 2

MICHIGAN
Cook 1 and 2
Fermi 2
Palisades

MINNESOTA
Monticello
Prairie Island 1 and 2

OHIO
Davis-Besse
Perry

WISCONSIN
Point Beach 1 and 2

REGION IV

ARKANSAS
Arkansas Nuclear 1 and 2

ARIZONA
Palo Verde 1, 2, and 3

CALIFORNIA
Diablo Canyon 1 and 2

KANSAS
Wolf Creek

LOUISIANA
River Bend 1
Waterford 3

MISSISSIPPI
Grand Gulf

MISSOURI
Callaway

NEBRASKA
Cooper

TEXAS
Comanche Peak 1 and 2
South Texas Project 1 and 2

WASHINGTON
Columbia

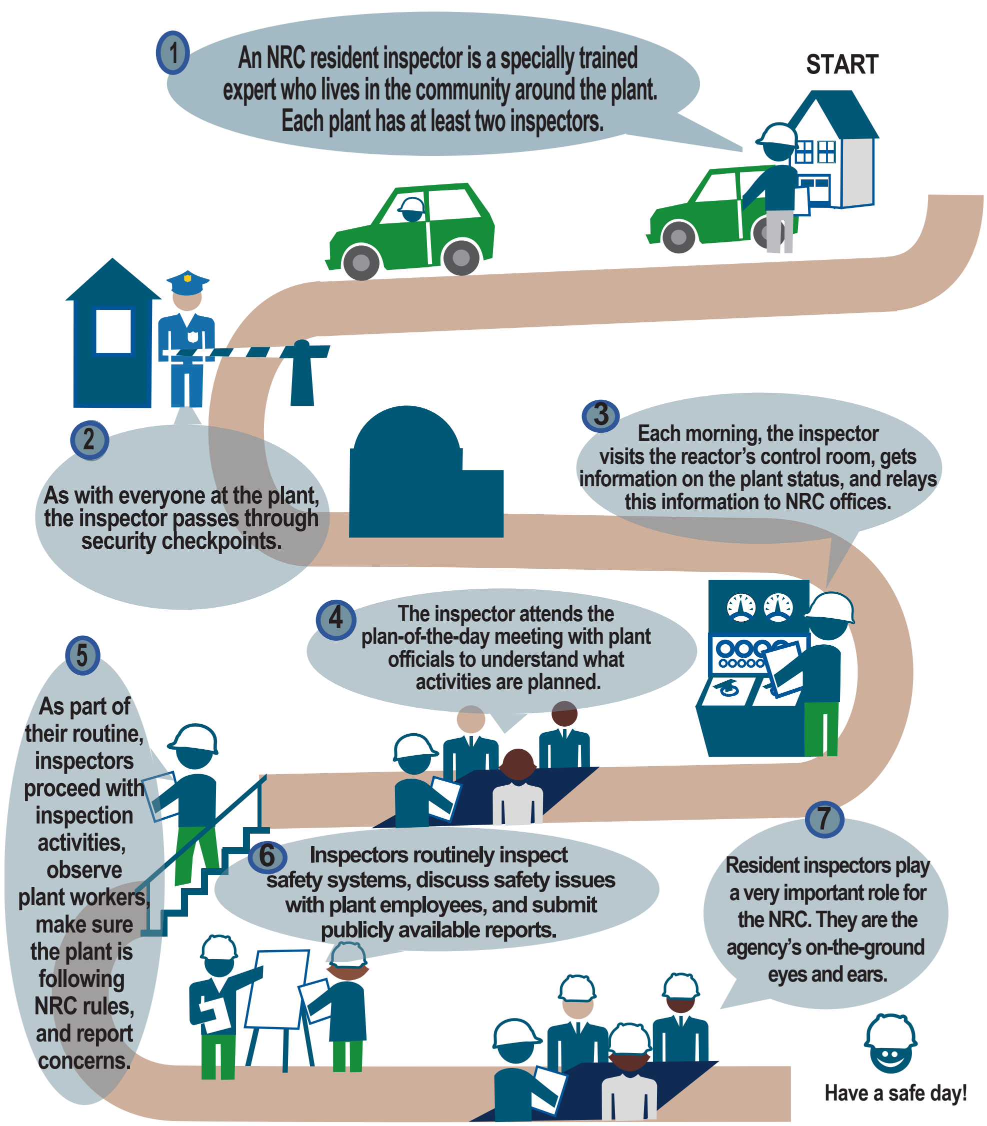
Note: NRC-abbreviated reactor names are listed. Data are current as of June 2021. For the most recent information, go to the NRC facility locator page at https://www.nrc.gov/info-finder/reactors/index.html.

Resident Inspectors

Since the late 1970s, the NRC has maintained its own sets of eyes and ears at the Nation's nuclear power plants. These onsite NRC personnel are referred to as "resident inspectors." Each plant has at least two resident inspectors, and their work is at the core of the agency's reactor inspection program. These highly trained and qualified professionals scrutinize activities at the plants and verify adherence to Federal safety requirements. The inspectors visit the control room and review operator logbook entries, visually assess areas of the plant, observe tests of (or repairs to) important systems or components, interact with plant employees, and check corrective action documents to ensure that problems have been identified and appropriate fixes implemented.

Resident inspectors promptly notify plant operators of any safety-significant issues they find so they are corrected, if necessary, and communicated to NRC management. If problems are significant enough, the NRC will consider whether enforcement action is warranted. More information about the NRC's Reactor Oversight Process and the resident inspector program is available on the agency's Web site (see Figure 13. Day in the Life of an NRC Resident Inspector).

Figure 13. Day in the Life of an NRC Resident Inspector



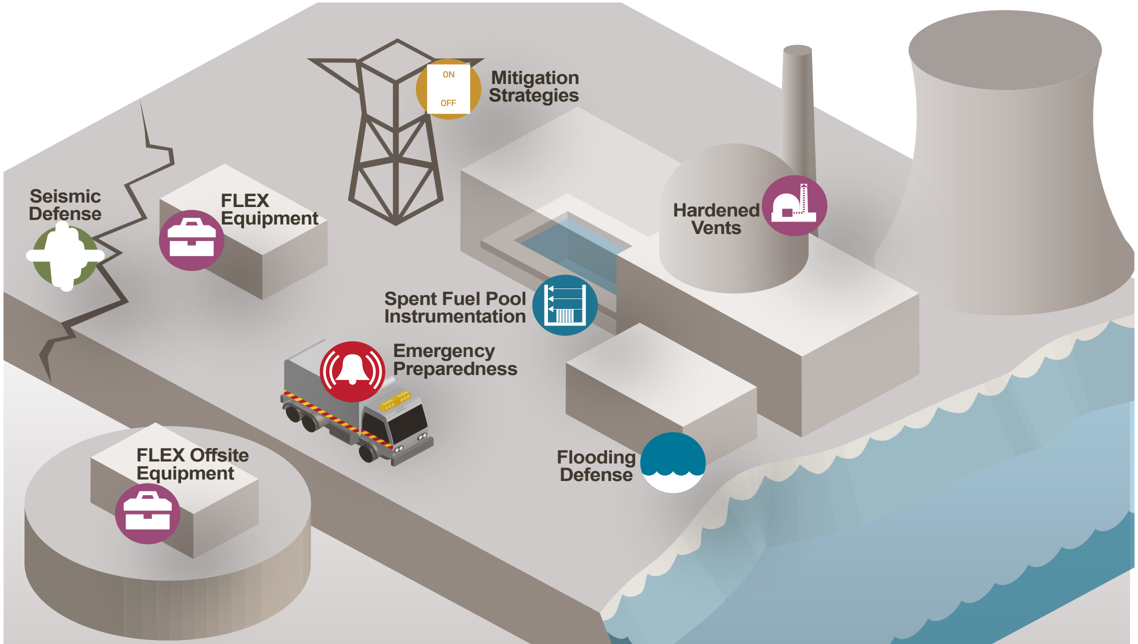
YouTube Learn more about resident inspectors. Watch the videos on the NRC YouTube Channel at https://www.youtube.com/user/NRCgov.

Post-Fukushima Safety Enhancements

On March 11, 2011, a 9.0-magnitude earthquake, followed by a 45-foot (13.7-meter) tsunami, heavily damaged the nuclear power reactors at Japan's Fukushima Dai-ichi facility. Following this accident, the NRC required significant enhancements to U.S. commercial nuclear power plants. At the front lines of this effort were the agency's resident inspectors and regional staff. They inspected and monitored U.S. reactors as the plants worked on these enhancements.

The enhancements included adding capabilities to maintain key plant safety functions following any kind of severe event, updating evaluations of potential impacts from seismic and flooding events, installing new equipment to better handle potential reactor core damage events, and strengthening emergency preparedness capabilities. These actions ensure the nuclear industry and the NRC are prepared for the unexpected. The NRC continues to inspect plants' efforts to ensure they have the required resources, plans, and training (see Figure 14. NRC Post-Fukushima Safety Enhancements and the Web Link Index).

Figure 14. NRC Post-Fukushima Safety Enhancements



Note: FLEX refers to the industry's term for mitigation strategy equipment.

Principal Licensing, Inspection, and Enforcement Activities

The NRC's commercial reactor licensing and inspection activities include the following:

- *reviewing separate license change requests, called "amendments," from power reactor licensees*
- *performing inspections at each operating reactor site*
- *conducting initial reactor operator licensing examinations*
- *ensuring NRC-licensed reactor operators maintain their knowledge and skills current by passing rigorous requalification exams every 2 years and obtaining an NRC license renewal every 6 years*
- *reviewing applications for proposed new reactors*
- *inspecting construction activities*
- *reviewing operating experience items each year and sharing lessons learned that could help licensed facilities operate more effectively*
- *issuing notices of violation, civil penalties, or orders to operating reactors for significant violations of NRC safety and security regulations*

- *investigating allegations of inadequacy or impropriety associated with NRC-regulated activities*
- *incorporating independent advice from the Advisory Committee on Reactor Safeguards (ACRS), which holds both full committee meetings and subcommittee meetings each year to examine potential safety issues for existing or proposed reactors*

OVERSIGHT OF U.S. COMMERCIAL NUCLEAR POWER REACTORS

The NRC establishes requirements for the design, construction, operation, and security of U.S. commercial nuclear power plants. The agency ensures plants operate safely and securely within these requirements by licensing the plants to operate, licensing control room personnel, establishing technical specifications for operating each plant, and inspecting plants daily.

Reactor Oversight Process

The NRC's Reactor Oversight Process (ROP) verifies that U.S. reactors are operating in accordance with NRC rules, regulations, and license requirements. If reactor performance declines, the NRC increases its oversight to protect public health and the environment. This can range from conducting additional inspections to shutting a reactor down.

The NRC staff uses the ROP to evaluate NRC inspection findings and performance records for each reactor and applies this information to assess the reactor's safety performance and security measures. Every 3 months, the NRC places each reactor in one of five categories. The top category is "fully meeting all safety cornerstone objectives," while the bottom is "unacceptable performance" (see Figure 15. Reactor Oversight Action Matrix Performance Indicators).

NRC inspections start with detailed baseline-level activities for every reactor. As the number of issues at a reactor increases, the NRC's inspections increase. The agency's supplemental inspections and other actions (if needed) ensure licensees promptly address significant performance issues. The latest reactor-specific inspection findings and historical performance information can be found on the NRC's Web site (see the Web Link Index).

The ROP is informed by 50 years of improvements in nuclear industry performance. The process continues to improve approaches to inspecting and evaluating the safety and security performance of NRC-licensed nuclear plants. More ROP information is available on the NRC's Web site and in NUREG-1649, Revision 6, "Reactor Oversight Process," issued July 2016 (see Figure 16. Reactor Oversight Framework).

NRC Commissioner Jeff Baran observes the reactor vessel head inside Unit 4 containment, currently under construction at the Vogtle site in Georgia.

Figure 15. Reactor Oversight Action Matrix Performance Indicators

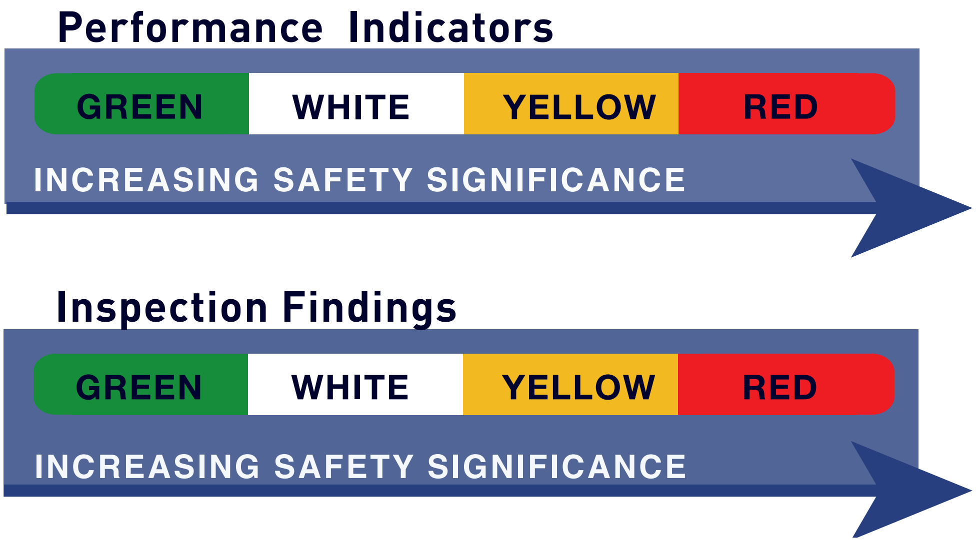
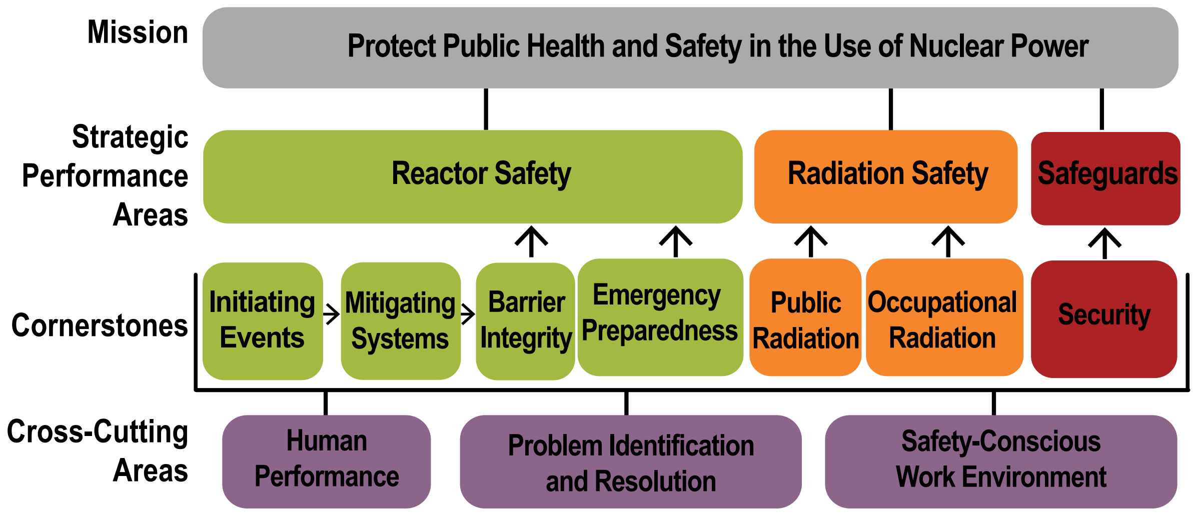


Figure 16. Reactor Oversight Framework



See Appendix C for a list of reactors undergoing decommissioning and permanently shutdowns; Appendix V for list of significant enforcement actions; and Appendices F and G for power reactor operating licenses issued and expiring by year.

APPENDIX

REACTOR LICENSE RENEWAL

The Atomic Energy Act of 1954, as amended, authorizes the NRC to issue 40-year initial licenses for commercial power reactors. The Act also allows the NRC to renew licenses. Under the NRC's current regulations, the agency can renew reactor licenses for 20 years at a time. Congress set the original 40-year term after considering economic and antitrust issues, as opposed to nuclear technology issues. Some parts of a reactor, however, may have been engineered based on an expected 40-year service life. These parts must be maintained and monitored during the additional period of operation, and licensees may choose to replace some components (see Figure 17. License Renewals Granted for Operating Nuclear Power Reactors). For current reactors grouped by how long they have operated, see Figure 18. U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2020. Nuclear power plant owners typically seek license renewal based on a plant's economic situation and on whether it can continue to meet NRC requirements in the future (see Figure 19. License Renewal Process).

The NRC reviews a license renewal application on two tracks: safety and environmental impacts. The safety review evaluates the licensee's plans for managing aging plant systems during the renewal period. For the environmental review, the agency uses the "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (NUREG-1437, Revision 1, issued June 2013) to evaluate impacts common to all nuclear power plants, then prepares a supplemental environmental impact statement for each individual plant. The supplement examines impacts unique to the plant's site. The public has two opportunities to contribute to the environmental review—at the beginning and when the draft report is published.

The NRC considered the environmental impacts of the continued storage of spent nuclear fuel during rulemaking activities and published its final continued storage rule and supporting generic environmental impact statement in 2014. The rule addresses the environmental impacts of the continued storage of spent nuclear fuel beyond a reactor's licensed operating life before ultimate disposal (previously referred to as "waste confidence"). The environmental impacts of continued storage of spent nuclear fuel are incorporated into each environmental review for license renewal.

Subsequent License Renewal

The NRC staff developed guidance and a standard review plan for "subsequent license renewals" that would allow plants to operate for more than 60 years (the 40 years of the original license plus 20 years in the initial license renewal).

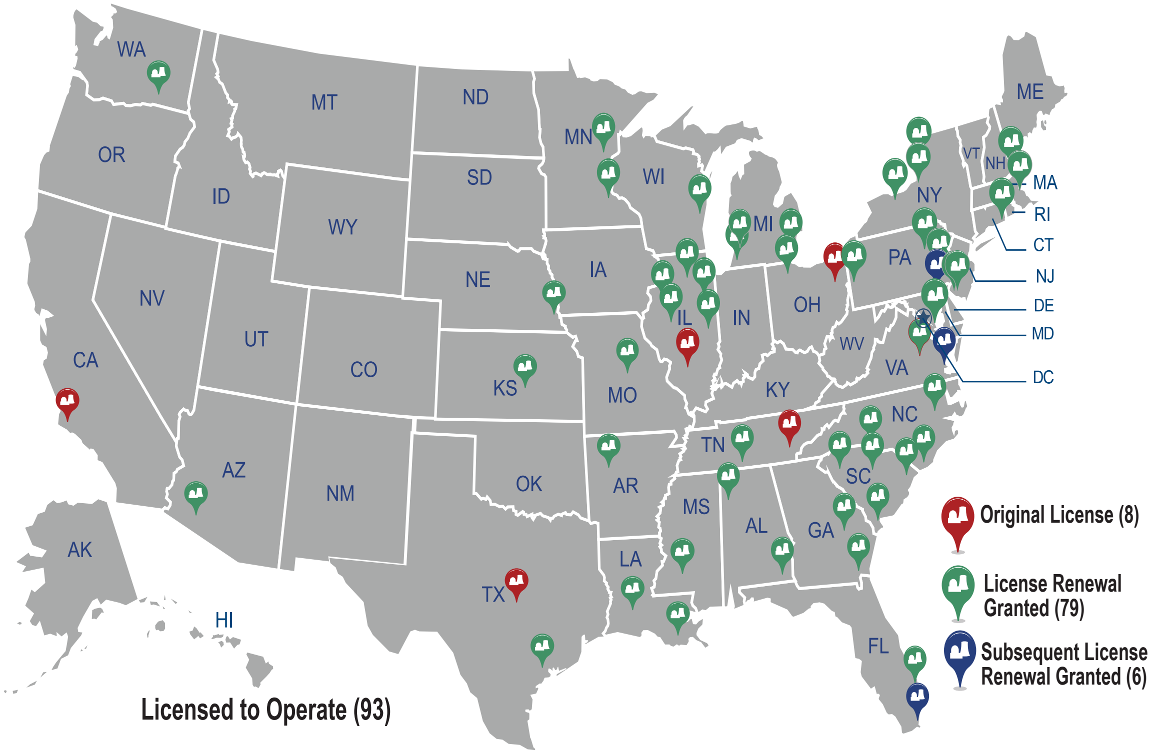
The Commission determined that the agency's existing regulations are adequate for subsequent license renewals. Nevertheless, the Commission asked the staff to develop new guidance to better help licensees develop aging management programs for the 60-year to 80-year period. The staff issued this guidance (NUREG-2191 and NUREG-2192) in July 2017.

Public Involvement

The public plays an important role in the license renewal process. Members of the public have several opportunities to contribute to the environmental review. The NRC shares information provided by the applicant, holds public meetings, and publicly documents the results of its technical and environmental reviews. In addition, the ACRS reviews license renewal applications and discusses them at its meetings.

Individuals or groups can raise legal arguments against a license renewal application in an Atomic Safety and Licensing Board hearing if they would be affected by the renewal and meet basic requirements for requesting a hearing. (For more information, see the Web Link Index.)

Figure 17. License Renewals Granted for Operating Nuclear Power Reactors



Note: The NRC has issued a total of 94 initial license renewals: 9 of these units have permanently shut down.
Data are as of July 2021. For the most recent information, go to NRC Web page at *https://www.nrc.gov/info-finder.html*

Figure 18. U.S. Commercial Nuclear Power Reactors —Years of Operation by the End of 2020

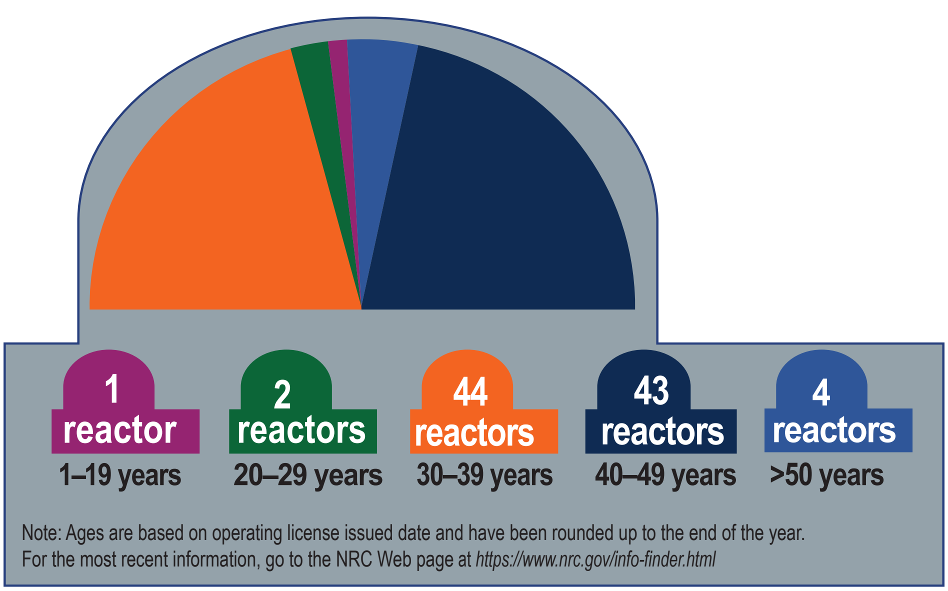
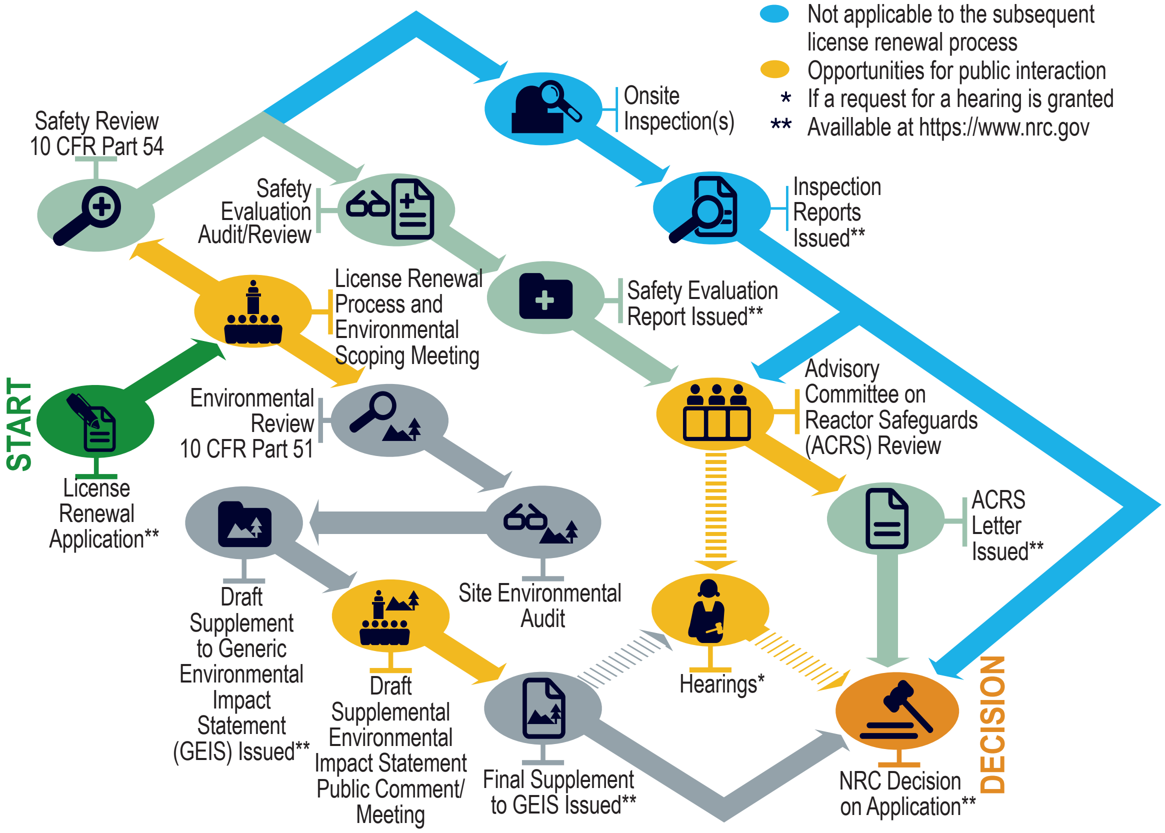


Figure 19. License Renewal Process



Turkey Point nuclear power plant in Florida was the first U.S. plant to be approved by the NRC for Subsequent License Renewal, or an additional 20 years of operation, for a total lifespan of 80 years.

NUCLEAR RESEARCH AND TEST REACTORS

Nuclear research and test reactors (RTRs), also called "nonpower" reactors, are a type of Nonpower Production and Utilization Facility (NPUF). RTRs are primarily used for research, training, and development to support science and education in nuclear engineering, physics, chemistry, biology, anthropology, medicine, materials sciences, and related fields. These reactors do not produce electricity. Most U.S. RTRs are at universities or colleges.

The largest U.S. RTR (which operates at 20 megawatts thermal (MWt) is approximately 80 times smaller than the smallest U.S. commercial power nuclear reactor (which operates at 1,677 MWt). The NRC regulates a wide variety of RTRs located across the country (see Figure 20. Size Comparison of Commercial and Research Reactors and Figure 21. U.S. Nuclear Research and Test Reactors). DOE also uses nonpower nuclear research reactors, but they are not regulated by the NRC.

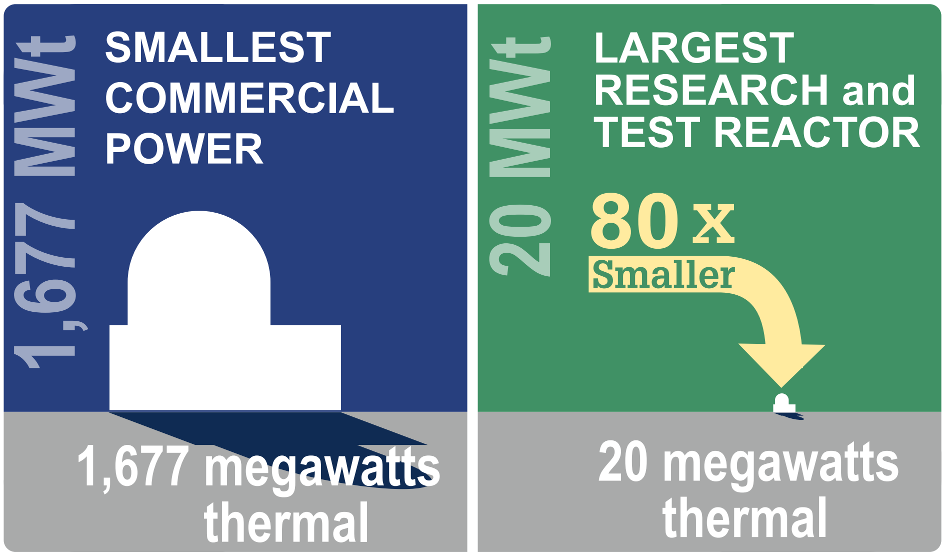
NRC inspectors visit each RTR facility about once a year to provide varying levels of oversight. RTRs licensed to operate at 2 MWt or more receive a full NRC inspection every year. Those licensed to operate at less than 2 MWt receive a full inspection every 2 years.

Principal Licensing and Inspection Activities

The NRC's RTR licensing and inspection activities include:

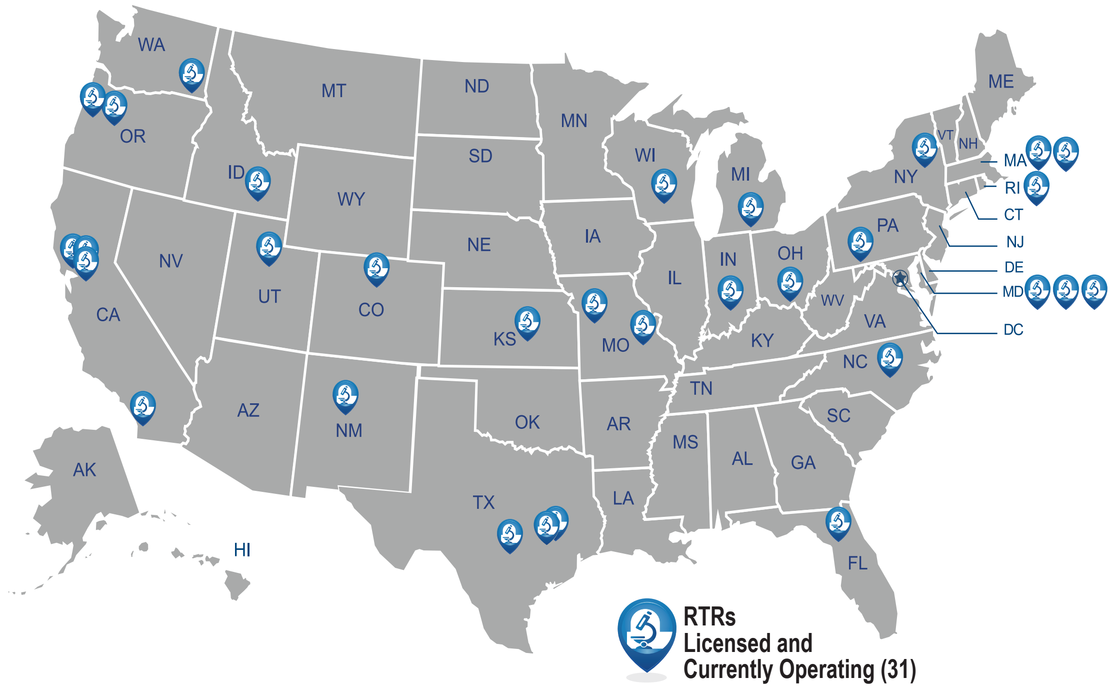
- *licensing new and current operating sites, including license renewals and license amendments*
- *overseeing decommissioning*
- *licensing operators*
- *overseeing operator relicensing programs*
- *conducting inspections each year, based on inspection frequency and procedures for operating RTRs*
- *overseeing facility security and emergency preparedness programs*

Figure 20. Size Comparison of Commercial and Research Reactors



For the most recent information, go to NRC Web page at *https://www.nrc.gov/info-finder.html*

Figure 21. U.S. Nuclear Research and Test Reactors



Note: RTRs are also referred to as "nonpower facilities." For the most recent information, go to NRC Web page at *https://www.nrc.gov/info-finder.html*

APPENDIX

See Appendices H and I for a list of RTRs regulated by the NRC that are operating or are in the process of decommissioning.

NEW COMMERCIAL NUCLEAR POWER REACTOR LICENSING

New reactors are any reactors proposed in addition to the current fleet of operating reactors (see Figure 22. The Different NRC Classifications for Types of Reactors).

The NRC's current review of new power reactor license applications improves on the process used through the 1990s (see Figure 23. New Reactor Licensing Process). In 2012, the NRC issued the first combined construction permit and operating license (called a "combined license," or COL) under the new licensing process. The NRC continues to review applications submitted by prospective licensees and (when appropriate) issues standard design approvals, standard design certifications, early site permits (ESPs), limited work authorizations, construction permits, operating licenses, and COLs for facilities in a variety of projected locations throughout the United States. The NRC has implemented the Commission's policies on new reactor safety through rules, guidance, staff reviews, and inspection.

The NRC's ongoing design certification, COL, and ESP reviews are incorporating lessons learned from the Fukushima accident. The environmental impacts of continued storage of spent nuclear fuel are incorporated into each environmental review for new reactor licensing. The NRC considered these impacts in a rulemaking and published its final continued storage rule and supporting generic environmental impact statement in September 2014. Section 5 discusses the continued storage rule in more detail.

Figure 22. The Different NRC Classifications for Types of Reactors

Operating Reactors

Design: The U.S. fleet consists mainly of large reactors that use regular water ("light" water, as opposed to "heavy" water that has a different type of hydrogen than commonly found in nature) for both cooling the core and facilitating the nuclear reaction.

Capacity: The generation base load of these plants is 1,677 MWt (approximately 570 MWe) or higher.

Safety: These reactors have "active" safety systems powered by alternating current (ac) and require an operator to reach a safe shutdown state.

Fuel: These reactors require enriched uranium.

Advanced Reactors

Design: Advanced reactors are a new generation of nonlight-water reactors.They use coolants including molten salts, liquid metals, and even gases such as helium.

Capacity: These plants range in power from very small reactors to a power level comparable to existing operating reactors.

Safety: These reactors are expected to provide enhanced margins of safety and use simplified, inherent, and passive means to ensure safety. They may not require an operator to shut down.

Fuel: These reactors could use enriched uranium, thorium, or used nuclear fuel.

Small Modular Reactors

Design: Small modular reactors (SMRs) are similar to large light-water reactors but are smaller, compact designs. These factory-fabricated reactors can be transported by truck or rail to a nuclear power site. Additional SMRs can be installed on site to scale or to meet increased energy needs.

Capacity: These reactors are about one-third the size of typical reactors with a generation base load of 1,000 MWt (300 MWe) or less.

Safety: These reactors can be installed underground, providing more safety and security. They are built with passive safety systems and can be shut down without an operator.

Fuel: These reactors require enriched uranium.

Research and Test Reactors

Design: Research and test reactors—also called "nonpower" reactors—are primarily used for research, training, and development. They are classified by their moderator, the material used to slow down the neutrons, in the nuclear reaction. Typical moderators include water (H_2O), heavy water (D_2O), polyethylene, and graphite.

Capacity: These current licensed facilities range in size from 5 watts (less than a night light) to 20 MWt (equivalent to 20 standard medical x-ray machines).

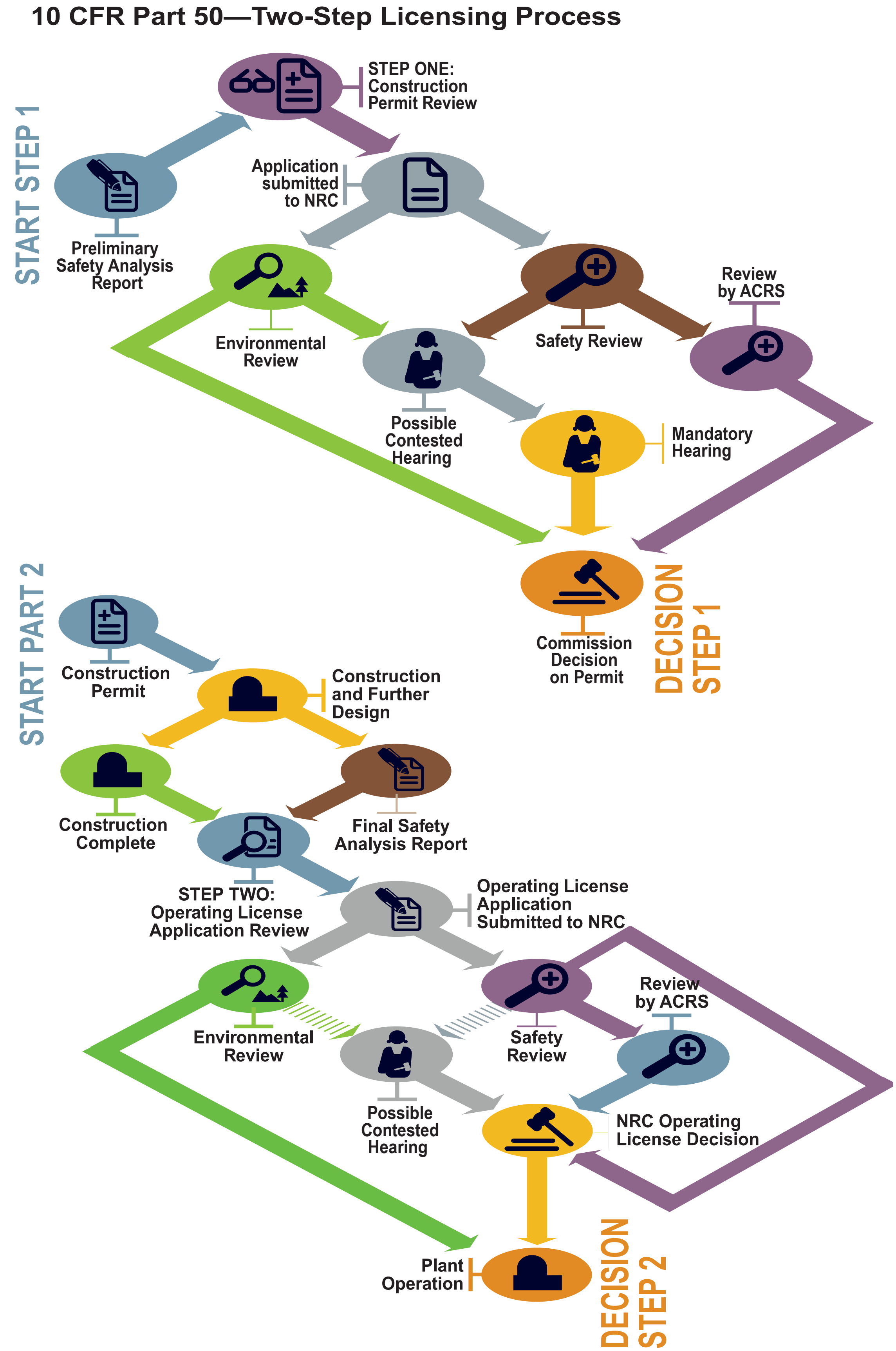
Safety: All NRC-licensed research and test reactors have a built-in safety feature that reduces reactor power during potential accidents before an unacceptable power level or temperature can be reached.

Fuel: Reactors may also be classified by the type of fuel used, such as MTR (plate-type fuel) or TRIGA fuel. TRIGA fuel is unique in that a moderator (hydrogen) is chemically bonded to the fuel.

See Appendix B for a list of new nuclear power plant licensing applications in the United States.

APPENDIX

Figure 23. New Reactor Licensing Process



10 CFR Part 52—Combined License Application Review Process

Combined License Applications—Construction and Operating

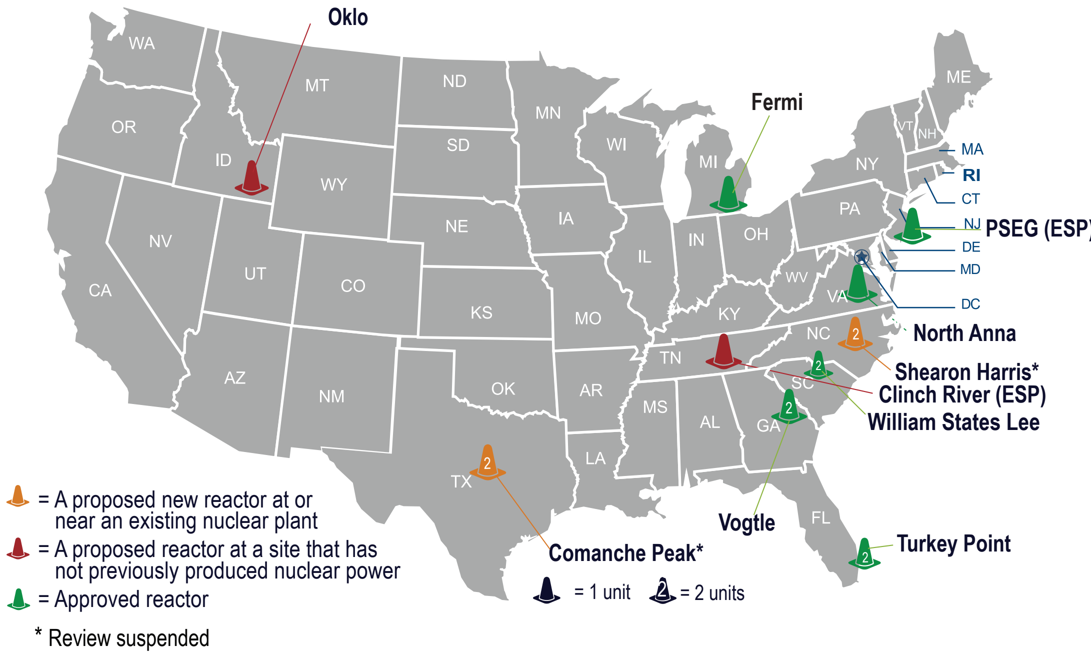
By issuing a COL, the NRC authorizes the licensee to construct and (with specified conditions) operate a nuclear power plant at a specific site, in accordance with established laws and regulations. If the Commission finds that the acceptance criteria are met, a COL is valid for 40 years. A COL can be renewed for additional 20-year terms (see Figure 24. Locations of New Nuclear Power Reactor Applications). For the current review schedule for active licensing applications, consult the NRC's Web site (see the Web Link Index).

Public Involvement

Even before the NRC receives an application, the agency holds a public meeting to talk to the community near the proposed reactor location. The agency explains the review process and outlines how the public may participate. After the application is submitted, the NRC asks the public to comment on which factors the agency should consider in its environmental review under the National Environmental Policy Act.

The NRC later posts a draft environmental evaluation on its Web site and asks for public input. There is no formal opportunity for public comment on the staff's safety evaluation, but members of the public are welcome to attend public meetings and make comments. Individuals or groups can raise legal arguments against a new reactor application in an Atomic Safety and Licensing Board hearing if they would be affected by the new reactor and meet basic requirements for requesting a hearing. The NRC announces opportunities to request these hearings in news releases, in the *Federal Register,* and on its Web site.

Figure 24. Locations of New Nuclear Power Reactor Active Applications and Approved Licenses



Note: Alaska and Hawaii are not pictured, but have no sites. On July 31, 2017, South Carolina Electric and Gas announced its decision to cease construction on V.C. Summer Units 2 and 3, and the licensee has requested that the COLs be withdrawn. As of October 2017, Duke Energy has announced plans to cancel reactors at Levy County, FL, and William States Lee, SC. Applications were withdrawn for Calvert Cliffs, Grand Gulf, Nine Mile Point, Victoria County, and Callaway (COL and ESP). In June 2018, Nuclear Innovation North America submitted a letter requesting that the COLs for South Texas Project Units 3 and 4 be withdrawn. NRC-abbreviated reactor names are listed. Data are current as of August 2021. For the most recent information, go to the NRC Web site at https://www.nrc.gov.

Early Site Permits

An ESP review examines whether a piece of land is suitable for a nuclear power plant. The review covers site safety, environmental protection, and emergency preparedness. The ACRS reviews safety-related portions of an ESP application. As with COL reviews, the public participates in the environmental portion of the NRC's ESP review, and the public can challenge an application in a hearing.

Design Certifications

The NRC issues standard design certifications through rulemaking for reactor designs that meet basic requirements for ensuring safe operation. Utilities can cite a certified design when applying for a nuclear power plant construction permit, COL, ESP, or manufacturing license. The certification is valid for 15 years from the date issued and can be renewed for an additional 15 years. The NRC staff has also issued standard design approvals upon completion of the final SER for the design. Standard design approvals may be referenced by a construction permit, combined license, or manufacturing license. The new reactor designs under review incorporate new elements such as passive safety systems and simplified system designs. The six certified designs are—

- *GE-Hitachi Nuclear Energy's Advanced Boiling-Water Reactor (ABWR)*
- *Westinghouse Electric Company's System 80+*
- *Westinghouse Electric Company's AP600*
- *Westinghouse Electric Company's AP1000*
- *GE-Hitachi Economic Simplified Boiling-Water Reactor (ESBWR)*
- *Korean Electric Power Corporation APR 1400 (Advanced Power Reactor)*

Design Certification Renewals

The NRC staff has completed its review of GE-Hitachi's application to renew the ABWR design certification. The direct final rule renewing this design certification was published on July 1, 2021, and was effective September 29, 2021.

Advanced Reactor Designs

Several companies are considering advanced reactor designs and technologies and are conducting preapplication activities with the NRC. These reactors are cooled by liquid metals, molten salt mixtures, or inert gases. Advanced reactors can also consider fuel materials and designs that differ radically from today's enriched-uranium dioxide (UO_2) pellets with zirconium cladding. While developing the regulatory framework for advanced reactor licensing, the NRC is examining policy issues in areas such as security and emergency preparedness.

Small Modular Reactors

Small modular reactors (SMRs) use water to cool the reactor core in the same way as today's large light-water reactors. SMR designs also use the same enriched uranium fuel as today's reactors. However, SMR designs are considerably smaller. Each SMR module generates 300 megawatts electric (MWe) (1,000 MWt) or less, compared to today's large designs that can generate 1,000 MWe (3,300 MWt) or more per reactor. The NRC's discussions to date with SMR designers involve modules generating less than 200 MWe (660 MWt).

New Reactor Construction Inspections

NRC inspectors based in the agency's Region II office in Atlanta, GA, monitor reactor construction activities. These expert staff members ensure licensees carry out construction according to NRC license specifications and related regulations.

The NRC staff examines the licensee's operational programs in areas such as security, radiation protection, and operator training and qualification. Inspections at a construction site verify that a licensee has completed required inspections, tests, and analyses and has met associated acceptance criteria. The NRC's onsite resident construction inspectors oversee day-to-day licensee and contractor activities.

In addition, specialists in NRC Region II's Division of Construction Oversight periodically visit the sites to ensure the facilities are being constructed using the approved design.

The NRC's Construction Reactor Oversight Process assesses all of these activities. Before the agency will allow a new reactor to start up, NRC inspectors must confirm that the licensee has met all the acceptance criteria in its COL.

The agency also inspects domestic and overseas factories and other vendor facilities. This ensures new U.S. reactors receive high-quality products and services that meet the NRC's regulatory requirements. The NRC's Web site has more information on new reactor licensing activities (see the Web Link Index).

NRC senior leaders observe new construction activities to ensure NRC regulations are being met at Vogtle Units 3 and 4, in Georgia.

NEW LICENSING OF NONPOWER PRODUCTION AND UTILIZATION FACILITIES

Research reactors, testing facilities, and other nonpower facilities can be used to produce medical radioisotopes and demonstrate advanced reactor technologies. These research and test reactors are used to demonstrate new reactor technologies to meet future energy needs, promote training and education, and support needed medical care. To support these efforts, the NRC staff conducts safety and environmental reviews of construction permit and operating license applications, which are also subject to regulatory requirements for hearings and an independent review by the ACRS.

Doctors worldwide rely on a steady supply of molybdenum-99 (Mo-99) to produce technetium-99m in hospitals, which is used in a radiopharmaceutical applied in approximately 50,000 medical diagnostic procedures daily in the United States. The NRC supports the national policy objective of establishing a reliable, domestically available supply of this medical radioisotope by reviewing license applications for these facilities submitted in accordance with the provisions of 10 CFR Part 50. Since 2013, the NRC staff has received two construction permit applications and one operating license application for these facilities. The proposed facilities would irradiate low-enriched uranium targets in utilization facilities, then separate Mo-99 from other fission products in hot cells contained within a production facility. The NRC approved the construction permits for SHINE Medical Technologies, LLC (SHINE), in February 2016 and for Northwest Medical Isotopes, LLC, in May 2018. The staff is reviewing SHINE's application for a license to operate its facility.

The NRC is also engaged in pre-application topical report reviews for Atomic Alchemy and Abilene Christian University, which have proposed to construct nonpower reactors for radioisotope production and molten salt reactor technology demonstration, respectively.

The NRC anticipates receiving additional topical reports, construction permit applications, operating license applications, materials license applications, and license amendment requests in the coming years from other potential Mo-99 producers and advanced nonpower reactor applicants.

The NRC continues to develop the necessary infrastructure programs for these facilities, including inspection procedures for construction and operation. The agency provides updates on the status of these licensing reviews through NRC-hosted public meetings, Commission meetings, and interagency interactions.

Technetium-99m is produced by the decay of molybdenum-99 and is used in diagnostic nuclear medical imaging procedures

NUCLEAR REGULATORY RESEARCH

The NRC's Office of Nuclear Regulatory Research supports the agency's mission by providing technical advice, tools, methods, data, and information. This research can identify, explore, and resolve safety issues, as well as provide information supporting licensing decisions and new regulations and guidance. The NRC's research includes the following:

- *independently confirming other parties' work through experiments and analyses*
- *developing technical support for agency safety decisions*
- *preparing for the future by evaluating the safety implications of new technologies and designs for nuclear reactors, materials, waste, and security*

The research program reflects the challenges of an evolving industry. The NRC's research covers the light-water reactor technology developed in the 1960s and 1970s, today's advanced light-water reactor designs, and fuel cycle facilities. The agency has longer term research plans for more advance reactor concepts, such as those cooled by high-temperature gases or molten salts. The NRC's research programs examine a broad range of subjects, such as the following:

- *material performance (for example, environmentally assisted degradation and cracking of metallic alloys, aging management of reactor components and materials, boric-acid corrosion, radiation effects on concrete, and embrittlement of reactor pressure vessel steels)*
- *events disrupting heat transfer from a reactor core, criticality safety, severe reactor accidents, how radioactive material moves through the environment, and how that material could affect human health (sometimes using NRC-developed computer codes for realistic simulations)*
- *computer codes used to analyze fire conditions in nuclear facilities, to examine how reactor fuel performs, and to assess nuclear power plant risk*
- *new and evolving technologies such as additive manufacturing, accident tolerant fuel, and advanced control and automation*
- *experience gained from operating reactors*
- *digital instrumentation and controls, including analyzing digital system components, security aspects of digital systems, and probabilistic assessment of digital system performance*
- *enhanced risk-assessment methods, tools, and models to support the increased use of probabilistic risk assessment in regulatory applications*
- *earthquake, flooding, and high-wind hazards*
- *ultrasonic testing and other nondestructive means of inspecting reactor components and dry cask storage systems and developing and accessing ultrasonic testing simulation tools to optimize examination procedure variables*
- *the human side of reactor operations, including safety culture, and computerization and automation of control rooms*

The Office of Nuclear Regulatory Research also plans, develops, and manages research on fire safety and risk, including modeling, and evaluates potential security vulnerabilities and possible solutions (see the Web Link Index for more information on specific NRC research projects and activities).

NRC Research Funding

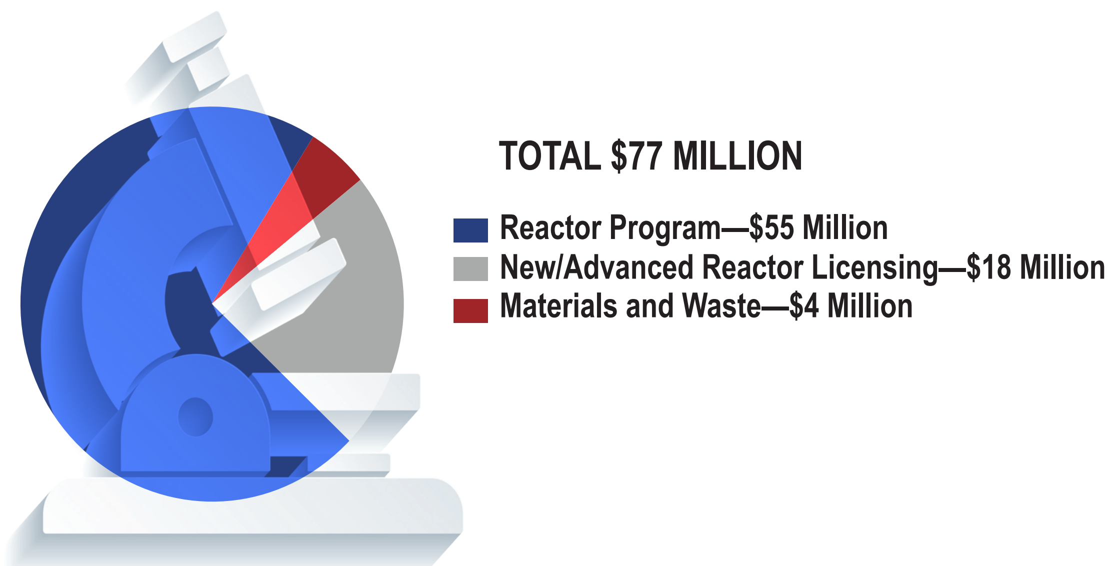
The NRC's research program involves about 5 percent of the agency's personnel and uses about 7 percent of its contracting funds. The NRC's $77 million research budget for Fiscal Year (FY) 2021 includes contracts with national laboratories, universities, research organizations, and other Federal agencies (e.g., the National Institute of Standards and Technology, the U.S. Army Corps of Engineers, and the U.S. Geological Survey). NRC research funds support access to a broader group of experts and international research facilities. Figure 25. NRC Research Funding, FY 2021, illustrates the primary areas of research.

The majority of the NRC's research budget supports maintaining operating reactor safety and security, while the remainder supports regulatory activities for new and advanced reactors, industrial and medical use of nuclear materials, and nuclear fuel cycle and radioactive waste programs. The NRC cooperates with universities and nonprofit organizations on research for the agency's specific interests.

The NRC's international cooperation in research areas leverages agency resources, facilitates work on advancing existing technologies, and determines any safety implications of new technologies. The agency's leadership role in international organizations such as IAEA and OECD/NEA helps guide the agency's collaborations.

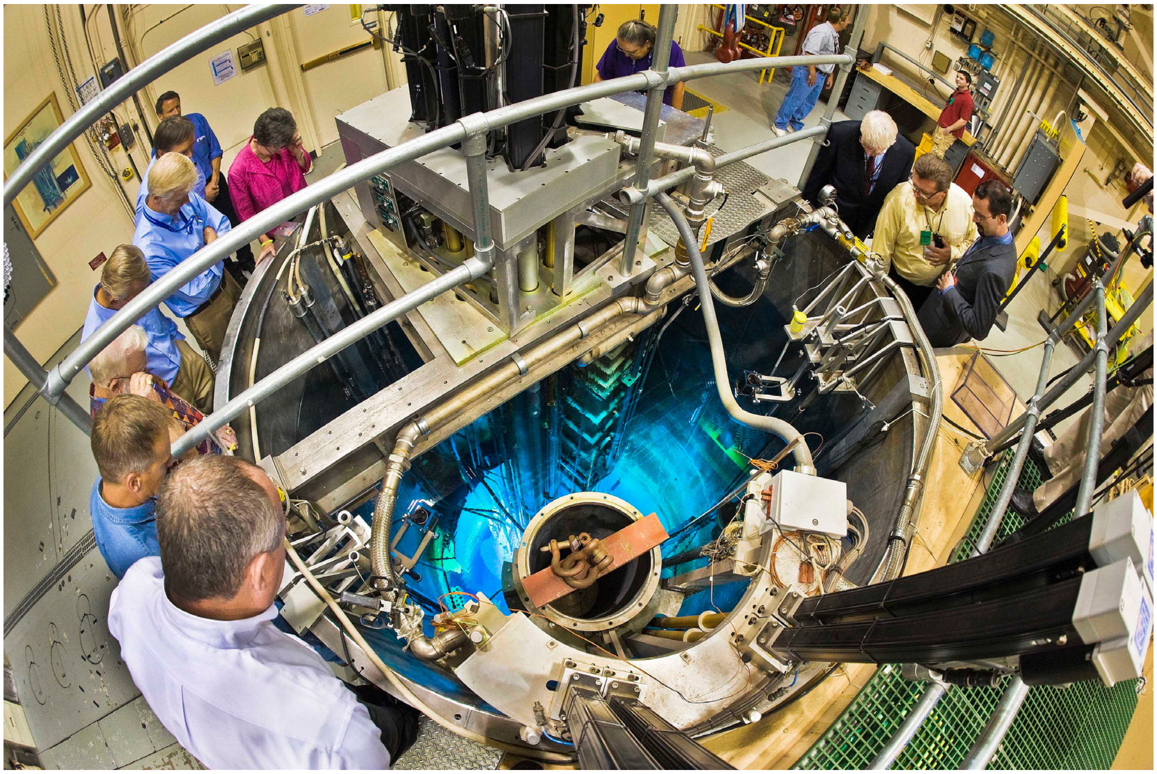
The NRC maintains international cooperative research agreements with more than two dozen foreign governments. This work covers technical areas from severe accident research and computer code development to materials degradation, nondestructive examination, fire risk, and human-factors research. Cooperation under these agreements is more efficient than conducting research independently.

Figure 25. NRC Research Funding, Fiscal Year 2021

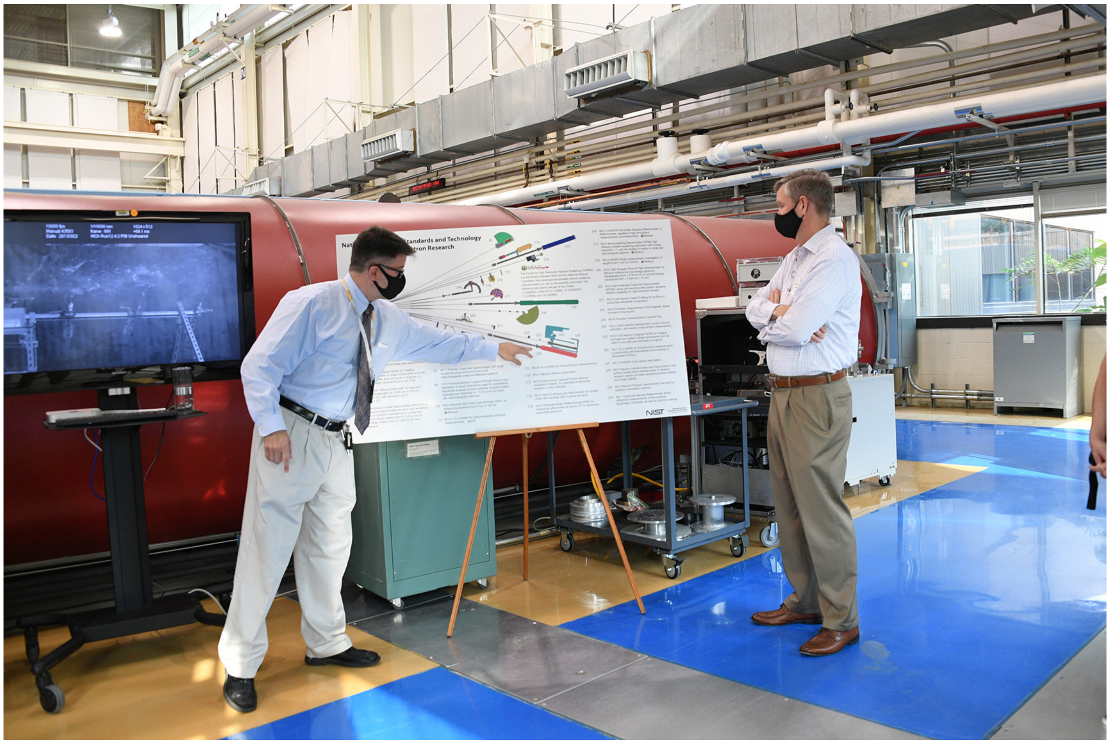


APPENDIX

See Appendix U for States with NRC Grant Award Recipients in Fiscal Year 2020



A group observes the Annular Core Research Reactor. The reactor has been in operation since 1979 at Sandia National Laboratories in New Mexico.



NRC Chairman Christopher T. Hanson tours the NIST Center for Neutron Research in Maryland, learning about some of the research conducted using the largest NRC-regulated nonpower reactor in the U.S.