NUCLEAR REACTORS

U.S. Electricity Generated by Commercial Nuclear Power

According to the U.S. Energy Information Administration (EIA), in 2018, about 4,178 billion kilowatt-hours (kWh) (or 4.18 trillion kWh) of electricity were generated at utility-scale electricity generation facilities in the United States. About 63 percent of this electricity generation was from fossil fuels (coal, natural gas, petroleum, and other gases). Nuclear energy provided 19.3 percent (807 billion kWh), and about 17 percent came from renewable energy sources. EIA estimates that an additional 30 billion kWh of electricity generation was from small-scale solar photovoltaic systems in 2018 (see Figure 9. U.S. Gross Electricity Share by Energy Source, 2018, and Figure 10. U.S. Electricity Generation by Energy Source, 2013–2018).

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 amount of heat, or power level, is used with other data in many analyses that demonstrate the safety of the nuclear power plant. 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 a license or technical specification. 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. The NRC expects a few more power uprate applications through 2019.

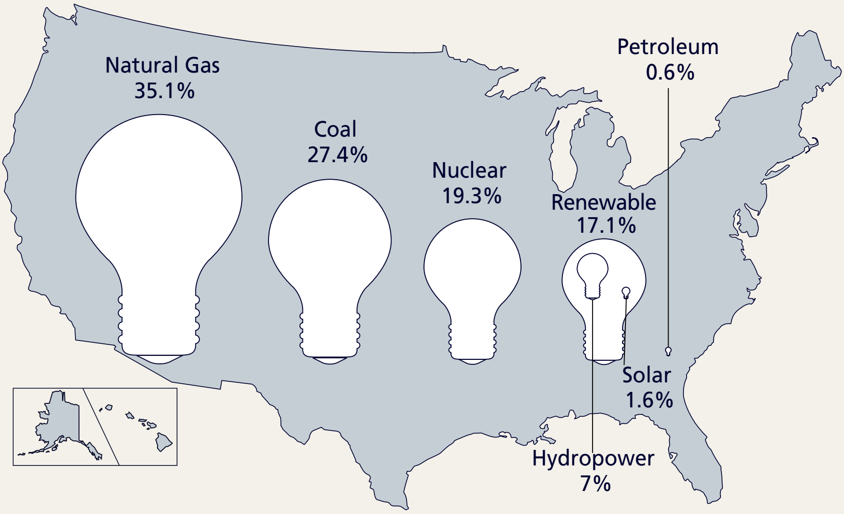
See Glossary for information on the electric power grid.

According to the EIA, in 2018, each of the following States generated more than 40,000 megawatt-hours of electricity from nuclear power: Illinois, Pennsylvania, South Carolina, New York, 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 2018 data cited reflect the total net generation electricity from nuclear sources in each of these States (see Figure 11. Gross Electricity Generated in Each State by Nuclear Power). In 2018, 30 of the 50 States generated electricity from nuclear power plants.

U.S. Commercial Nuclear Power Reactors

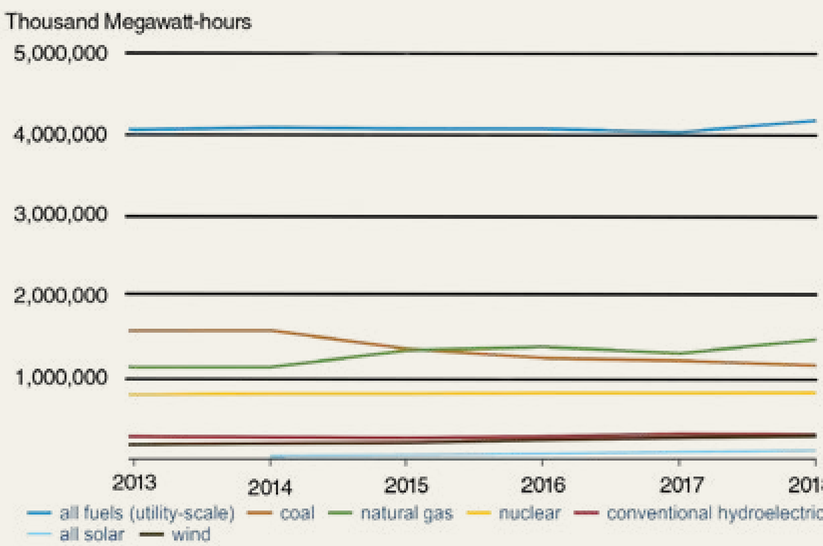
Power plants convert heat into electricity using steam. At nuclear power plants, the heat to make the steam is created when atoms split apart in a process called fission. When the process is repeated over and over, it is called a chain reaction. The heat from fission creates steam to turn a turbine.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

Figure 9. U.S. Gross Electricity Share by Energy Source, 2018



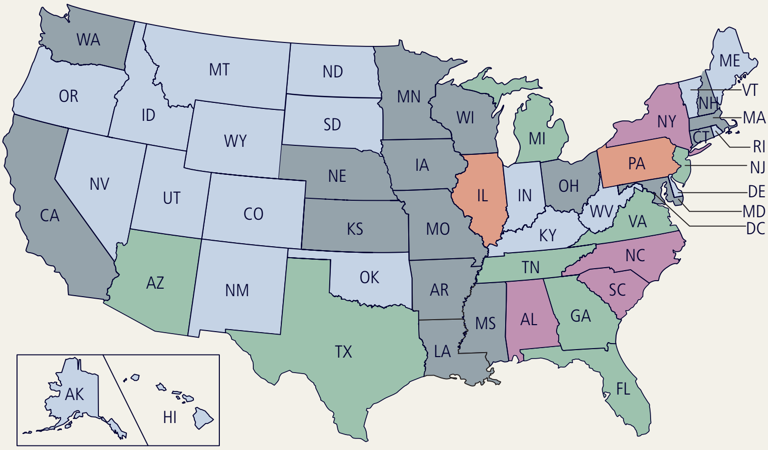
Note: Figures are rounded.
Source: DOE/EIA, April 19, 2019, *https://www.eia.gov*—Table 7.2a Electricity Net Generation: Total (All Sectors)

Figure 10. U.S. Electricity Generation by Energy Source, 2013–2018



Note: Figures are rounded.
Source: DOE/EIA, April 19, 2019, *https://www.eia.gov*—Electricity Data Browser—Electricity Net Generation: Total (All Sectors—Annually 2013–2018)

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+
20 States	16 States	8 States	4 States	2 States

Note: *U.S. Territories not pictured. American Samoa, Guam, Northern Mariana Islands, Puerto Rico, U.S. Virgin Islands, and Minor Outlying Islands do not generate nuclear power.

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

State	Total Nuclear Generated	% of Nuclear Electricity
Illinois	97,191	53%
Pennsylvania	83,199	39%
S. Carolina	54,344	58%
Alabama	42,651	42%
N. Carolina	42,374	33%
New York	42,167	33%
Texas	38,581	9%
New Jersey	34,032	45%
Georgia	33,708	26%
Michigan	32,381	29%
Arizona	32,340	31%
Tennessee	31,817	40%
Virginia	30,533	34%
Florida	29,146	12%
California	17,901	9%

State	Total Nuclear Generated	% of Nuclear Electricity
Ohio	17,687	15%
Connecticut	16,499	48%
Louisiana	15,409	16%
Maryland	15,106	44%
Minnesota	13,904	24%
Arkansas	12,691	21%
Kansas	10,647	21%
New Hampshire	9,990	57%
Wisconsin	9,648	15%
Washington	8,128	7%
Missouri	8,304	10%
Nebraska	6,912	20%
Mississippi	7,364	12%
Massachusetts	5,047	16%
Iowa	5,213	9%

Source: DOE/EIA, Net Generation by State, Type of Producer and Energy Source—Tables for 2017 Released September 2018. Next Update: November 2019, "Monthly Nuclear Utility Generation by State and Reactor," Annual December 2017, EIA-923 and EIA-860 Reports, *https://www.eia.gov*

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. Some of the systems 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 or half 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.

The United States has two types of commercial nuclear reactors. Pressurized-water reactors are known as PWRs. They keep water 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 (BWRs), the water heated in the reactor actually boils and turns into steam, which then turns a turbine generator that produces electricity. In both types of plants, the steam is turned back into water and is used again in the process.

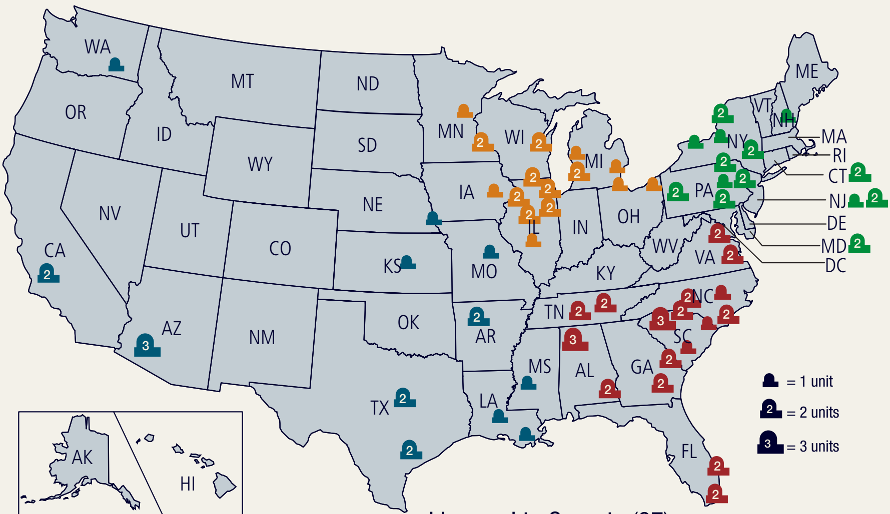
The NRC regulates commercial nuclear power plants that generate electricity. There are several operating companies and vendors and many different types of reactor designs. Of these designs, only PWRs and BWRs are currently in commercial operation in the United States. Although commercial U.S. reactors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

See Glossary for typical PWR and BWR designs.

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 such 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. Oversight includes inspectors visiting the control room and reviewing operator logbook entries, visually assessing areas of the plant, observing tests of (or repairs to) important systems or components, interacting with plant employees, and checking corrective action documents to ensure that problems have been identified and appropriate fixes implemented.

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



Licensed to Operate (97)

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
- Indian Point 2 and 3
- 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
- Three Mile Island 1

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

IOWA
- Duane Arnold

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 1

LOUISIANA
- River Bend 1
- Waterford 3

MISSISSIPPI
- Grand Gulf

MISSOURI
- Callaway

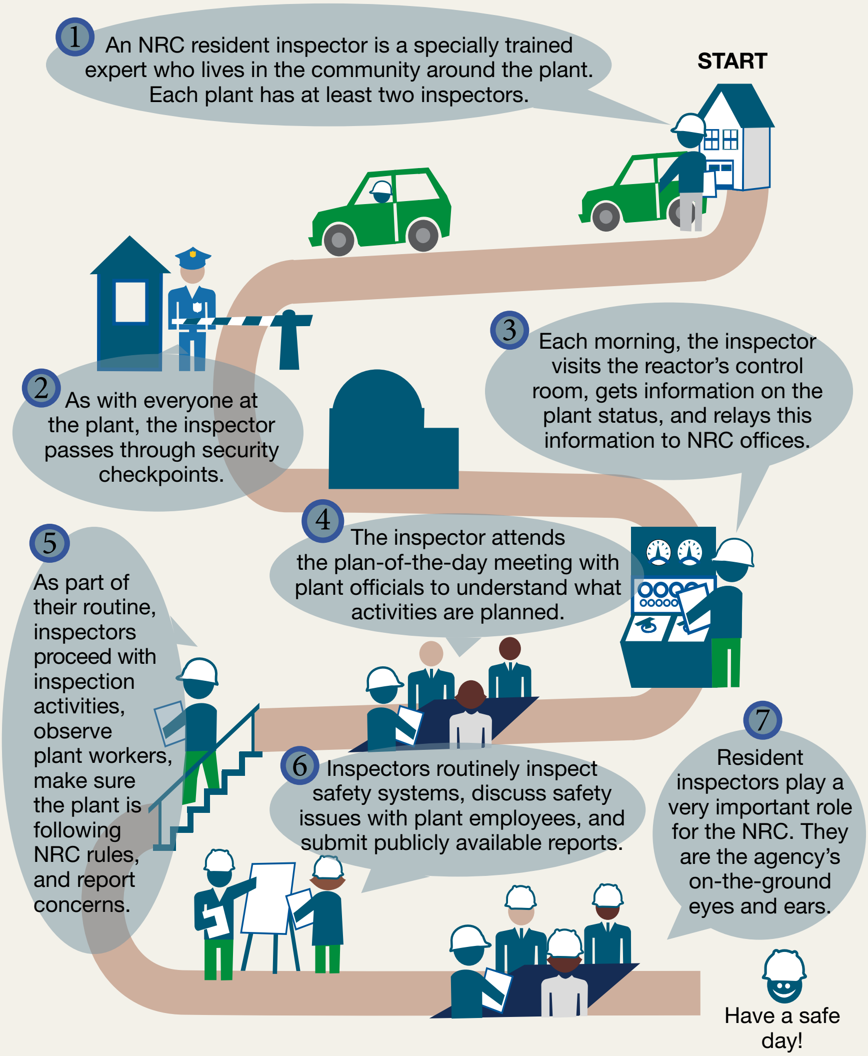
NEBRASKA
- Cooper

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

WASHINGTON
- Columbia

Note: NRC-abbreviated reactor names listed. Data are current as of July 2019. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*.

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



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

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).

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 a large-scale natural disaster, updating evaluations on the potential impact from seismic and flooding events, installing new equipment to better handle potential reactor core damage events, and strengthening emergency preparedness capabilities. Combined, these actions ensure that the nuclear industry and the NRC are prepared for the unexpected. This work will continue to ensure plants have the required resources, plans, and training (see Figure 14. NRC Post-Fukushima Safety Enhancements and the Web Link Index).

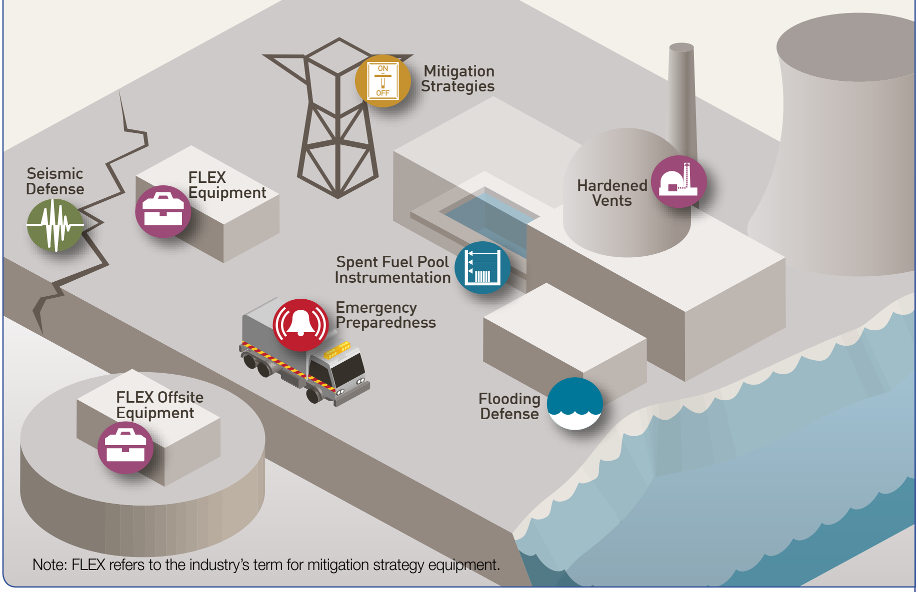
Principal Licensing, Inspection, and Enforcement Activities

See Appendix C for a list of reactors undergoing decommissioning and permanently shut down and Appendix V for a list of significant enforcement actions.

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

- reviewing separate license change requests from power reactor licensees
- performing inspection-related activities 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 distributing 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 regulations on public health and safety

Figure 14. NRC Post-Fukushima Safety Enhancements



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

The NRC Region I Deputy Administrator Ray Lorson (left), dressed in anticontamination clothing, accompanies NRC resident inspectors Brian Haagensen (middle) and Nik Floyd during a visit to New York's Indian Point nuclear plant, Unit 3. The gear was necessary to view calibrations of a submersible inspection device, which can be used to perform ultrasonic testing on hard-to-reach baffle bolts.

- investigating allegations of inadequacy or impropriety associated with NRC-regulated activities
- incorporating independent advice from the ACRS, which holds both full committee meetings and subcommittee meetings during 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 the 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, through the ROP, 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).

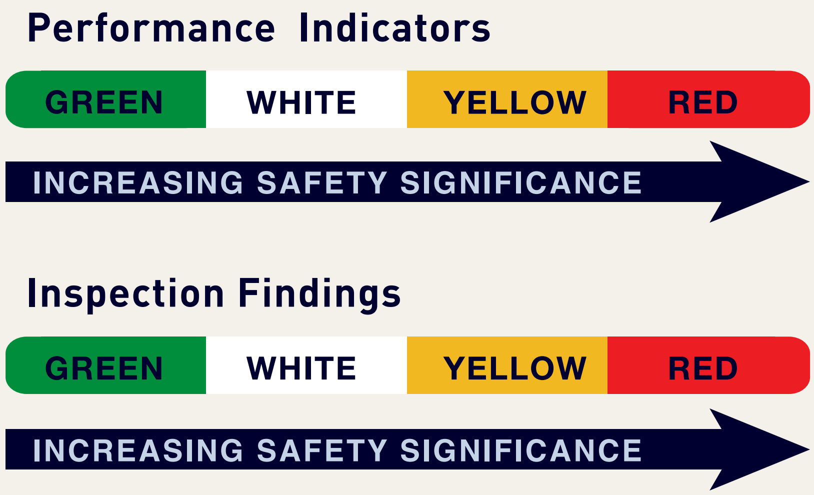


Figure 15. Reactor Oversight Action Matrix Performance Indicators

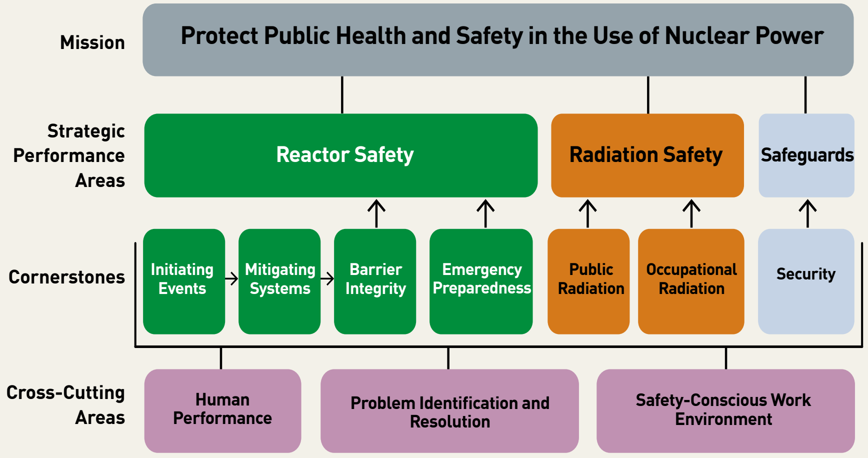


Figure 16. Reactor Oversight Framework

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 2019. 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, issued May 1996) (GEIS) 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.

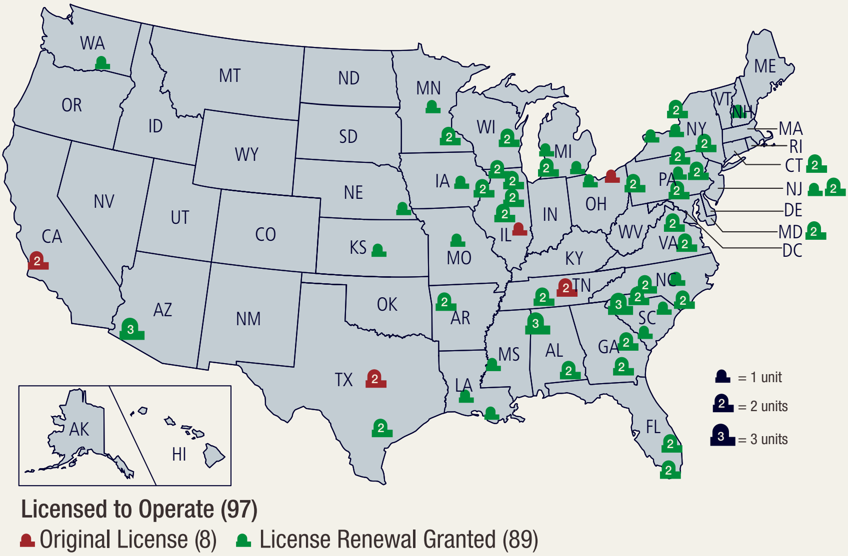
See Appendices F and G for power reactor operating licenses issued and expired by year.

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

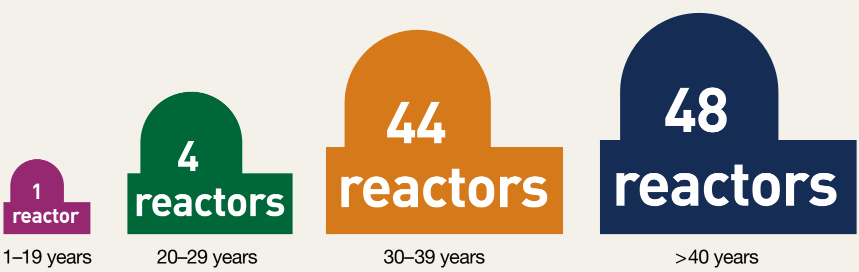
The NRC staff developed guidance and a standard review plan for "subsequent license renewals" that would allow plants to operate for more than 60 years (the 40 years of the original license plus 20 years in the initial license renewal). The Commission determined the agency's existing regulations are adequate for subsequent license renewals, but the new guidance would help licensees develop aging management programs appropriate for the 60-year to 80-year period.

Figure 17. License Renewals Granted for Operating Nuclear Power Reactors



Note: The NRC has issued a total of 94 license renewals; five of these units have permanently shut down. Data are current as of June 2019. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/.*

Figure 18. U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2019



Note: Ages are based on operating license issued date and have been rounded up to the end of the year. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/.*

Figure 19. License Renewal Process

The agency is reviewing three applications for subsequent license renewal for Turkey Point Units 3 and 4, Peach Bottom Units 2 and 3, and Surry Units 1 and 2. The NRC has also received a letter of intent for North Anna Units 1 and 2 to apply for subsequent license renewal in 2020.

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 and holds public meetings. The agency fully and publicly documents the results of its technical and environmental reviews. In addition, ACRS public meetings often discuss technical or safety issues related to reactor designs or a particular plant or site. Individuals or groups can raise legal arguments against a license renewal application in an Atomic Safety and Licensing Board (ASLB) 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.)

Research and Test Reactors

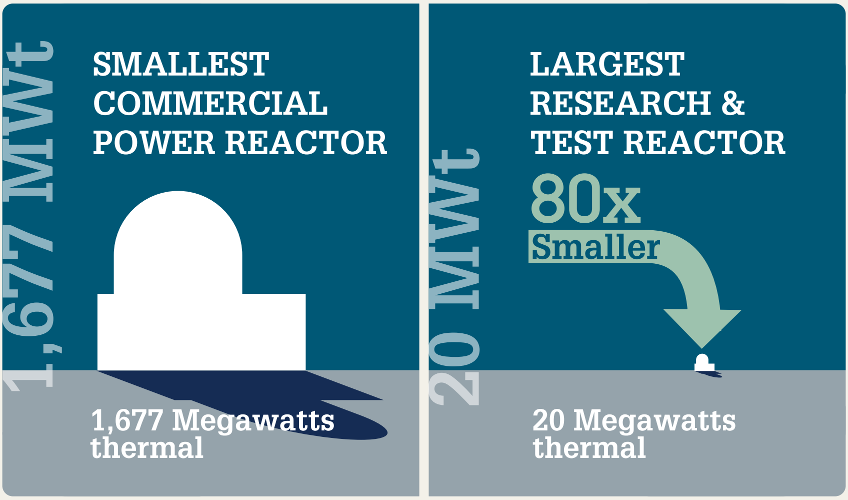
Nuclear research and test reactors (RTRs), also called "nonpower" reactors, are primarily used for research, training, and development to support science and education in nuclear engineering, physics, chemistry, biology, anthropology, medicine, materials sciences, and related fields. These reactors do 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.

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

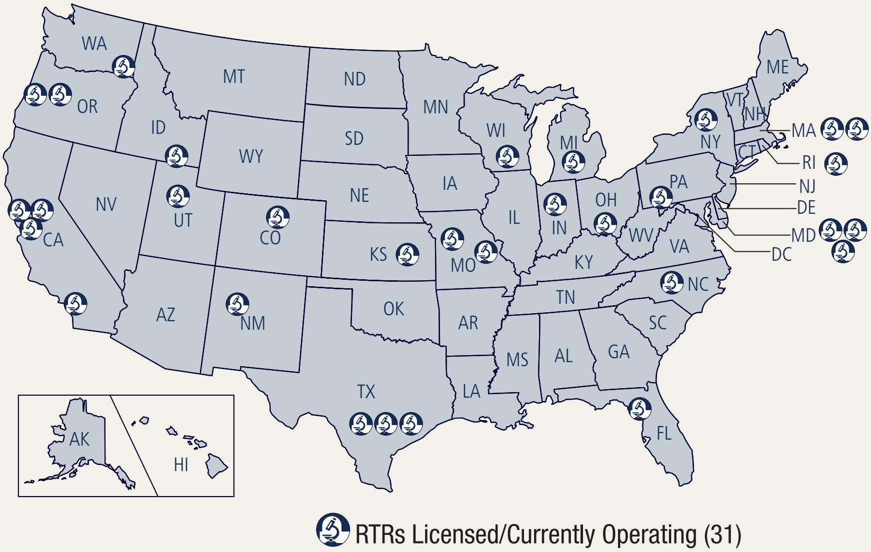
NRC inspectors visit each RTR facility about once a year to conduct varying levels of oversight. RTRs licensed to operate at 2 MWt or more receive a full NRC inspection every year. Those licensed to operate at less than 2 MWt receive a full inspection every 2 years.

Figure 20. Size Comparison of Commercial and Research Reactors



Note: Nuclear research and test reactors, also known as "nonpower" reactors, do not produce commercial electricity.

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



Note: For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*.

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

NRC staff examine control panels during a license renewal site visit at the North Carolina State University PULSTAR Research Reactor Building.

New Commercial Nuclear Power Reactor Licensing

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

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

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 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.

See Glossary for typical PWR and BWR designs.

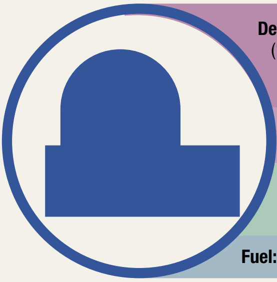
The NRC's ongoing design certification, COL, and ESP reviews are incorporating lessons learned from the Fukushima accident. The environmental impacts of continued storage of spent nuclear fuel are incorporated into each environmental review for new reactor licensing. The NRC considered these impacts 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.

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).

Figure 22. The Different NRC Classifications for Types of Reactors

Operating Reactors



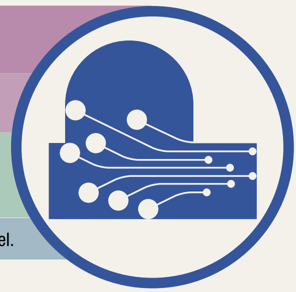
Design: The U.S. fleet consists mainly of large reactors that use regular water ("light" water, as opposed to "heavy" water that has a different type of hydrogen than commonly found in nature) for both cooling the core and facilitating the nuclear reaction.

Capacity: The generation base load of these plants is 1,500 MWt (495 MWe) or higher.

Safety: These reactors have "active" safety systems powered by alternating current (ac) and require an operator to shut down.

Fuel: These reactors require enriched uranium.

Advanced Reactors



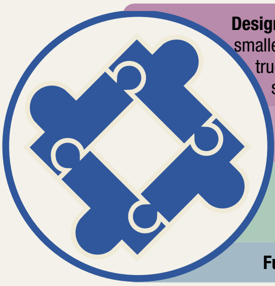
Design: Advanced reactors are a new generation of nonlight-water reactors. They use coolants including molten salts, liquid metals, and even gases such as helium.

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



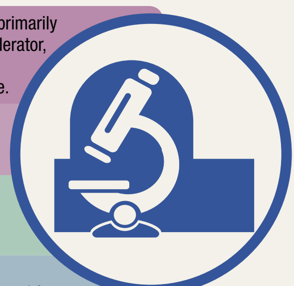
Design: Small modular reactors (SMRs) are similar to light-water reactors but are smaller, compact designs. These factory-fabricated reactors can be transported by truck or rail to a nuclear power site. Additional SMRs can be installed on site to scale or to meet increased energy needs.

Capacity: These reactors are about one-third the size of typical reactors with 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.

Figure 23. New Reactor Licensing Process

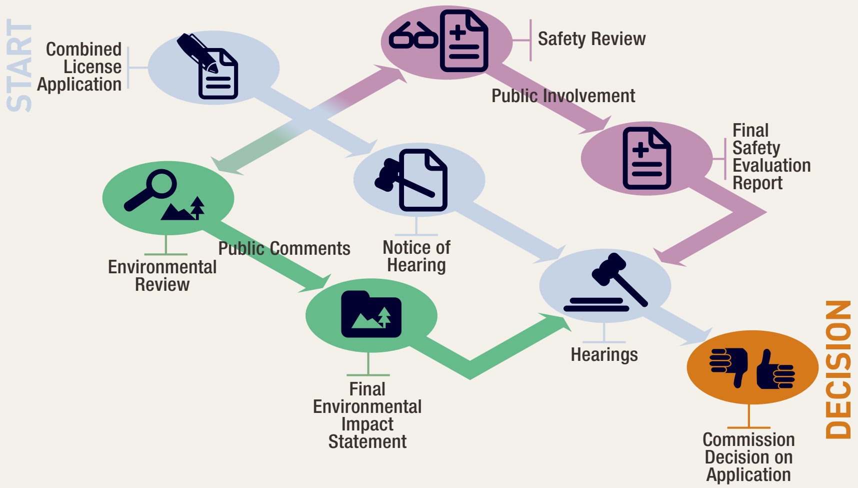
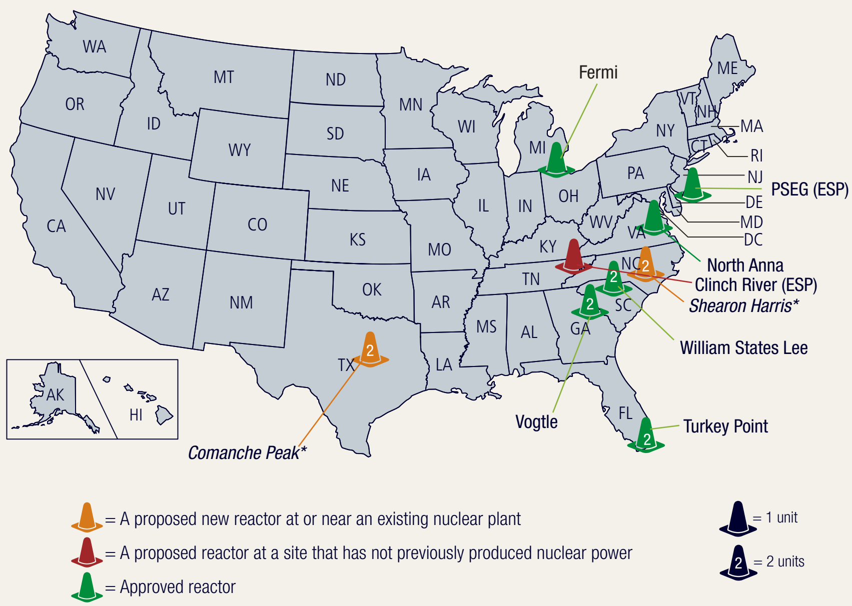


Figure 24. Locations of New Nuclear Power Reactor Applications



* *Review suspended*

Note: On July 31, 2017, South Carolina Electric & 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 listed. Data are current as of July 2019. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*.

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 the agency's 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 ASLB 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 press releases, in the *Federal Register,* and on the NRC's Web site.

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 certifications for reactor designs that meet basic requirements for ensuring safe operation. Utilities can cite a certified design when applying for a nuclear power plant COL. The certification is valid for 15 years from the date issued and can be renewed for an additional 15 years. 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)

The NRC is reviewing three applications for design certifications for the APR1400, U.S. Advanced Pressurized-Water Reactor (US-APWR), and NuScale designs.

Design Certification Renewals

The NRC is reviewing a GEH application to renew the ABWR design certification. GEH submitted its application in 2010.

Advanced Reactor Designs

Several companies are considering advanced reactor designs and technologies and are conducting preapplication activities with the NRC. These technologies 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 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 activity. 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 at NRC Region II's Center for Construction Inspection 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 of 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).

New Commercial Nonpower Production and Utilization Facility Licensing

Doctors worldwide rely on a steady supply of molybdenum-99 (Mo-99) to produce technetium-99m in hospitals, which is used in radiopharmaceuticals 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 Mo-99 production facilities submitted in accordance with the provisions of Title 10 of the *Code of Federal Regulations*. Since 2013, the NRC staff has received two construction permit applications for nonpower production and utilization facilities, from SHINE Medical Technologies, Inc. (SHINE), and Northwest Medical Isotopes, LLC. The proposed facilities would irradiate low-enriched uranium targets in utilization facilities, such as SHINE's proposed accelerator-driven subcritical operating assemblies, then separate Mo-99 from other fission products in hot cells contained within a production facility. The NRC approved the construction permits for SHINE in February 2016 and for Northwest Medical Isotopes in May 2018.

The NRC staff conducts safety and environmental reviews on these construction permit applications, which will also be the subject of both a mandatory hearing and an independent review by the ACRS. If the NRC issues these construction permits, each facility must also submit an application for, and be granted, an operating license.

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

Ahead of the issuance of any permit or license, the NRC continues to develop 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 (Mo-99) and is used in diagnostic nuclear medical imaging procedures.

Nuclear Regulatory Research

The NRC's 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:

- 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 focuses on the challenges of an evolving industry, as well as on retaining technical skills when experienced staff members retire. 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 exotic 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:

- material performance (such as environmentally assisted degradation and cracking of metallic alloys, aging management of reactor components and materials, boric-acid corrosion, radiation effects on concrete, alkali-silica reaction in concretes, 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 and accident-tolerant fuel)
- experience gained from operating reactors
- digital instrumentation and controls (such as 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 and flooding 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 $63 million research budget for FY 2019 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 2019, illustrates the primary areas of research.

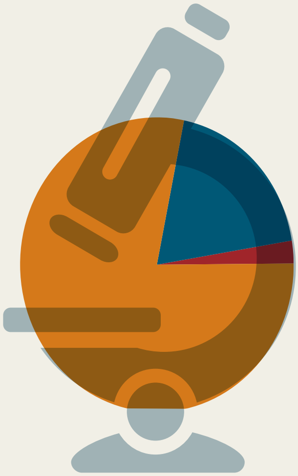
The majority of the NRC's research program supports maintaining operating reactor safety and security. The remaining research budget supports regulatory activities for new and advanced reactors, industrial and medical use of nuclear materials, and nuclear fuel cycle and radioactive waste programs. The 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 NRC's leadership role in international organizations such as the IAEA and the 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.

See Appendix U for States with Integrated University Grants Program recipients.

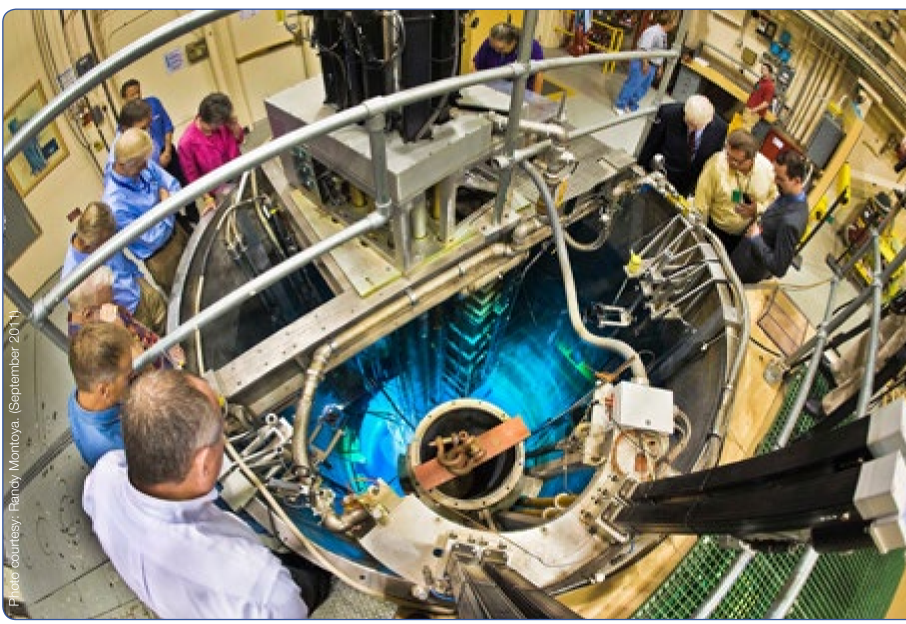
Figure 25. NRC Research Funding, FY 2019



Total $63 Million

- Reactor Program—$47 Million
- New/Advanced Reactor Licensing—$14 Million
- Materials and Waste—$2 Million

Note: Dollars are rounded to the nearest million.



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