Nuclear Reactors

U.S. Electricity Generated by Commercial Nuclear Power

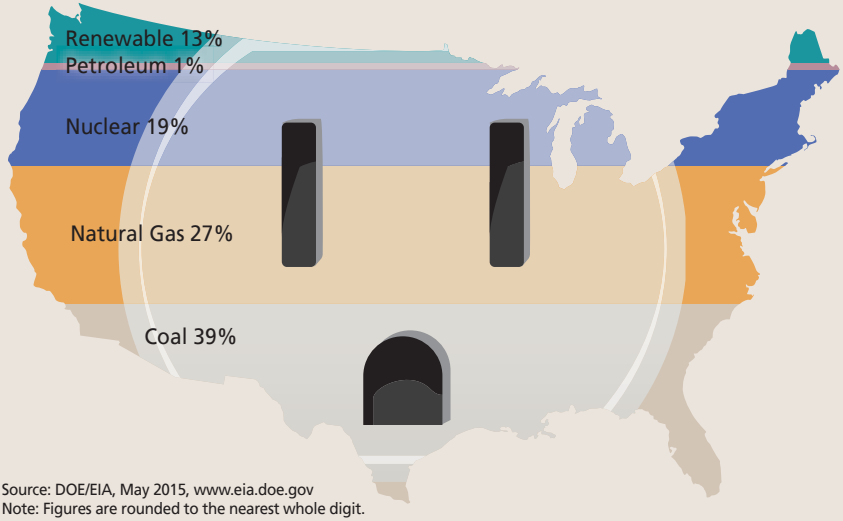
In 2014, NRC-licensed nuclear reactors generated about 19 percent of U.S. net electricity, or about 771 billion kilowatt-hours (see Figure 9: U.S. Net Electric Generation by Energy Source, 2014, and Figure 10: U.S. Net Electric Generation by Energy Source, 2004–2014).

Since the 1970s, the Nation's utilities have asked permission to generate more electricity from existing nuclear plants. By August 2014, the NRC had approved 156 of these "power uprates," resulting in an additional 7,095 MWe from existing plants. Collectively, these uprates have added the equivalent of seven new reactors' worth of electrical generation to the power grid. Licensees responding to a December 2014 NRC survey indicated that, by 2019, they planned to submit seven more power uprate applications, beyond those in review at that time. If approved, the resulting uprates would add another 580 MWe to the Nation's generating capacity (see Figure 11: Power Uprates: Past, Current, and Future).

See Glossary for information on electric power grid.

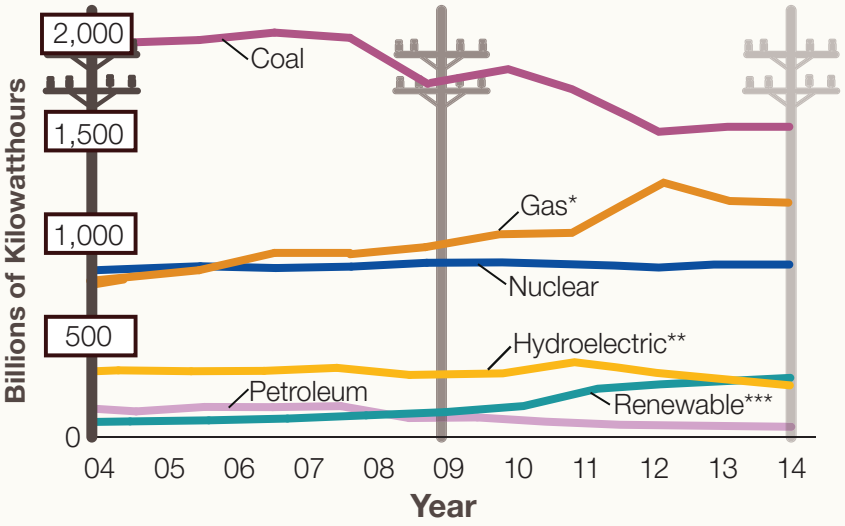
Thirty of the 50 States generate electricity from nuclear power plants. Of these States, three (New Hampshire, New Jersey, and South Carolina) generated more than 50 percent of their electricity from nuclear power last year. In addition, 11 States generated 25 to 50 percent of their electricity from nuclear power in 2013. The data cited reflect the percentages of the total net generation from nuclear sources in these States (see Figure 12: Net Electricity Generated in Each State by Nuclear Power).

Figure 9. U.S. Net Electric Generation by Energy Source, 2014



Source: DOE/EIA, May 2015, www.eia.doe.gov
Note: Figures are rounded to the nearest whole digit.

Figure 10. U.S. Net Electric Generation by Energy Source, 2004–2014



* Gas includes natural gas, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuel.
** Hydroelectric includes conventional hydroelectric and hydroelectric pumped storage.
*** Renewable energy includes geothermal, wood and nonwood waste, wind, and solar energy.
Source: DOE/EIA, May 2015, www.eia.doe.gov

Figure 11. Power Uprates: Past, Current, and Future

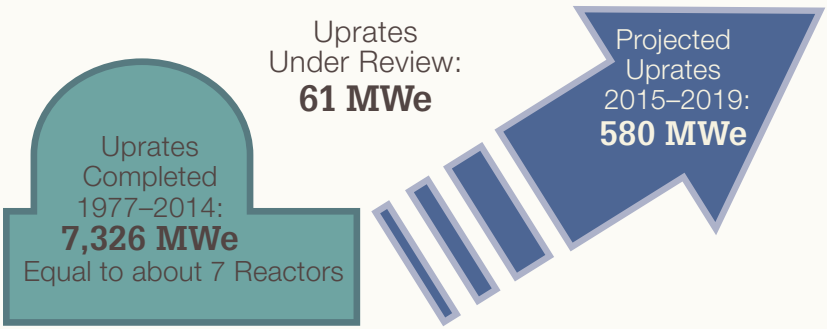
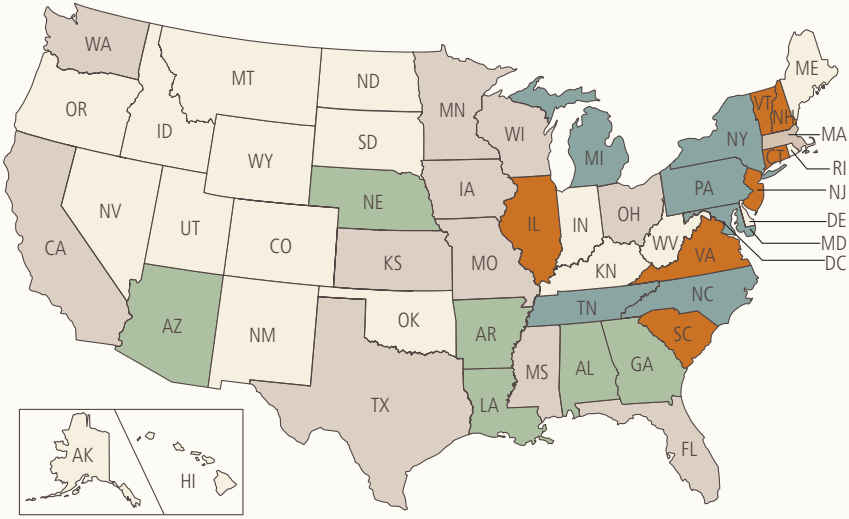


Figure 12. Net Electricity Generated in Each State by Nuclear Power

Percent of Total Nuclear Power Generated



None	1–20%	21–29%	30–39%	40+%
19 States	12 States	6 States	6 States	7 States

Total Nuclear Power Generated (in Megawatts)

Illinois	97,858 MWe	Ohio	16,284 MWe
Pennsylvania	78,715 MWe	Connecticut	15,841 MWe
S. Carolina	52,419 MWe	Arkansas	14,481 MWe
New York	43,039 MWe	Maryland	14,343 MWe
Alabama	41,244 MWe	Minnesota	12,707 MWe
N. Carolina	40,967 MWe	New Hampshire	10,168 MWe
Texas	39,287 MWe	Mississippi	10,151 MWe
Georgia	32,570 MWe	Nebraska	10,102 MWe
Arizona	32,321 MWe	Washington	9,497 MWe
New Jersey	31,507 MWe	Wisconsin	9,447 MWe
Virginia	30,221 MWe	Missouri	9,276 MWe
Michigan	31,246 MWe	Kansas	8,558 MWe
Florida	27,868 MWe	Massachusetts	5,769 MWe
Tennessee	27,670 MWe	Vermont	5,061 MWe
Louisiana	17,311 MWe	Iowa	4,152 MWe
California	16,986 MWe		

Source: DOE/EIA, "State Electricity Profiles," Data from June 2015, www.eia.doe.gov

U.S. Commercial Nuclear Power Reactors

As of August 2015, the NRC oversees 99 licensed commercial nuclear power reactors operating at 61 sites in 30 States. The Vermont Yankee nuclear power reactor permanently shut down at the end of 2014 and entered the decommissioning process.

The Nation's 99 commercial power reactors fall into several categories:

- four different reactor vendors
- 23 operating companies
- about 80 different designs
- 65 pressurized-water reactors (PWRs) and 34 boiling-water reactors (BWRs)

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

Although commercial U.S. reactors have many similarities, each one can be considered unique.

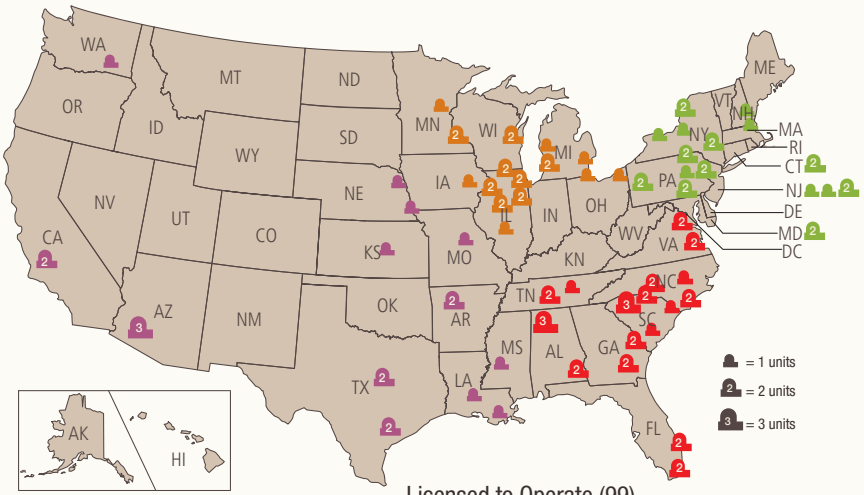
See Glossary for typical PWR and BWR design Illustrations.

Resident Inspectors

At least two NRC inspectors work full time at each nuclear power plant site to ensure the reactors are meeting NRC regulations (see Figure 13: U.S. Operating Commercial Nuclear Power Reactors and Figure 14: Day in the Life of an NRC Resident Inspector).

An NRC inspector conducts routine inspections of plant equipment to ensure the plant is meeting NRC regulations.

Figure 13. U.S. Operating Commercial Nuclear Power Reactors



Licensed to Operate (99)

REGION I

CONNECTICUT
- Millstone 2 and 3

MARYLAND
- Calvert Cliffs 1 and 2

MASSACHUSETTS
- Pilgrim

NEW HAMPSHIRE
- Seabrook

NEW JERSEY
- Hope Creek
- Oyster 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
- Edwin I. 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

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

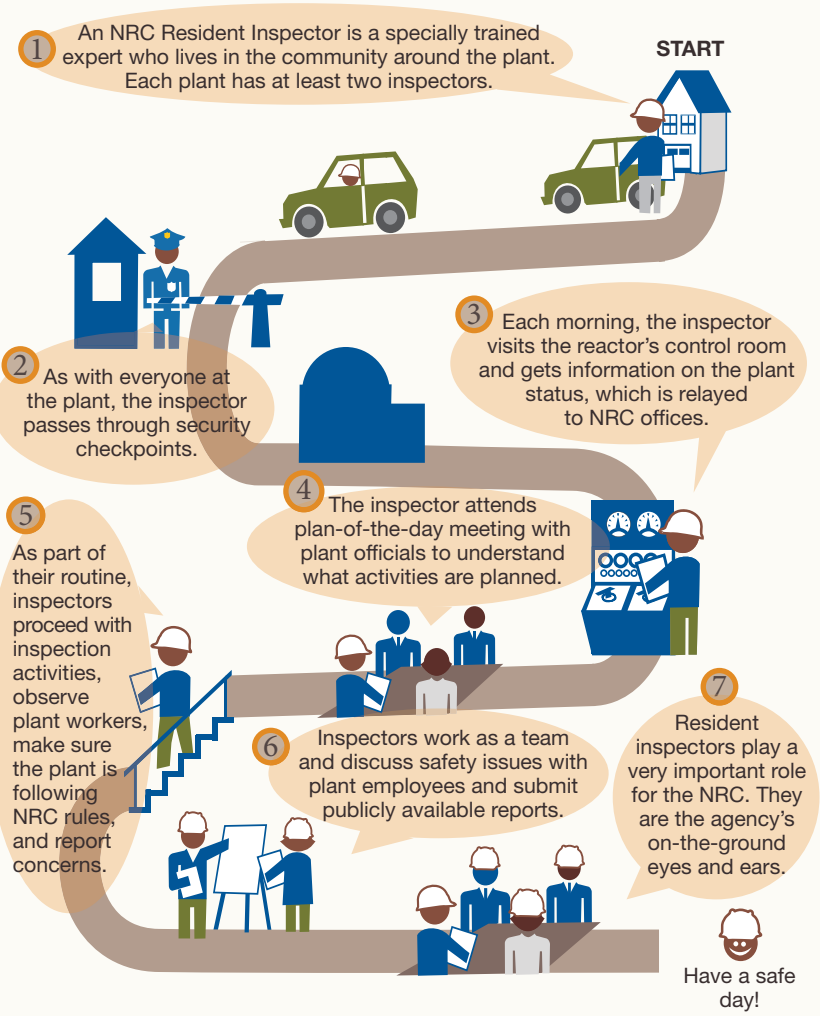
NEBRASKA
- Cooper
- Fort Calhoun

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

WASHINGTON
- Columbia

NRC-abbreviated reactor names listed

Figure 14. Day in the Life of an NRC Resident Inspector



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

Japan Lessons Learned

A few months after Japan's Fukushima Dai-ichi nuclear accident in March 2011, an NRC task force issued several recommendations for enhancing safety at U.S. nuclear plants. Approximately 55 full-time NRC employees work with experts from across the agency to act on what the NRC learned from the events at Fukushima. A steering committee of senior NRC managers directs these activities.

The NRC developed and issued three orders in March 2012, requiring U.S. reactors to:

- obtain and protect additional emergency equipment, such as pumps and generators, to support all reactors at a given site simultaneously following a natural disaster
- install enhanced equipment for monitoring water levels in each plant's spent fuel pool
- improve and install emergency venting systems that can relieve accident pressure at reactors with designs similar to the Fukushima plant (additional NRC venting requirements added in June 2013)

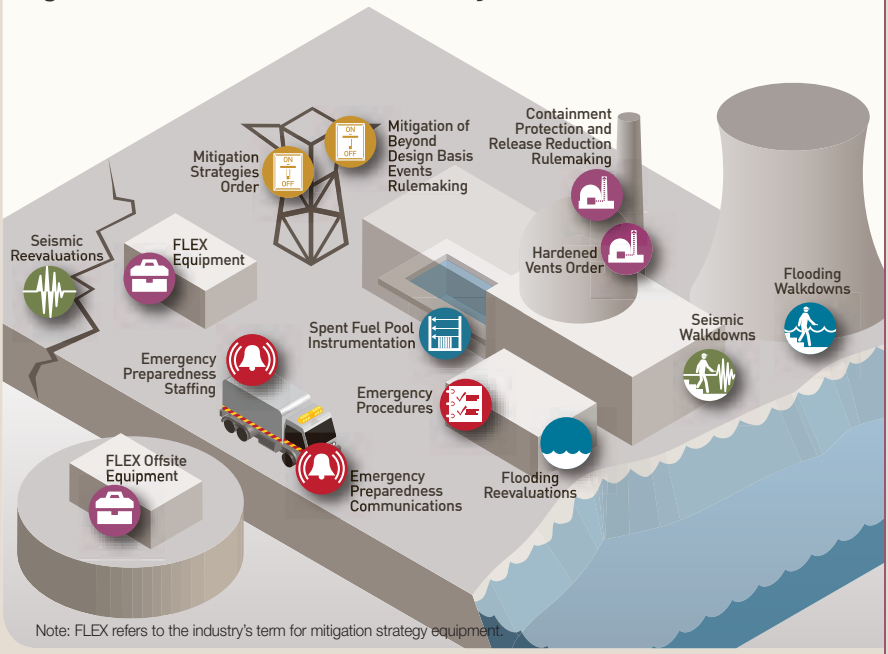
The Japan Lessons-Learned efforts included detailed seismic and flooding inspections (called walkdowns) to reaffirm plants' existing abilities to withstand earthquakes and flooding. The NRC has been receiving and analyzing information from all U.S. reactors related to earthquake and flooding hazards. The agency is also working on new or revised post-Fukushima rules related to filtering radioactive material after an accident, maintaining key safety functions in an extended power blackout situation, and improving several aspects of emergency preparedness (see Figure 15: NRC Post-Fukushima Safety Enhancements).

Principal Licensing, Inspection, and Enforcement Activities

The NRC's commercial reactor licensing and inspection activities in 2014 included:

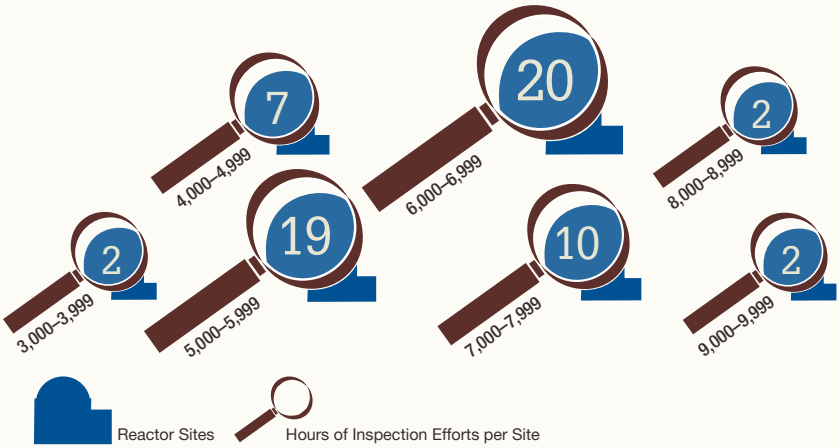
- reviewing the Tennessee Valley Authority's operating license application for the Watts Bar Unit 2 reactor, now under construction near Spring City, TN
- reviewing 670 separate license change requests from power reactor licensees in FY 2014, which averages about seven reviews per licensee
- spending an average of 6,326 hours performing inspection-related activities at each operating reactor site (see Figure 16: NRC Inspection Effort at Operating Reactors, 2014)

Figure 15. NRC Post-Fukushima Safety Enhancements



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

Figure 16. NRC Inspection Effort at Operating Reactors, 2014



Note: Data include calendar year (CY) 2014 hours for all activities related to baseline, plant-specific, generic safety issue, and allegation inspections.

- ensuring the qualifications of approximately 4,600 NRC-licensed reactor operators who must requalify every 2 years and ask the NRC to renew their license every 6 years
- reviewing 7 applications for proposed 11 new reactors
- inspecting construction activities at three U.S. sites
- reviewing approximately 3,000 operating experience items each year and distributing lessons learned that could help licensed facilities operate more effectively
- issuing about 36 notices of violation, civil penalties, or orders to operating reactors for significant violations of NRC regulations regarding public health and safety
- investigating approximately 500 allegations of inadequacy or impropriety associated with NRC-regulated activities
- incorporating independent advice from the ACRS, which held 10 full Committee meetings and approximately 47 subcommittee meetings during FY 2014 to examine potential safety issues for existing or proposed reactors

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

An NRC inspector conducts routine inspections of plant equipment to ensure the plant is meeting NRC regulations.

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.

See Appendix I for a list of Industry Performance Indicators: Averages for FYs 2005–2014.)

The NRC staff uses the ROP to evaluate NRC inspection findings and performance records for each reactor and uses 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 17: 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 30 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 5, "Reactor Oversight Process," issued February 2014 (see Figure 18: Reactor Oversight Framework). In addition to evaluating individual plant performance, the NRC compiles data on overall nuclear industry performance using industry-level statistics.

Figure 17. Reactor Oversight Action Matrix Performance Indicators

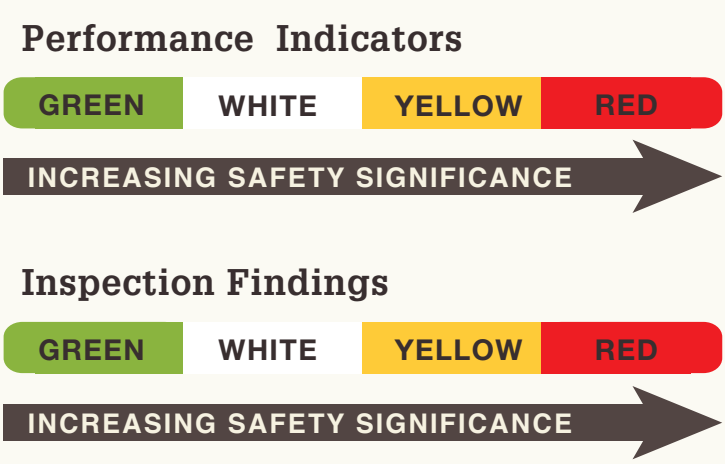
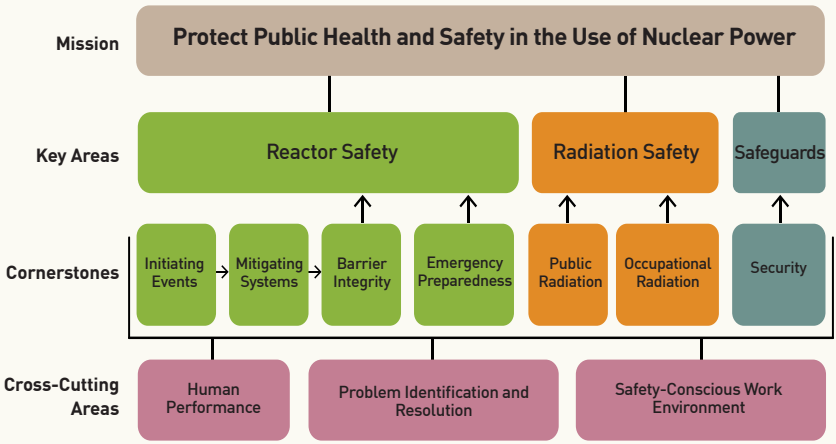


Figure 18. Reactor Oversight Framework



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.

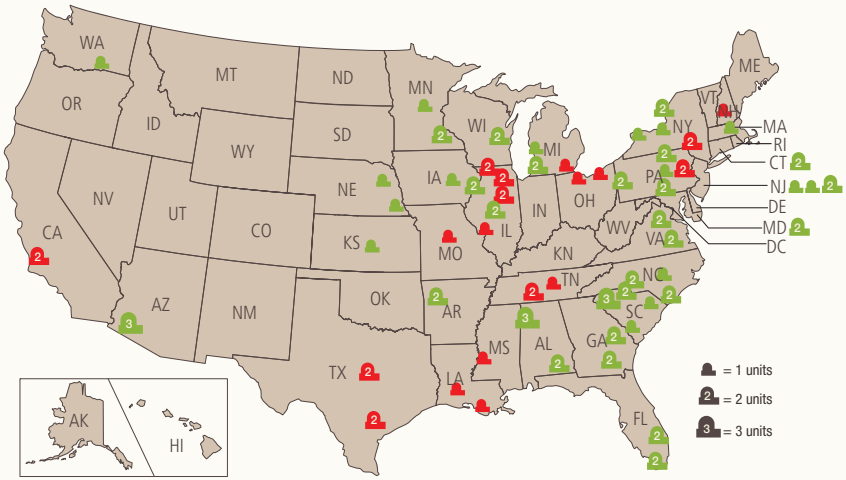
See Appendices G and H for power reactor operating licenses issued and expired by year.

As of June 2015, 74 operating reactors (at 43 sites) have received renewed licenses (see Figure 19: License Renewals Granted for Operating Nuclear Power Reactors). To see current reactors grouped by how long they have operated, see Figure 20: U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2015. To see reactors listed by license expiration dates, see Figure 21: U.S. Commercial Nuclear Power Reactor Operating Licenses—Expiration by Year. 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.

The NRC's license renewal reviews determine whether a plant can continue to operate safely beyond 40 years. The NRC reviews renewal applications for both safety issues and environmental impacts (see Figure 22: License Renewal Process). A plant owner must evaluate how the plant will address aging of plant systems not already covered by NRC inspection and maintenance rules. The plant owner must also report on the potential environmental impacts if the plant operates for up to an additional 20 years. The regulations are contained in 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," while the NRC's environmental review requirements for license renewal are found in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." If the NRC concludes extended operation will be safe, the staff verifies that safety evaluation through onsite inspections as the plant continues to operate.

The NRC considered the environmental impacts of the continued storage of spent nuclear fuel during rulemaking activities in 2013–2014. The Commission published its final Continued Storage Rule and supporting generic environmental impact statement in September 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. The Continued Storage Rule is discussed in more detail in Section 5.

Figure 19. License Renewals Granted for Operating Nuclear Power Reactors



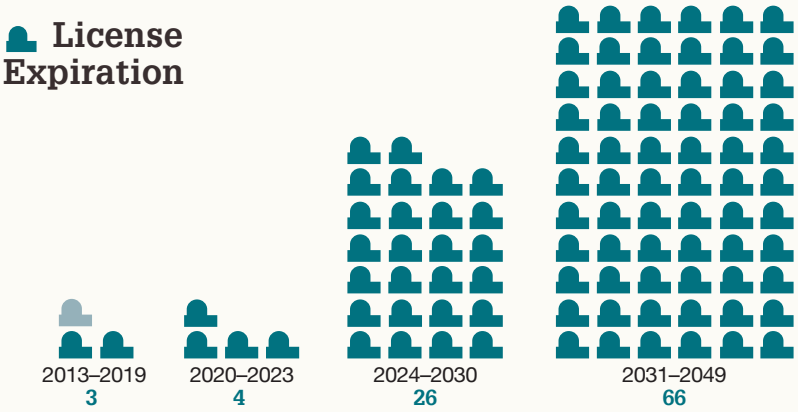
Licensed to Operate (99)

Original License (25) License Renewal Granted (74)

Figure 20. U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2015

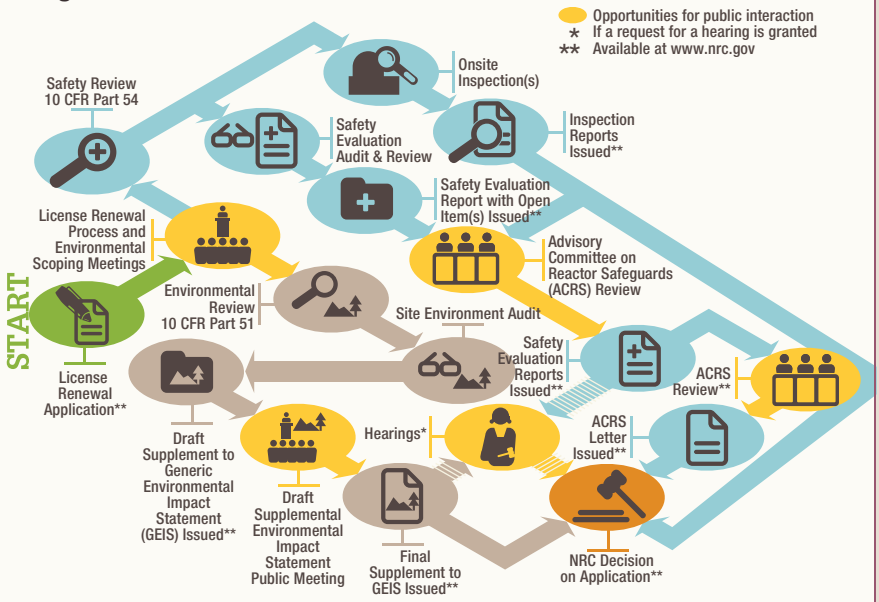
Note: Ages have been rounded up to the end of the year.

Figure 21. U.S. Commercial Nuclear Power Reactor Operating Licenses—Expiration by Year



Indicates Indian Point 2, which entered timely renewal on Sept. 29, 2013.

Figure 22. License Renewal Process



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. They can also discuss how aging will be managed if a plant operates beyond 40 years. 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) support science and education in nuclear engineering, physics, chemistry, biology, anthropology, medicine, materials sciences, and related fields. These reactors do not produce electricity. The largest U.S. RTR (which produces 20 megawatts thermal [MWt]) is 75 times smaller than the smallest U.S. commercial power nuclear reactor (which produces 1,500 MWt). There are 36 licensed RTRs:

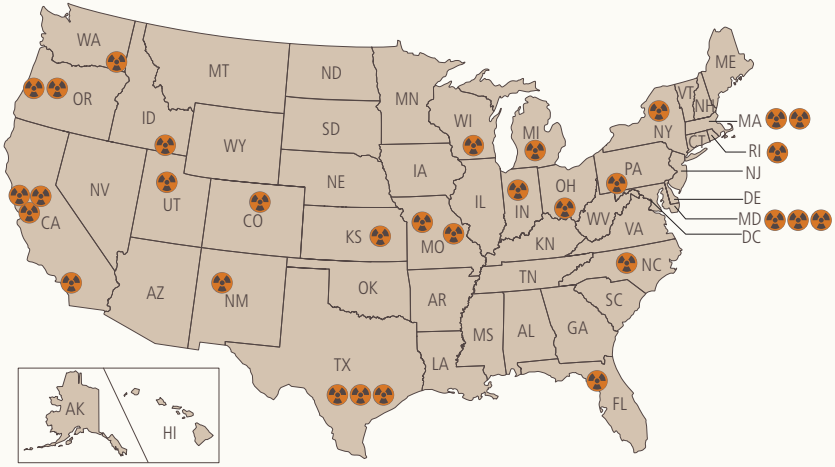
- 31 RTRs operating in 21 States (see Figure 23: U.S. Nuclear Research and Test Reactors)
- five RTRs shut down and are in various stages of decommissioning

NRC inspectors visit each RTR facility at least once a year to conduct varying levels of oversight. RTRs licensed to produce 2 MWt or more receive a full NRC inspection every year. RTRs licensed to produce less than 2 MWt receive a full inspection every 2 years. Since 1958, 86 licensed RTRs have been decommissioned.

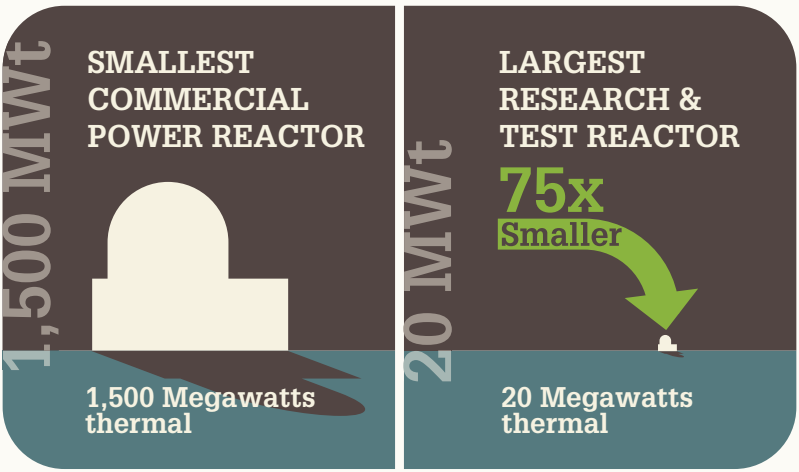
Photo courtesy Oregon State University

University students conduct experiments at the Advanced Plant Experimental Facility.

Figure 23. U.S. Nuclear Research and Test Reactors



RTRs Licensed/Currently Operating (31)



Principal Licensing and Inspection Activities

The NRC's RTR licensing and inspection activities include:

- licensing the 31 operating sites, including license renewals and license amendments
- overseeing decommissioning
- licensing approximately 100 operators
- overseeing operator relicensing programs
- overseeing security programs
- conducting approximately 50 inspections each year, based on inspection frequency and procedures for operating RTRs

See Appendices J and K for a list of research and test reactors regulated by the NRC that are operating or are in the process of decommissioning.

New Commercial Nonpower Production and Utilization Facility Licensing

Doctors worldwide rely on a steady supply of molybdenum-99 (Mo-99), which is used 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.

A supply of molybdenum-99 (Mo-99) which is used in medical diagnostic procedures.

The NRC staff will conduct 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 Advisory Committee on Reactor Safeguards. 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 interactions with the White House Office of Science and Technology Policy Mo-99 Interagency Working Group.

New Commercial Nuclear Power Reactor Licensing

The NRC's current review of new power reactor license applications improves on the process used through the 1990s (see Figure 24: New Reactor Licensing Process). In early 2012, the NRC issued the first combined construction permit and operating license (called a combined license or COL) under the new licensing process. In April 2015, the NRC issued a COL for the Fermi site in Michigan.

The NRC will continue reviewing six additional COL applications (which would authorize 10 new reactors) over the next several years (see Figure 25: Locations of New Nuclear Power Reactor Applications, and the Web Link Index). The NRC's ongoing design certification, COL, and early site permit (ESP) reviews are incorporating lessons learned from the Fukushima accident.

The NRC considered the environmental impacts of the continued storage of spent nuclear fuel during rulemaking activities in 2013–2014. The Commission published its final Continued Storage Rule and supporting generic environmental impact statement in September 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 new reactor licensing. The Continued Storage Rule is discussed in more detail in Section 5.

Combined License Applications—Construction and Operating

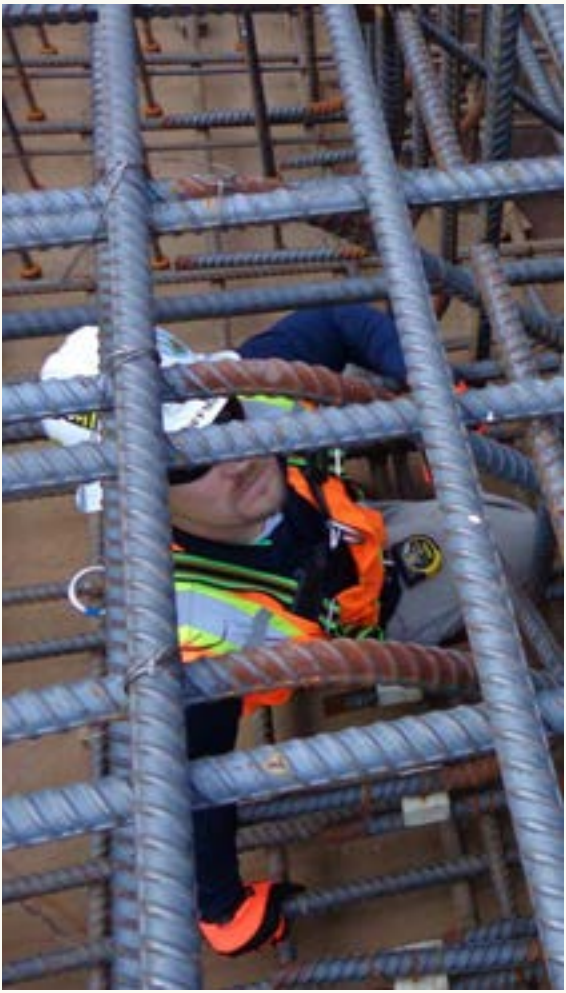
The NRC has issued COLs for five reactors at Vogtle, V.C. Summer and Fermi and as of June 2015 is currently reviewing six applications for the total of ten reactors.

See Appendix B: List of the U.S. New Nuclear Power Plant Licensing Applications.

- South Texas Project (TX)
- North Anna (VA)
- William States Lee III (SC)
- Levy County (FL)
- Bell Bend (PA)
- Turkey Point (FL)

Since June 2007, the NRC has received 18 COL applications for 28 new reactor units. The NRC suspended or cancelled nine COL application reviews at the request of the applicants, due to changes to their business plans (Calvert Cliffs, Grand Gulf, Callaway, Nine Mile Point, River Bend, Shearon Harris, Victoria County Station, Bellefonte, and Comanche Peak).

For the current review schedule for the active licensing applications, consult the NRC's public Web site (see the Web Link Index).



A construction resident inspector inspects inside the containment vessel of Vogtle Unit 3 in Georgia.

Figure 24. New Reactor Licensing Process

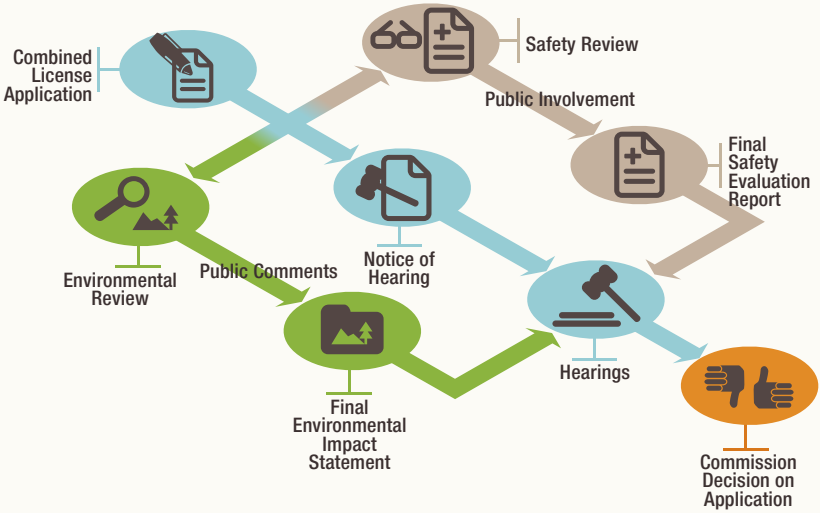
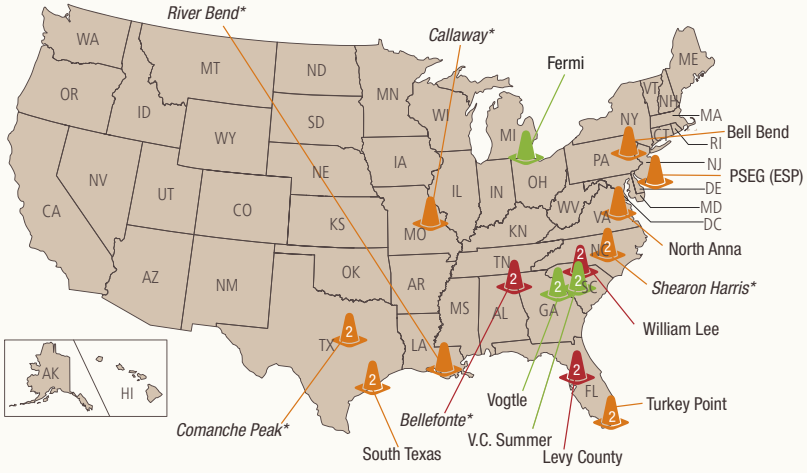


Figure 25. Locations of New Nuclear Power Reactor Applications



** Review suspended*

Note: Data is as of June 2015. Withdraw was requested for Calvert Cliffs, Grand Gulf, Nine Mile Point, and Victoria County (COL and ESP). NRC-abbreviated reactor names listed

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 in the process. After the application is submitted, the NRC asks the public to comment on which factors should be considered in the agency's environmental review conducted 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.

NRC staff members provide information about the agency's role and mission, and the performance of area nuclear power plants at public meetings.

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.

The NRC has issued ESPs to:

- System Energy Resources, Inc. (Entergy), for the Grand Gulf site in Mississippi
- Exelon Generation Company, LLC, for the Clinton site in Illinois
- Dominion Nuclear North Anna, LLC, for the North Anna site in Virginia
- Southern Nuclear Operating Company, for the Vogtle site in Georgia

The NRC is currently reviewing an ESP application submitted in May 2010 for a site located near the Hope Creek/Salem operating reactors in New Jersey. The NRC expects to receive one additional ESP application in 2016.

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 five certified designs are:

- General Electric-Hitachi (GEH) Nuclear Energy's Advanced Boiling-Water Reactor (ABWR)
- Westinghouse's System 80+
- Westinghouse's AP600
- Westinghouse's amended AP1000
- GEH's Economic Simplified Boiling-Water Reactor

The NRC is reviewing Korea Hydro Nuclear Power's APR1400 design.

Design Certification Renewals

The NRC is reviewing applications from GEH and Toshiba to renew the ABWR design certification. The companies submitted the applications in 2010.

Advanced Reactor Designs

Several companies are considering advanced reactor designs and technologies and are conducting preapplication activities with the NRC. These technologies include light-water reactors a fraction of the size of today's designs. Other potential reactor designs are cooled by liquid metals or high-temperature gas. The NRC's advanced reactor efforts will ensure the agency has the resources and expertise to address these new technologies. While developing the regulatory framework for advanced reactor licensing, the NRC is also examining policy issues in areas such as security and emergency preparedness.

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 a licensee has completed required inspections, tests and analyses, and met associated acceptance criteria.

In February 2012, the NRC issued COLs to Southern Nuclear Operating Company for Vogtle, Units 3 and 4. In March 2012, the NRC issued COLs to South Carolina Electric and Gas for V.C. Summer, Units 2 and 3. The NRC's onsite resident construction inspectors at both Vogtle and V.C. Summer oversee day-to-day licensee and contractor activities. In addition, specialists at the 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 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).

Photo courtesy of Southern Nuclear Operating Company

NRC Chairman Stephen Burns (center) and NRC Regional Administrator Victor McCree (left) listen as NRC construction inspector Justin Fuller points out a feature of the new reactor construction at the Vogtle plant near Augusta, GA.

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, cooled by high-temperature gases or liquid metals. The NRC's research programs examine a broad range of subjects, such as:

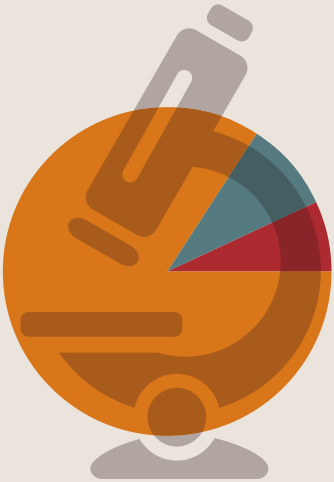
- material performance (such as environmentally assisted degradation and cracking of metallic alloys, aging management of reactor components and materials, boric-acid corrosion, radiation effects on concrete, alkali-silica reaction in concretes, the use of high-density polyethylene material for buried piping, 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—some of this research involves NRC-developed and approved computer codes (the codes use modern hardware, software, and plant data for the most realistic simulations. Additionally, computer codes are used to analyze fire conditions in nuclear facilities, examine how reactor fuel performs, and assess nuclear power plant risk)
- new and evolving technologies (such as the performance of mixed uranium-plutonium, computerized instrumentation and control, and safety-critical software)
- 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
- equipment performance under extreme conditions (e.g., heat, radiation, or humidity)
- ultrasonic testing (UT) and other nondestructive means of inspecting reactor components and dry cask storage systems; developing and accessing UT 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.

The NRC's research program involves about 6 percent of the agency's personnel and uses about 14 percent of its contracting funds. The NRC's $55.2 million research budget for FY 2015 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 26: NRC Research Funding, FY 2015, illustrates the primary areas of research. Approximately 84 percent 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

Figure 26. NRC Research Funding, FY 2015



Total $55.2 Million

- Reactor Program—$46.2 M
- New/Advanced Reactor Licensing—$4.9 M
- Materials and Waste—$3.7 M

Note: Totals may not equal sum of components because of independent rounding.

fuel cycle and radioactive waste programs. The NRC cooperates with universities and nonprofit organizations on research for the agency's specific interests.

See Appendix V for a list of the NRC's cooperative research agreements.

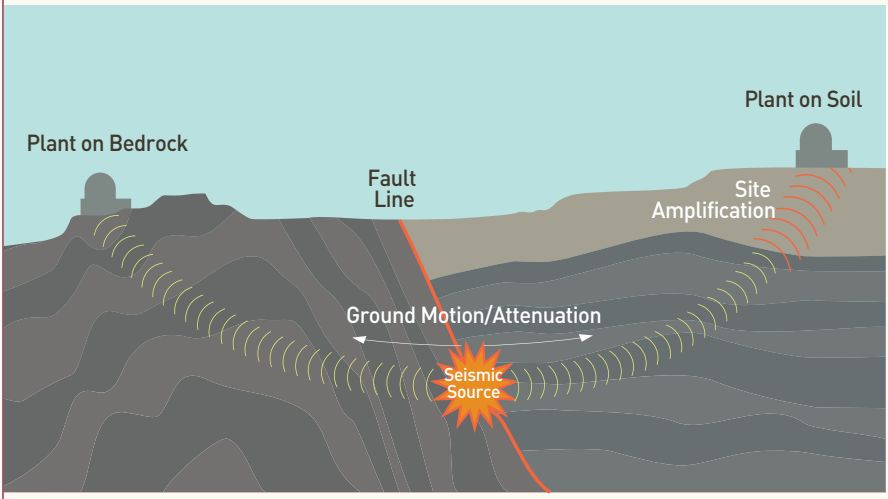
NRC's collaboration with the U.S. Department of Energy and the Electric Power Research Institute created a new seismic source characterization model for the Central and Eastern United States (CEUS), as well as development of a ground motion attenuation model for the CEUS. Other ongoing activities include enhancing software to perform seismic hazard calculations using the model and the latest ground motion attenuation relationships. The collaboration is also developing software to improve modeling of local site amplification of ground motion, as well as further guidance on the treatment of uncertainty and the use of experts in hazard assessment. All this work estimates the likelihood of various levels of earthquake-caused ground motions. It supports both new nuclear facility licensing and reanalysis of existing reactors east of the Rockies, as part of the NRC's lessons learned from the 2011 Fukushima nuclear accident in Japan.

NRC research activities also support regulatory activities. For example, the NRC completed the Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling-Water Reactor, also referred to as the Spent Fuel Pool Study. This study examined whether faster transfer of older, colder spent fuel from the pool to dry cask storage significantly reduces risks to public health and safety. The study concluded that existing

The NRC delegation listens to Naohiro Masuda, former Fukushima Dai-ni Superintendent, explain the events of March 11, 2011.

protective actions would limit any public radiation doses and keep long-term cancer fatality risk low for the scenarios studied. The NRC continues to conclude that the available evidence shows spent fuel pools adequately protect public health and safety. The insights from this analysis informed a broader regulatory analysis of the spent fuel pools at U.S. nuclear reactors as part of the Japan lessons-learned Tier 3 plan. The final report incorporated comments from the public and was published as NUREG-2161 in September 2014.

NRC research also informs the public. NUREG-1935, The State-of-the-Art Reactor Consequence Analyses (SOARCA) project, examined potential severe accidents at two pilot plants and concluded that populations near the plants would see only a very small increase in fatal cancer risk if the analyzed, but unlikely, accidents occurred. The SOARCA project, NUREG/CR-7155, "Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station", corroborated that plant's results in NUREG-1935. A study to quantify the uncertainty of parameters used in the Surry SOARCA analysis is underway. Another SOARCA analysis is reviewing for the Sequoyah Nuclear Plant's "ice condenser" type of containment. This study will build on the knowledge gained from the previous work to determine the effects of severe accidents on this type of containment and quantify the effectiveness of new accident mitigation techniques that have been put in place since the previous study was performed.



The NRC requires all of its licensees to take seismic activity into account when designing and maintaining their nuclear power plants. When new seismic hazard information becomes available, the NRC evaluates the new data and models and determines if any changes are needed at plants.

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 Nuclear Energy Agency helps guide the agency's collaborations.

The NRC maintains more than 100 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. Examples of agreements include:

- the NRC's Program on Steam Generator Tube Integrity involving regulators and researchers from five foreign nations
- more than 25 agreements with foreign regulators and research organizations for participation in the NRC's Code Applications and Maintenance Program

See the Web Link Index for more information on specific NRC research projects and activities.

Photo courtesy Oregon State University

Universities and other academic institutions use nuclear materials in laboratory experiments while conducting research.