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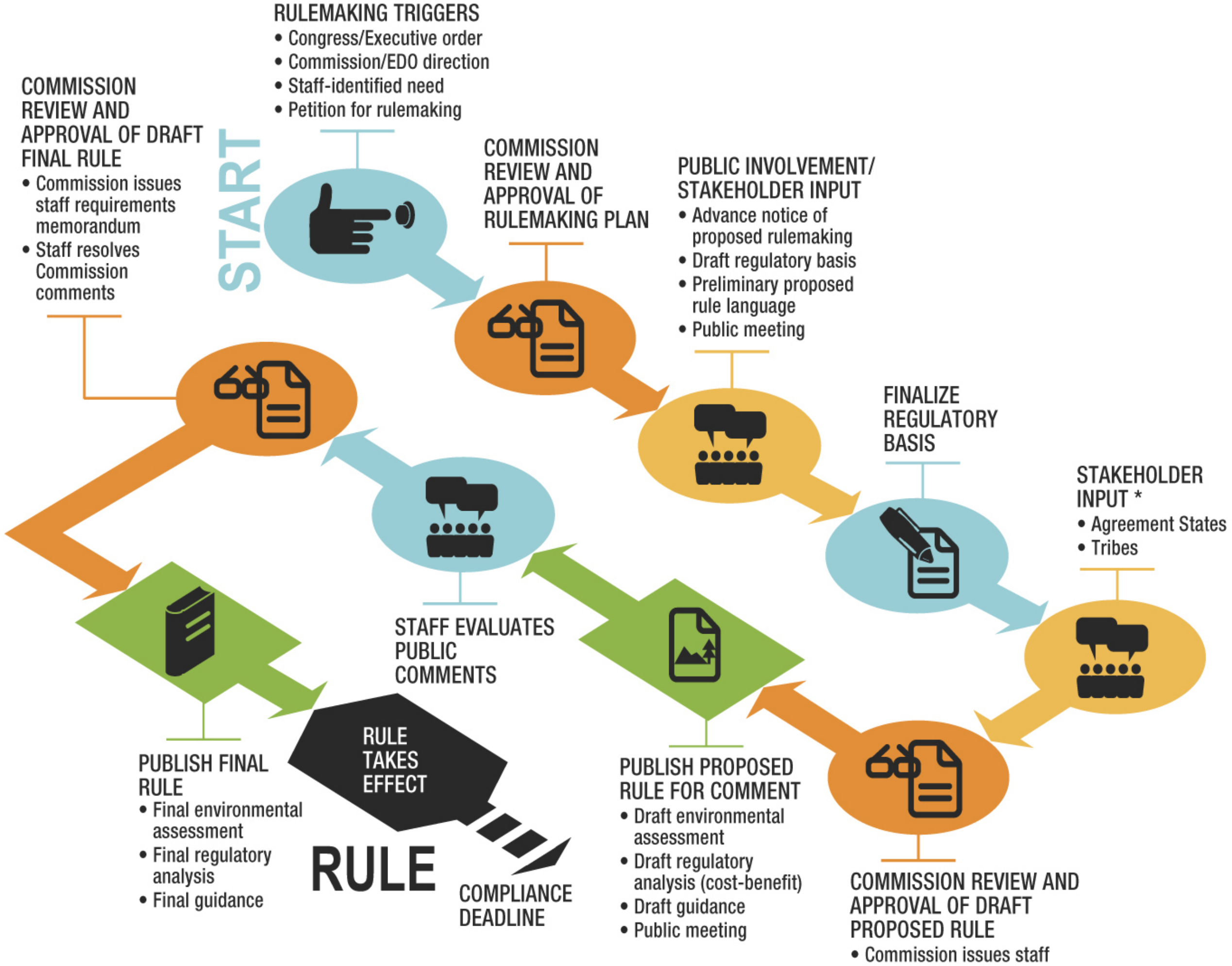
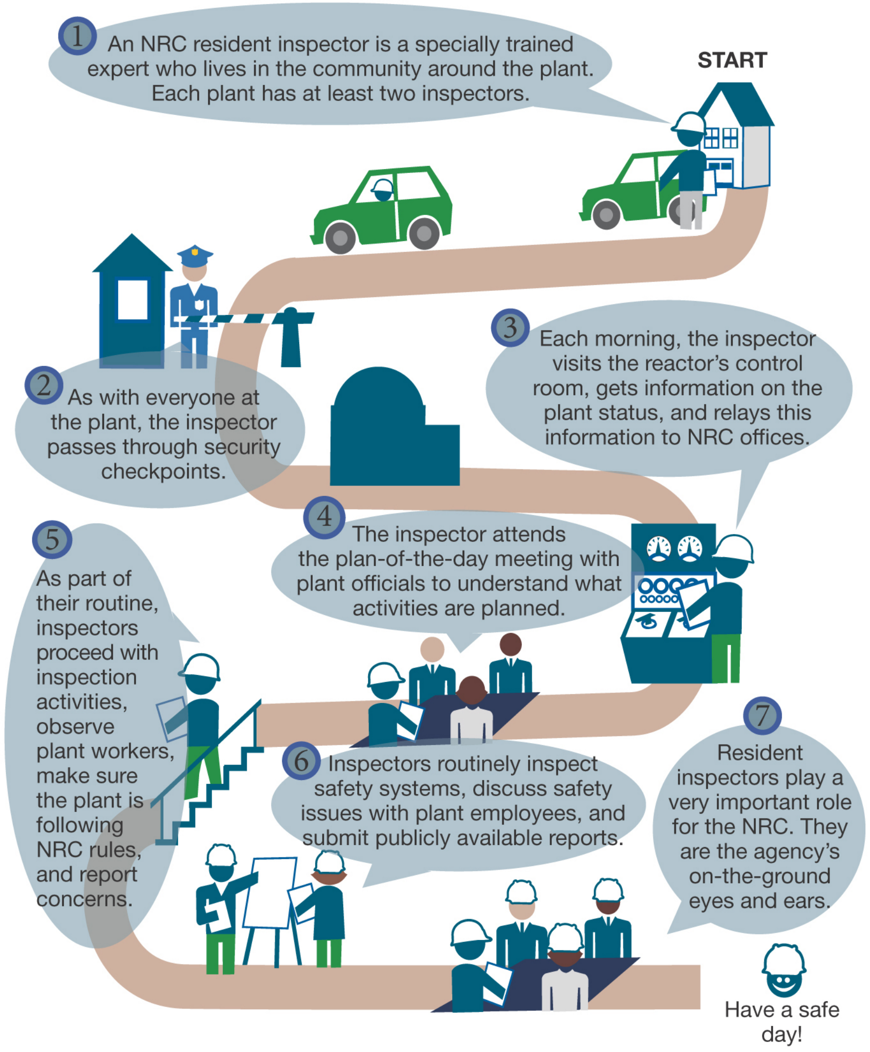
# A Typical Rulemaking Process




* Stakeholder input occurs for materials-related rulemaking and other activities as needed.

As of August 2019

## 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.*

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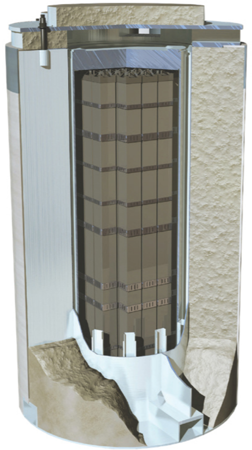
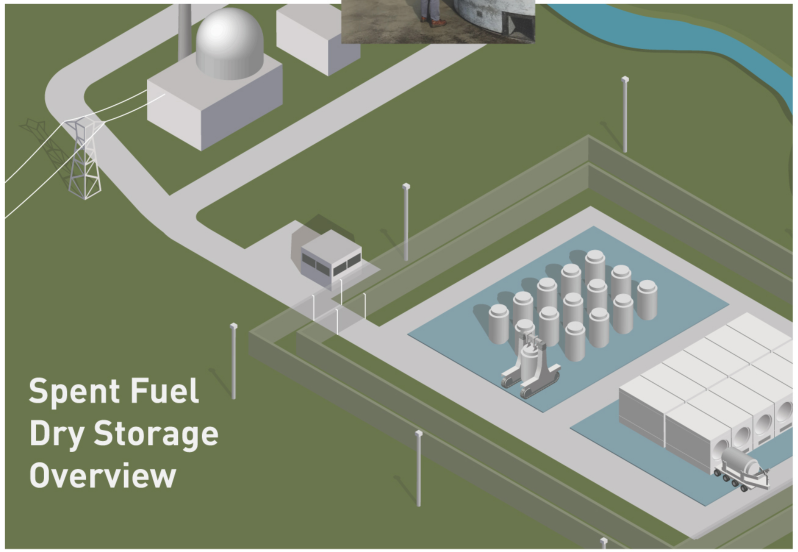
## Dry Storage of Spent Nuclear Fuel

At nuclear reactors across the country, spent fuel is kept on site, typically above ground, in systems basically similar to the ones shown here. The NRC reviews and approves the designs of these spent fuel storage systems before they can be used.

1 Once the spent fuel has sufficiently cooled, it is loaded into special canisters that are designed to hold nuclear fuel assemblies. Water and air are removed. The canister is filled with inert gas, welded shut, and rigorously tested for leaks. It is then placed in a cask for storage or transportation. The dry casks are then loaded onto concrete pads.



2 The canisters can also be stored in aboveground concrete bunkers, each of which is about the size of a one-car garage.



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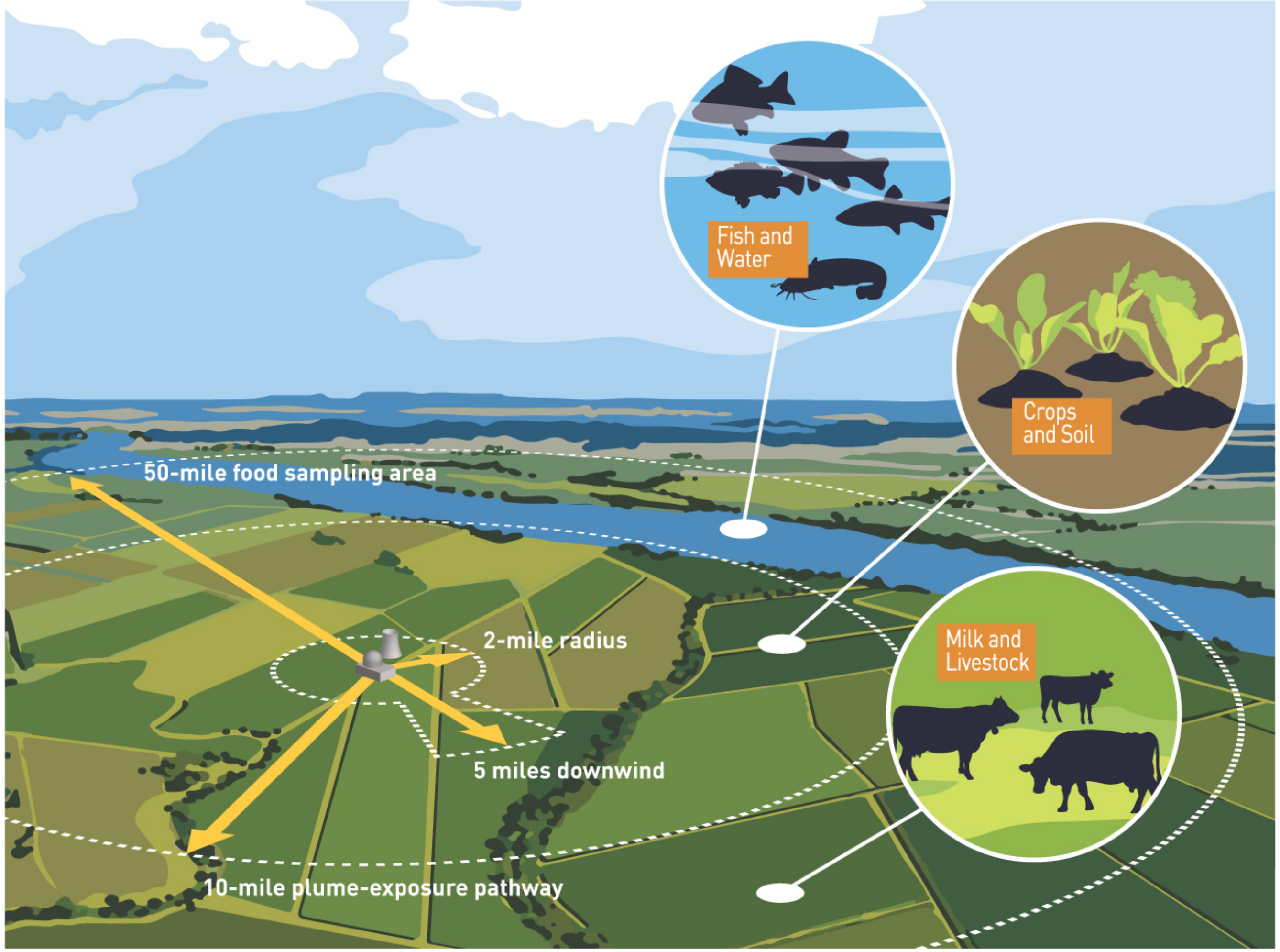
# Emergency Planning Zones




Note: A 2-mile (3.2-kilometer) ring around the plant is identified for evacuation, along with a 5-mile (8-kilometer) zone downwind of the projected release path.

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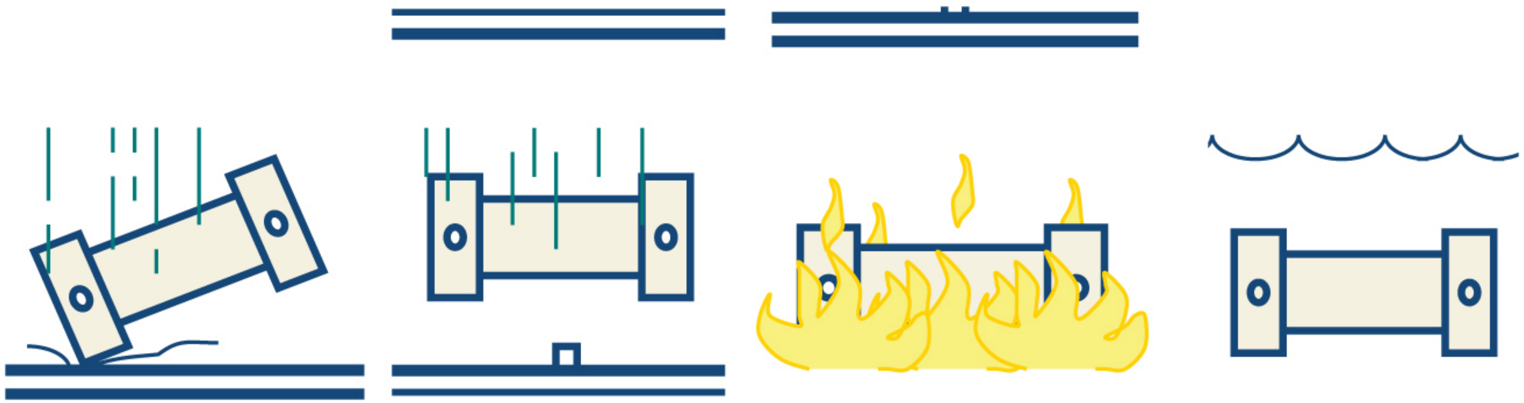
## Ensuring Safe Spent Fuel Shipping Containers



The impact (free drop and puncture), fire, and water immersion tests are considered in sequence to determine their cumulative effects on a given package.

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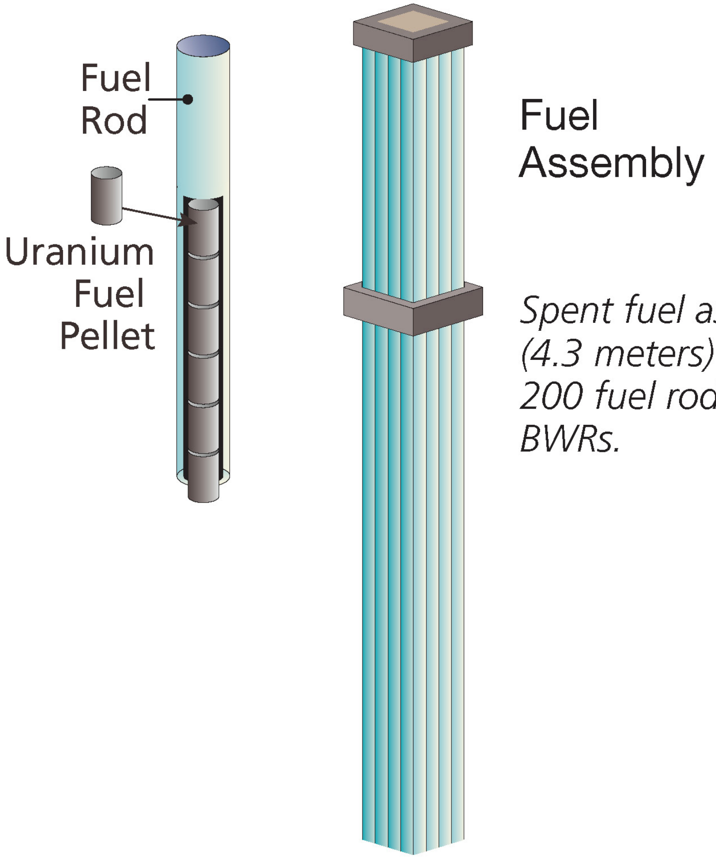


*Spent fuel assemblies are typically 14 feet (4.3 meters) long and contain nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs.*

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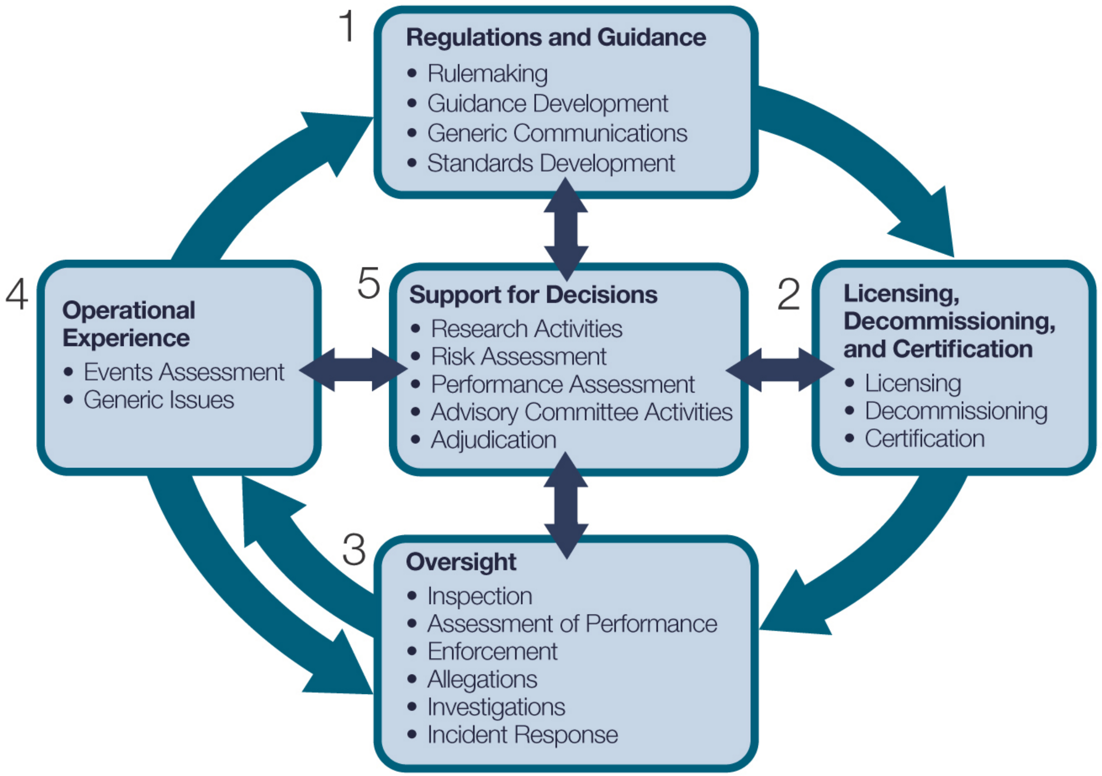
## How the NRC Regulates




1. Developing regulations and guidance for applicants and licensees.
2. Licensing or certifying applicants to use nuclear materials, operate nuclear facilities, and decommission facilities.
3. Inspecting and assessing licensee operations and facilities to ensure licensees comply with NRC requirements, responding to incidents, investigation allegations of wrongdoing, and taking appropriate followup or enforcement actions when necessary.
4. Evaluating operational experience of licensed facilities and activities.
5. Conducting research, holding hearings, and obtaining independent reviews to support regulatory decisions.



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## License Renewal Process


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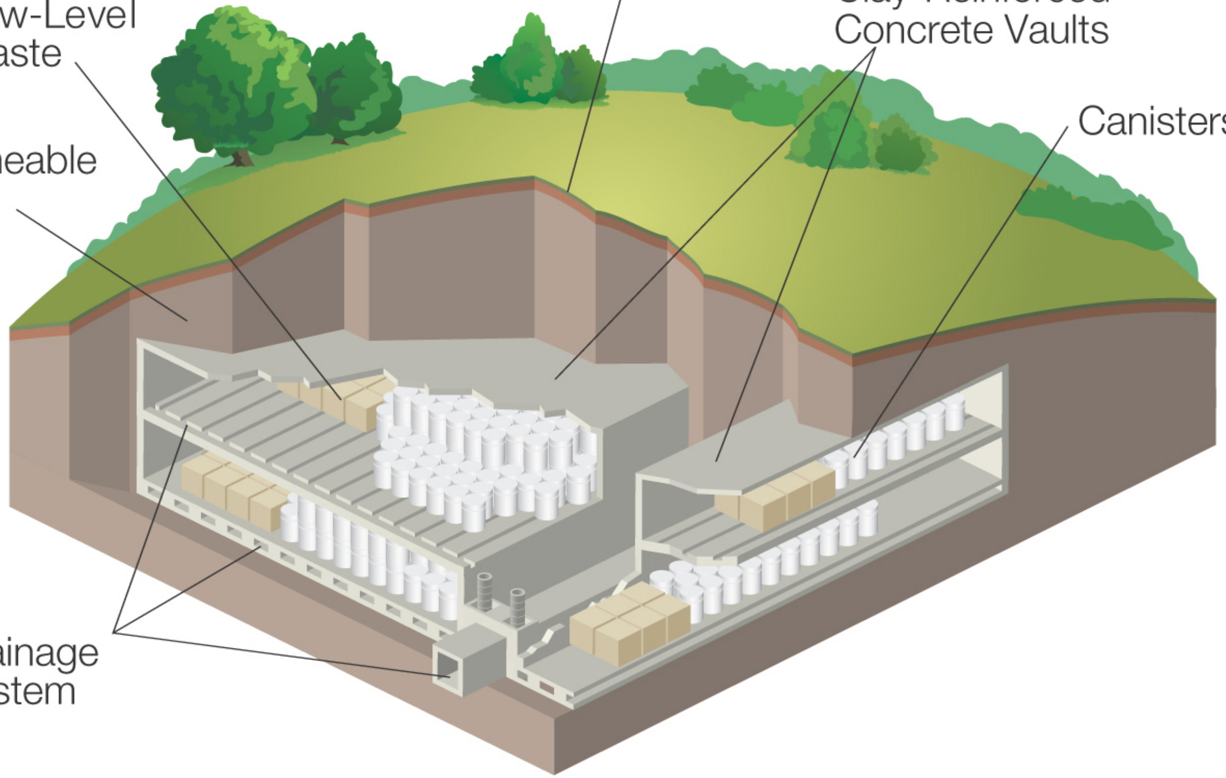
## Low-Level Radioactive Waste Disposal




*This LLW disposal site accepts waste from States participating in a regional disposal agreement.*

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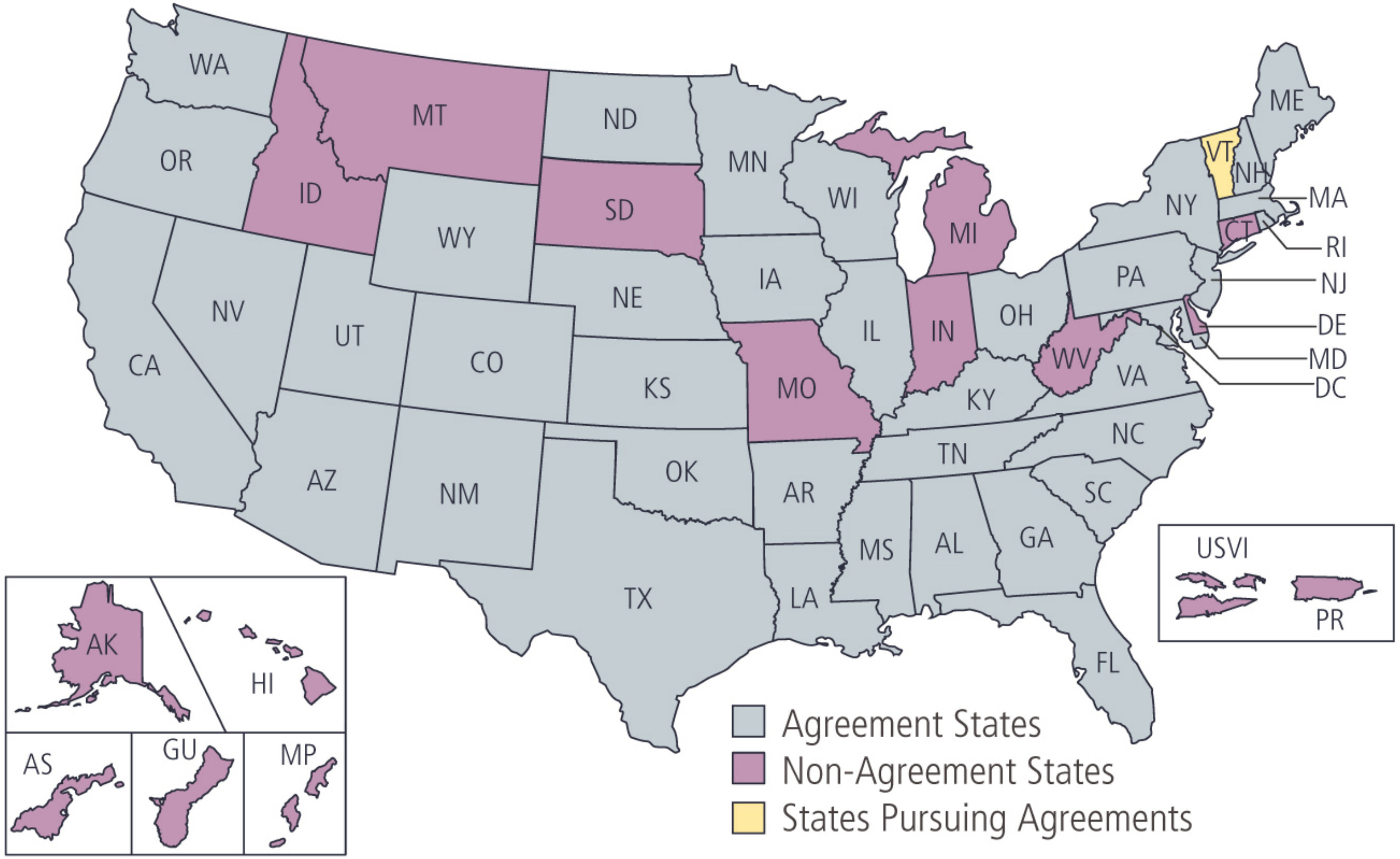
## Agreement States




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

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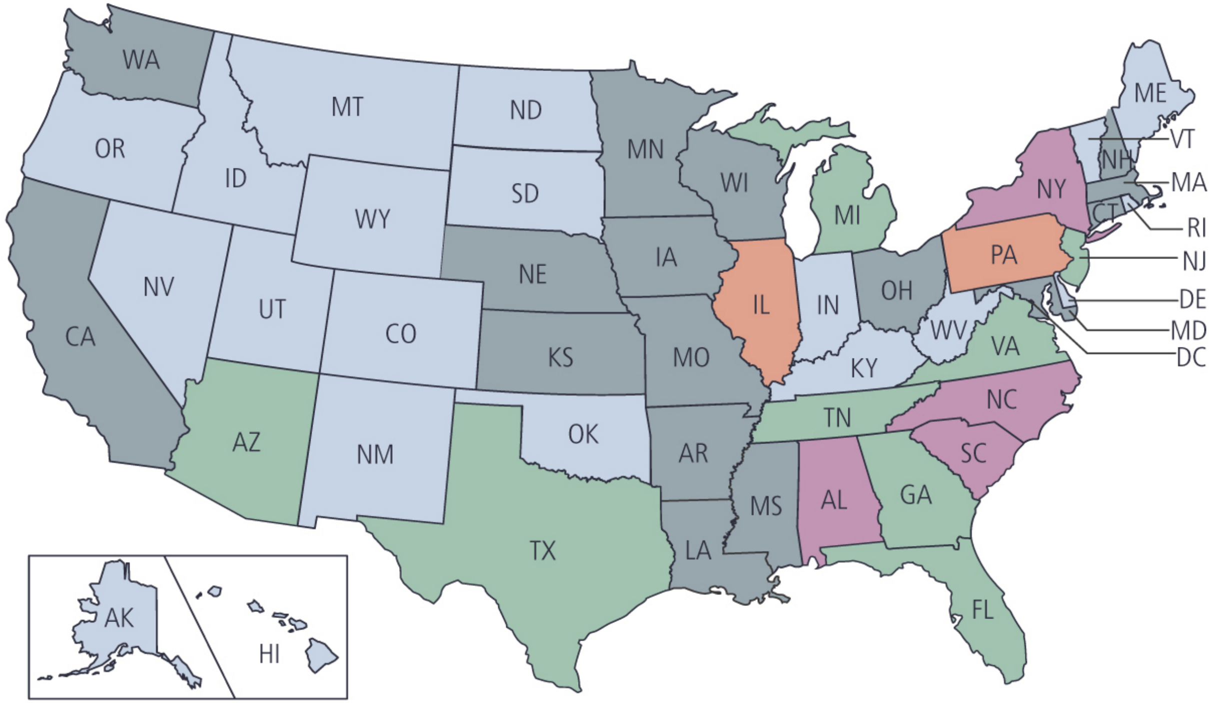
# Gross Electricity Generated in Each State by Nuclear Power




***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.

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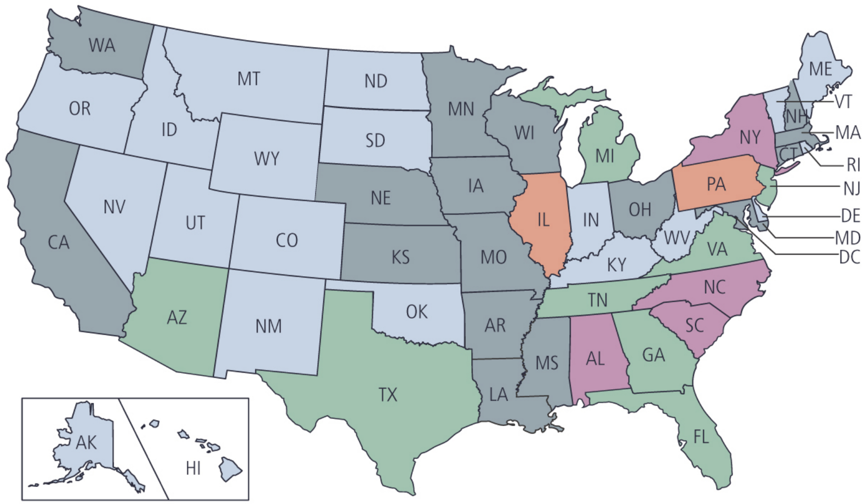


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| 20 States | 16 States | 8 States | 4 States | 2 States |

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*

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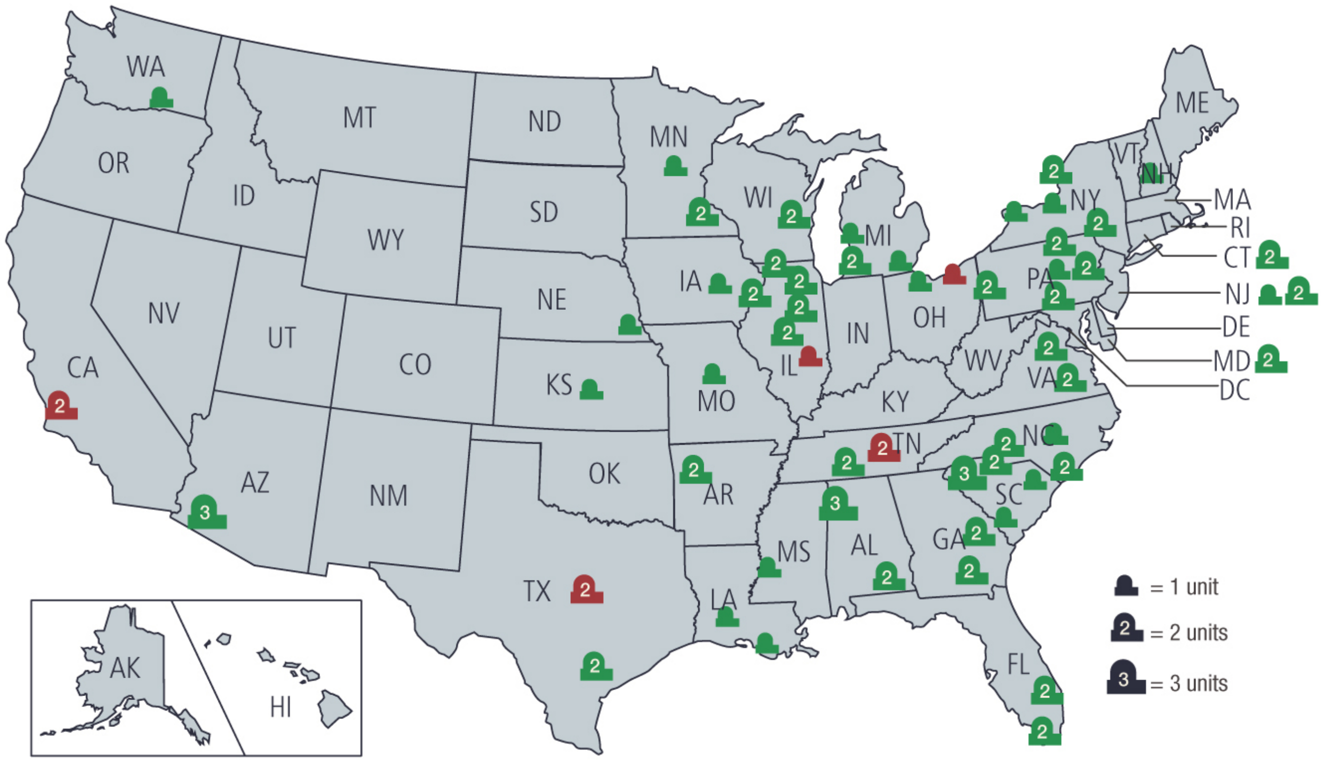
# License Renewals Granted for Operating Nuclear Power Reactors




**Licensed to Operate (97)**

Original License (8) License Renewal Granted (89)

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/*.

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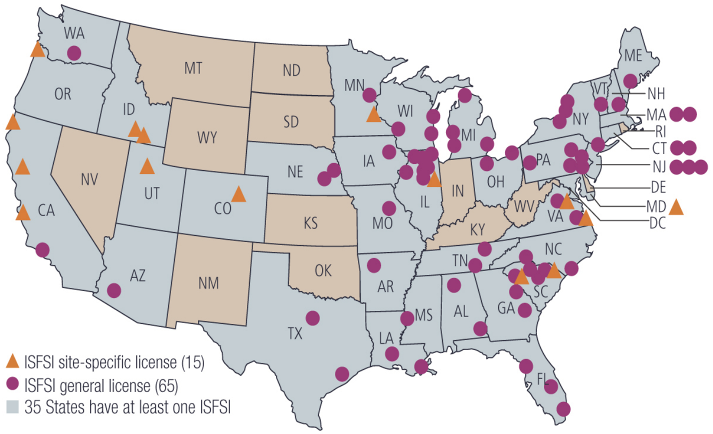
## Licensed and Operating Independent Spent Fuel Storage Installations by State




ALABAMA
- ● Browns Ferry
- ● Farley

ARIZONA
- ● Palo Verde

ARKANSAS
- ● Arkansas Nuclear

CALIFORNIA
- ▲ Diablo Canyon
- ▲ Rancho Seco
- ● San Onofre
- ▲ Humboldt Bay

COLORADO
- ▲ Fort St. Vrain

CONNECTICUT
- ● Haddam Neck
- ● Millstone

FLORIDA
- ● Crystal River
- ● St. Lucie
- ● Turkey Point

GEORGIA
- ● Hatch
- ● Vogtle

IDAHO
- ▲ DOE: Three Mile Island-2 (Fuel Debris)
- ▲ DOE: Idaho Spent Fuel Facility

ILLINOIS
- ● Braidwood
- ● Byron
- ● Clinton
- ▲ GEH Morris (Wet)
- ● Dresden
- ● La Salle
- ● Quad Cities
- ● Zion

IOWA
- ● Duane Arnold

LOUISIANA
- ● River Bend
- ● Waterford

MAINE
- ● Maine Yankee

MARYLAND
- ▲ Calvert Cliffs

MASSACHUSETTS
- ● Yankee Rowe
- ● Pilgrim

MICHIGAN
- ● Big Rock Point
- ● Palisades
- ● Cook
- ● Fermi

MINNESOTA
- ● Monticello
- ▲ Prairie Island

MISSISSIPPI
- ● Grand Gulf

MISSOURI
- ● Callaway

NEBRASKA
- ● Cooper
- ● Ft. Calhoun

NEW HAMPSHIRE
- ● Seabrook

NEW JERSEY
- ● Hope Creek
- ● Salem
- ● Oyster Creek

NEW YORK
- ● Indian Point
- ● FitzPatrick
- ● Ginna
- ● Nine Mile Point

NORTH CAROLINA
- ● Brunswick
- ● McGuire

OHIO
- ● Davis-Besse
- ● Perry

OREGON
- ▲ Trojan

PENNSYLVANIA
- ● Limerick
- ● Susquehanna
- ● Peach Bottom
- ● Beaver Valley
- ● Three Mile Island

SOUTH CAROLINA
- ● ▲ Oconee
- ● ▲ Robinson
- ● Catawba
- ● Summer

TENNESSEE
- ● Sequoyah
- ● Watts Bar

TEXAS
- ● Comanche Peak
- ● South Texas Project

UTAH
- ▲ Private Fuel Storage*

VERMONT
- ● Vermont Yankee

VIRGINIA
- ● ▲ Surry
- ● ▲ North Anna

WASHINGTON
- ● Columbia

WISCONSIN
- ● Point Beach
- ● Kewaunee
- ● LaCrosse

* Facility licensed only, never built or operated. Alaska and Hawaii are not pictured and have no sites. Data are current as of June 2019. NRC-abbreviated site names listed. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*.



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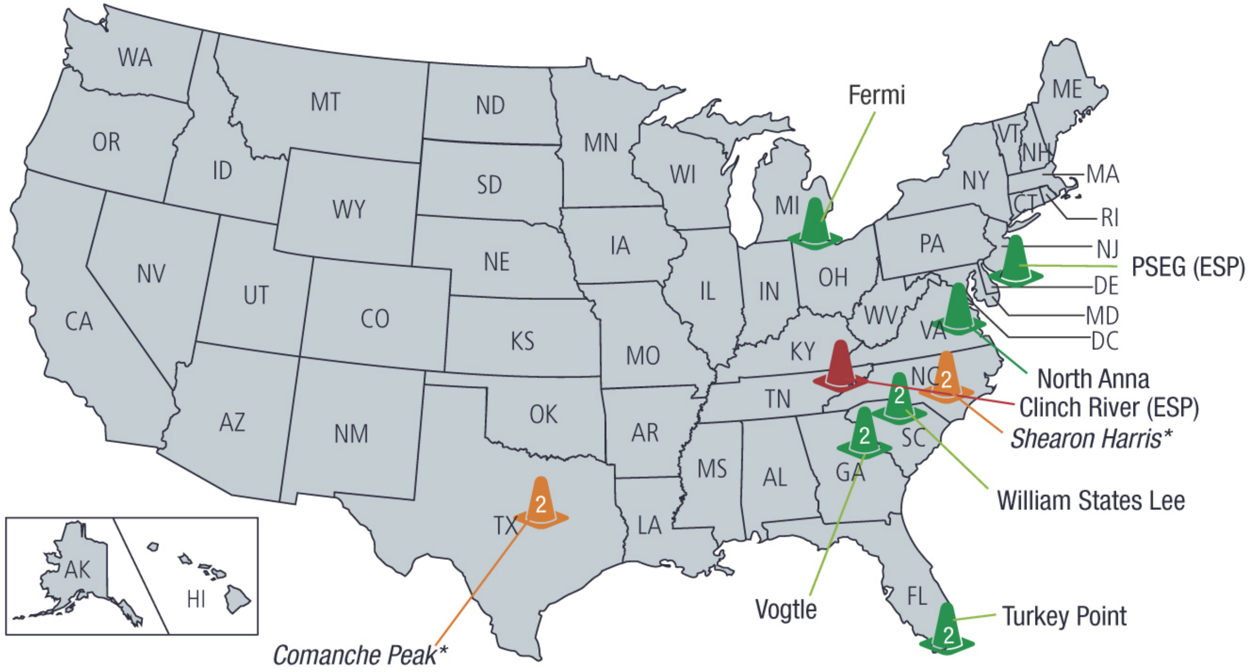
# Locations of New Nuclear Power Reactor Applications




= A proposed new reactor at or near an existing nuclear plant

= A proposed reactor at a site that has not previously produced nuclear power

= Approved reactor

= 1 unit

2 = 2 units

* *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/*.



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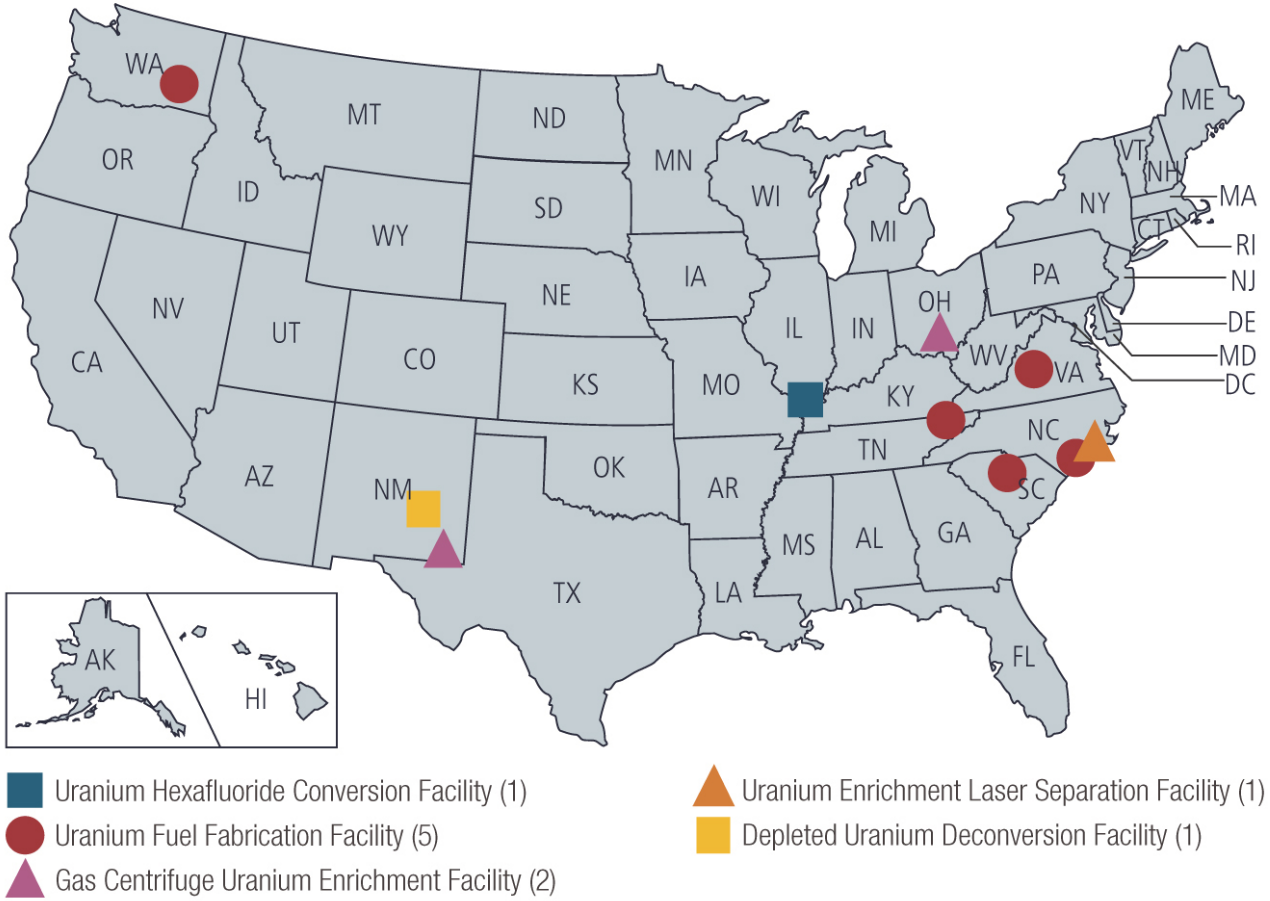
## Locations of NRC-Licensed Fuel Cycle Facilities




Note: There are no fuel cycle facilities in Alaska or Hawaii.
For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*.

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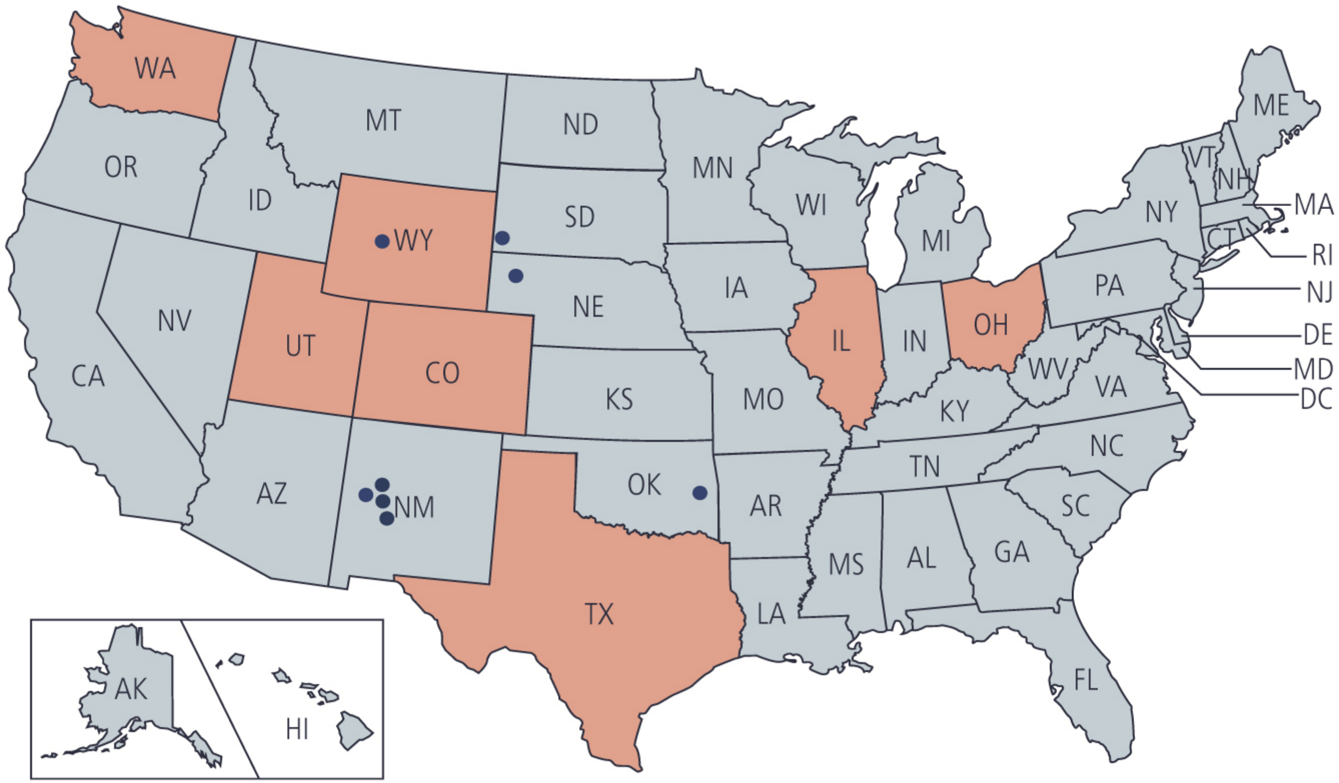
## Locations of NRC-Licensed Uranium Recovery Facility Sites

*(Includes sites undergoing decommissioning)*




- States with authority to license uranium recovery facility sites
- States where the NRC has retained authority to license uranium recovery facilities
- ● NRC-licensed uranium recovery facility sites (8)

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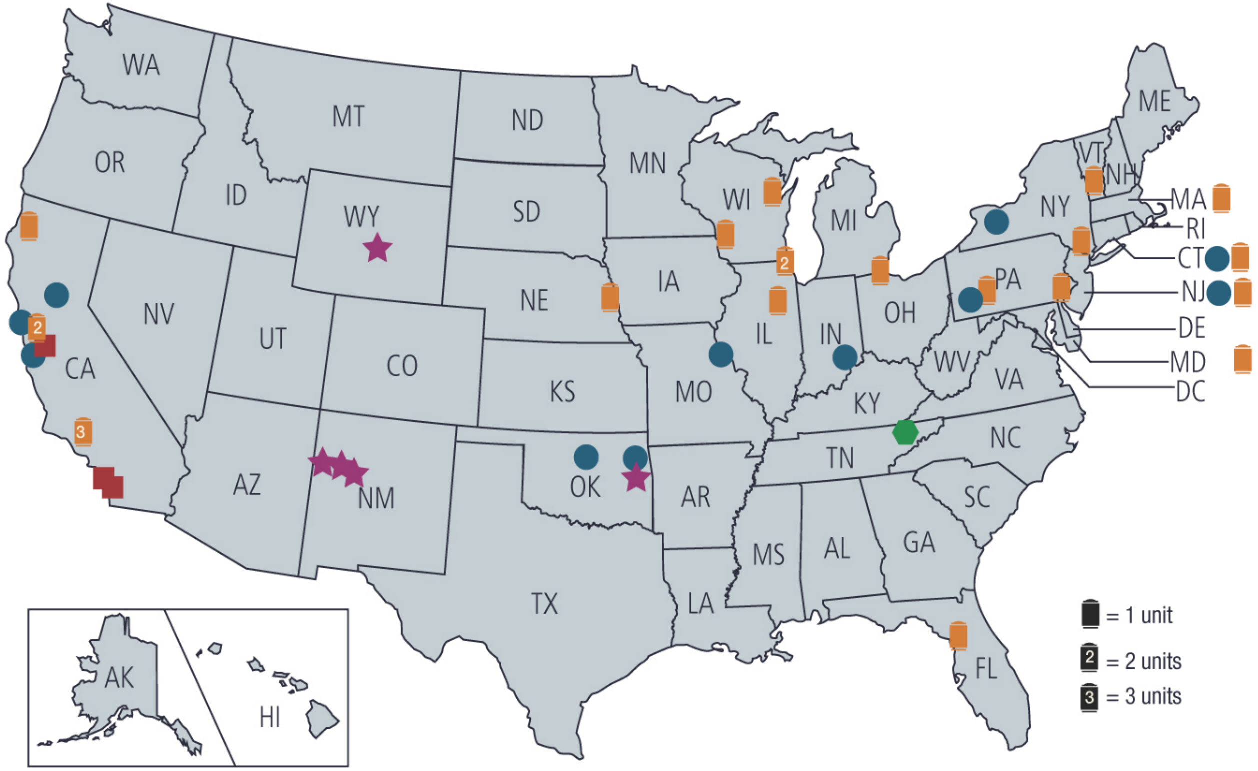
## Locations of NRC-Regulated Sites Undergoing Decommissioning




Power Reactor Sites (22)

Complex Materials (11)

Fuel Cycle Facilities (1)

Research and Test Reactors (3)

Uranium Recovery (5)

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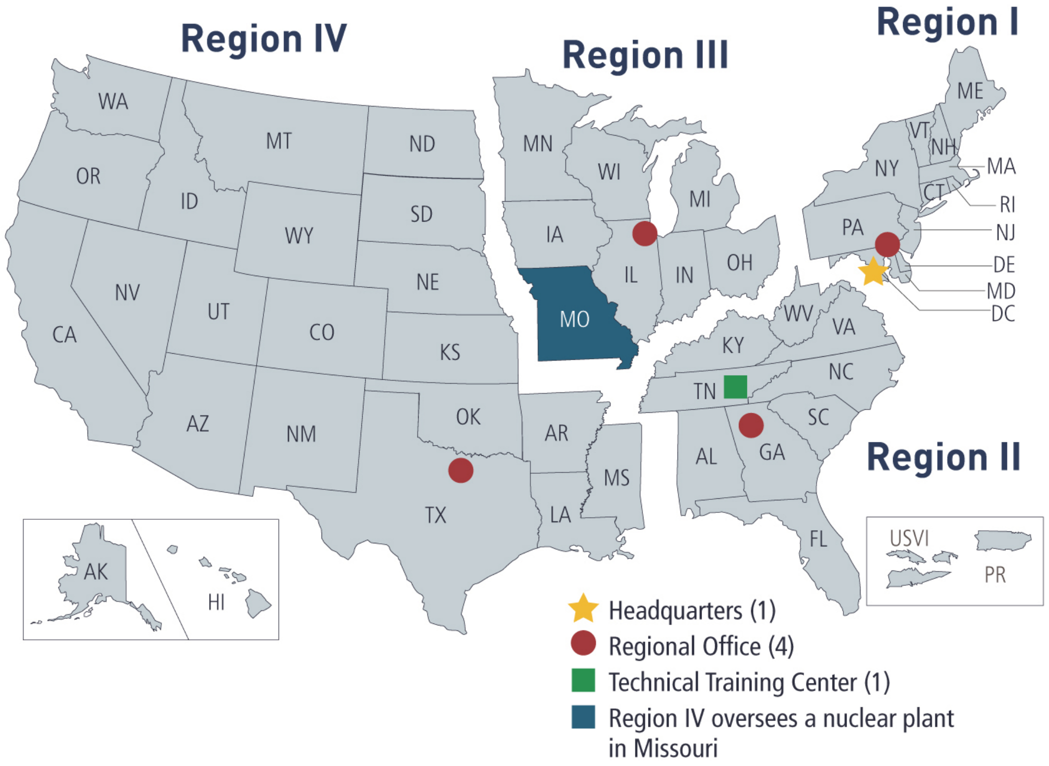
## NRC Regions




**Nuclear Power Plants**

- Each regional office oversees the plants in its region—except for the Callaway plant in Missouri, which Region IV oversees.

**Materials Licensees**

- Region I oversees licensees and Federal facilities located in Region I and Region II.
- Region III oversees licensees and Federal facilities located in Region III.
- Region IV oversees licensees and Federal facilities located in Region IV.

**Nuclear Fuel Processing Facilities**

- Region II oversees all the fuel processing facilities in all regions.
- Region II also handles all construction inspection activities for new nuclear power plants and fuel cycle facilities in all regions.

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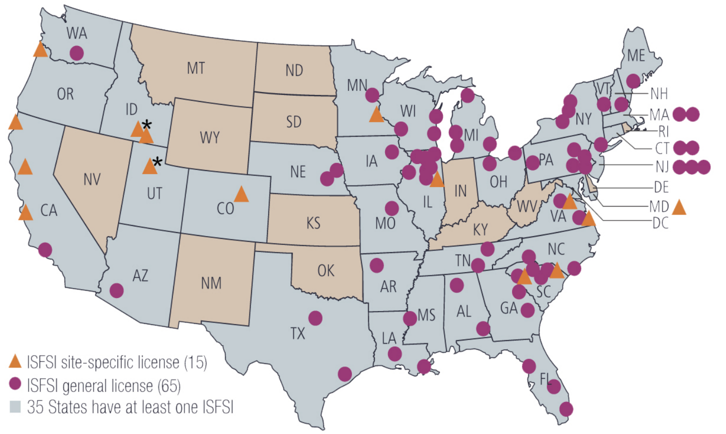
## Licensed and Operating Independent Spent Fuel Storage Installations by State

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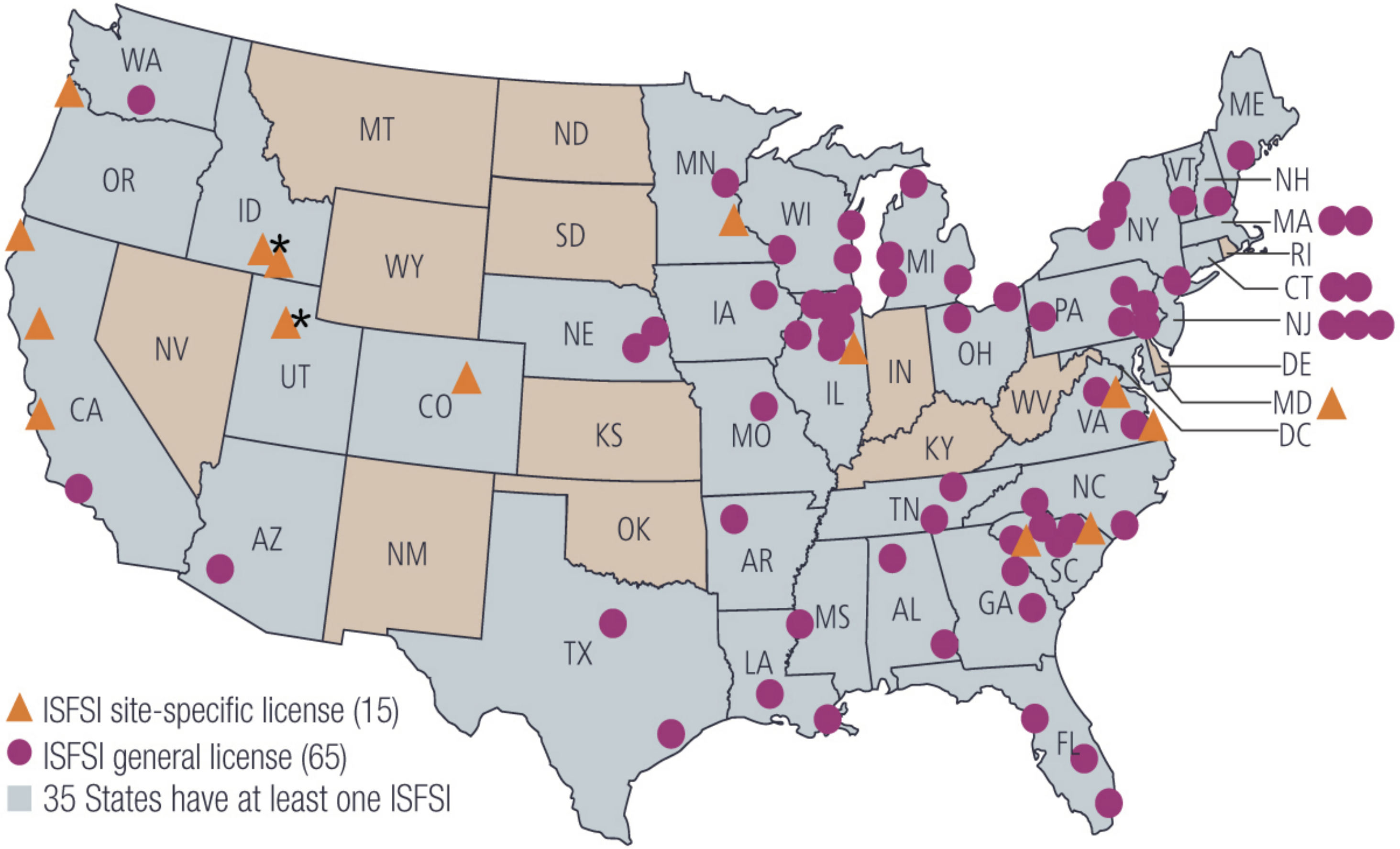


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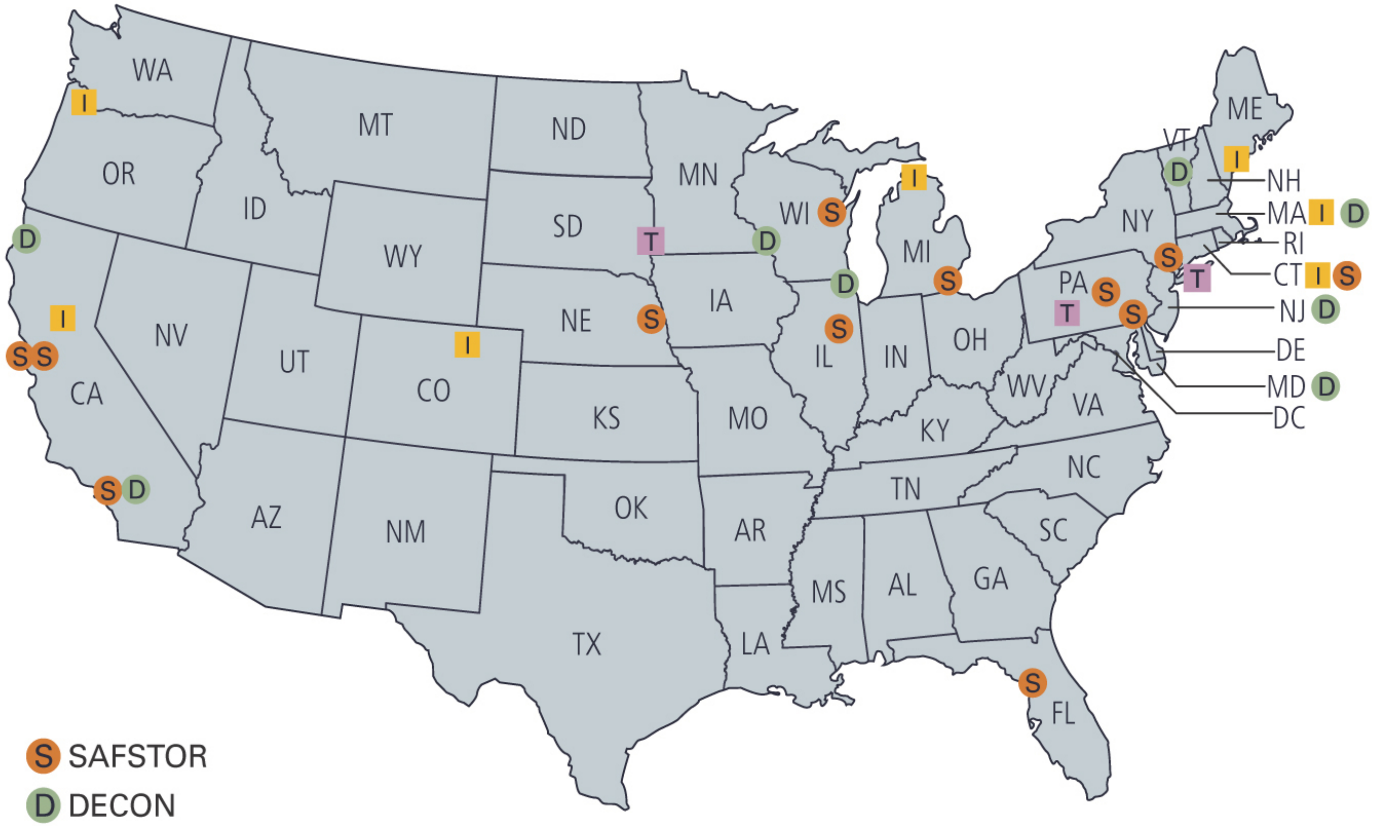
# Power Reactor Decommissioning Status




S SAFSTOR

D DECON

*Decommissioning Completed*

I ISFSI (Independent Spent Fuel Storage Installation) only

T License Terminated (no fuel on site)

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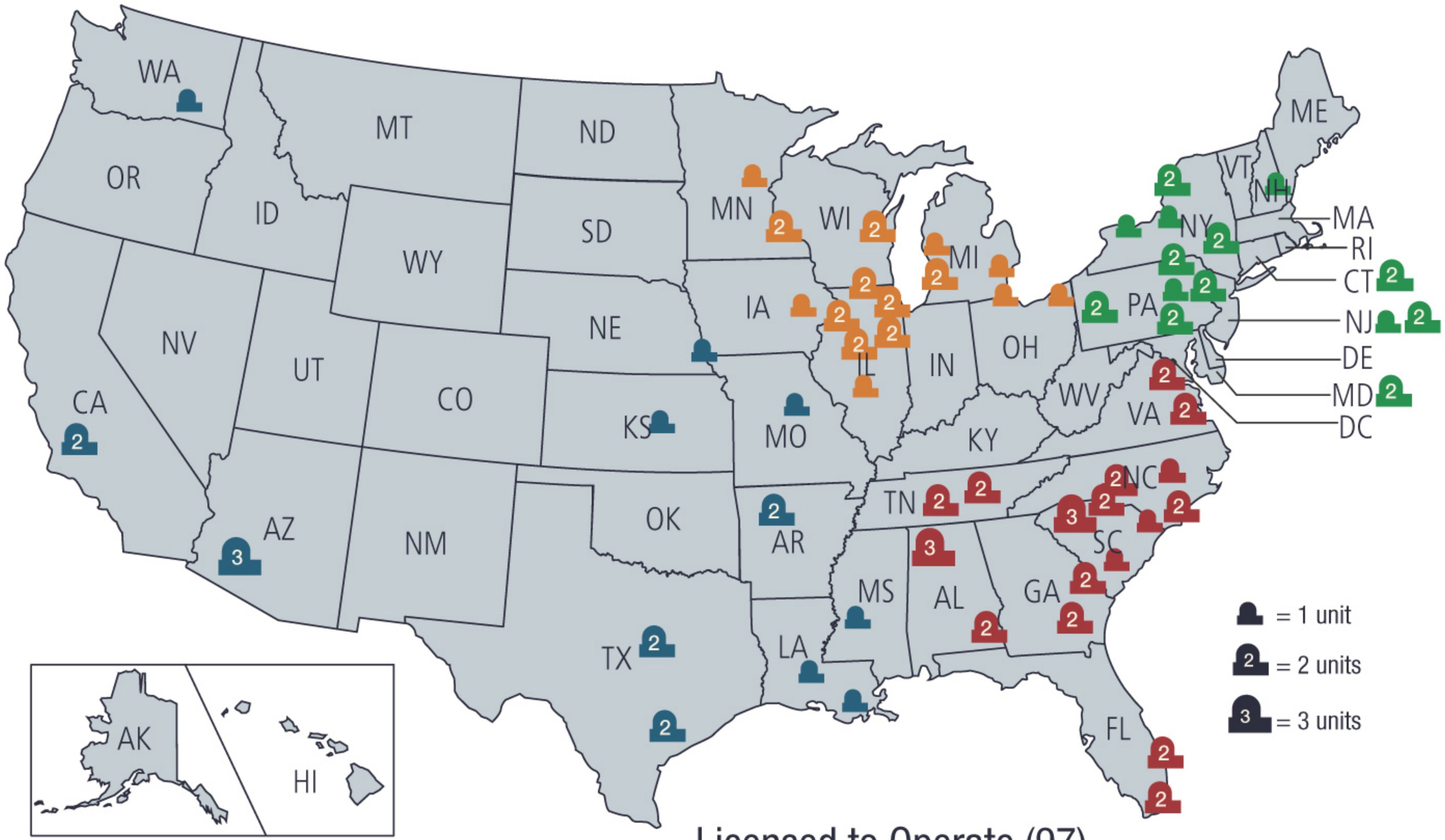
# U.S. Operating Commercial Nuclear Power Reactors




Licensed to Operate (97)

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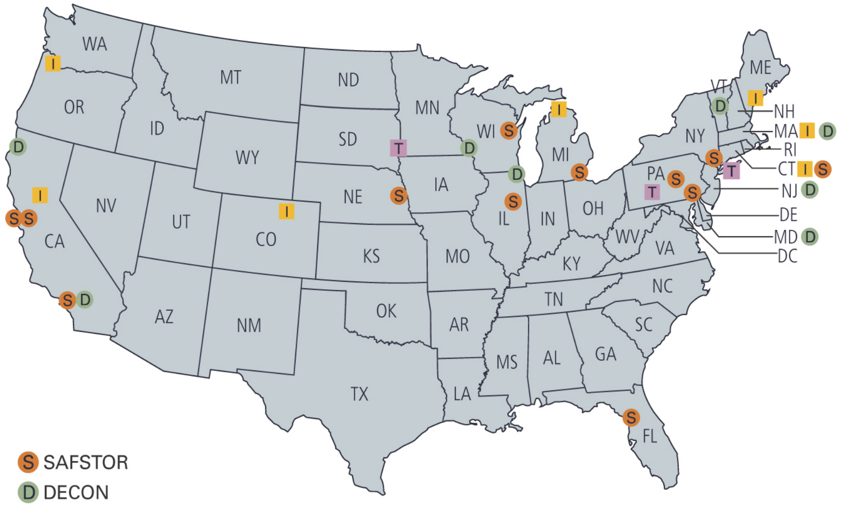
## Power Reactor Decommissioning Status




S SAFSTOR
D DECON

*Decommissioning Completed*
I ISFSI (Independent Spent Fuel Storage Installation) only
T License Terminated (no fuel on site)

**CALIFORNIA**
S GE EVESR
S GE VBWR
D Humboldt Bay 3
I Rancho Seco
S San Onofre 1
D San Onofre 2 and 3

**COLORADO**
I Fort St. Vrain
*(DOE License)*

**CONNECTICUT**
S Millstone 1
I Haddam Neck

**FLORIDA**
S Crystal River 3

**ILLINOIS**
S Dresden 1
D Zion 1 and 2

**MARYLAND**
D N.S. Savannah

**MASSACHUSETTS**
D Pilgrim
I Yankee Rowe

**MAINE**
I Maine Yankee

**MICHIGAN**
S Fermi 1
I Big Rock Point

**NEBRASKA**
S Fort Calhoun

**NEW JERSEY**
D Oyster Creek

**NEW YORK**
S Indian Point 1
T Shoreham

**OREGON**
I Trojan

**PENNSYLVANIA**
T Saxton
S Peach Bottom 1
S Three Mile Island 2

**SOUTH DAKOTA**
T Pathfinder

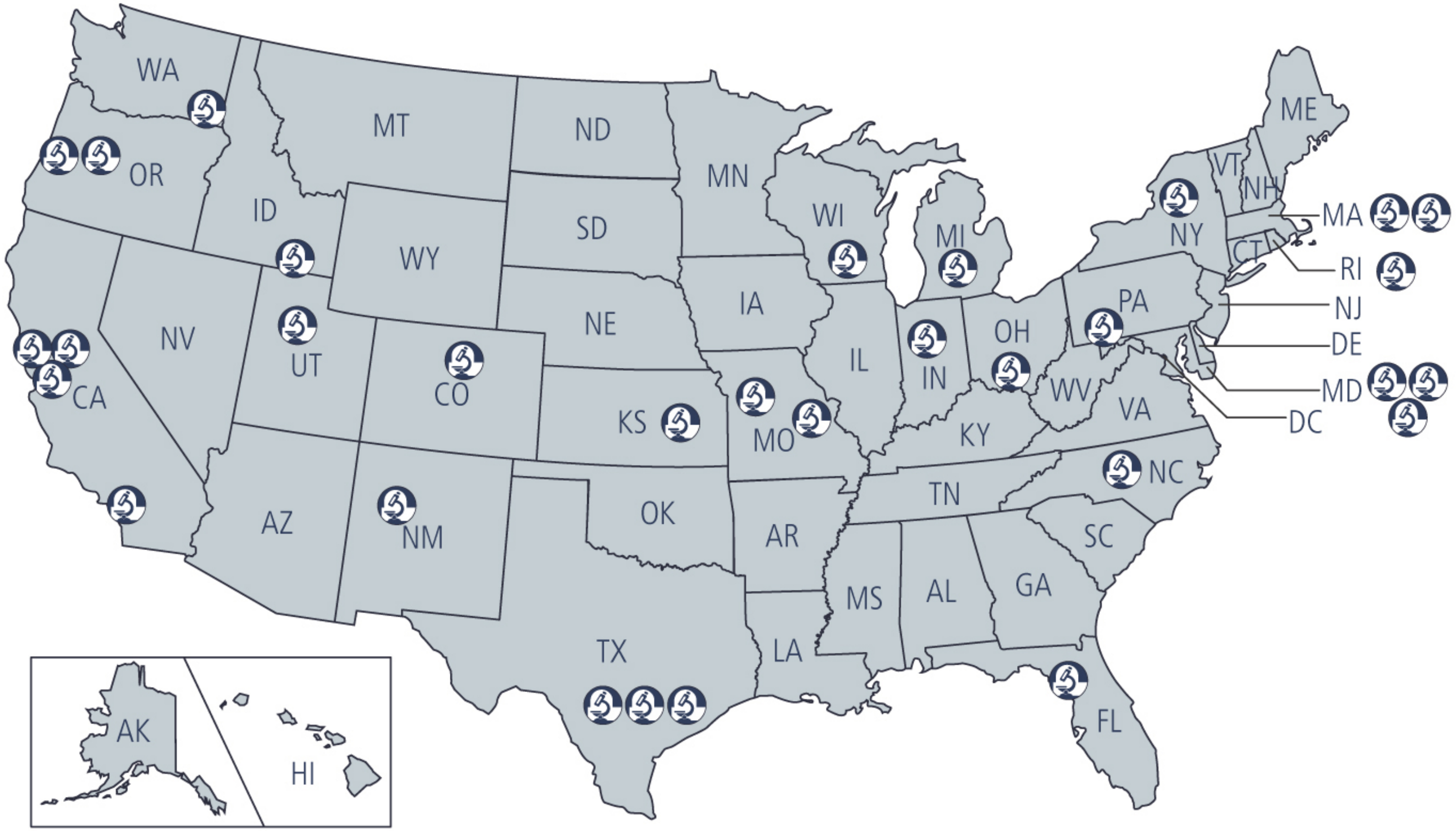
**VERMONT**
D Vermont Yankee

**WISCONSIN**
D LaCrosse
S Kewaunee

Alaska and Hawaii are not pictured and have no sites.
Notes: ISFSIs are also located at all sites undergoing decommissioning or in SAFSTOR. GE Bonus, Hallam, and Piqua decommissioned reactor sites are part of the DOE nuclear legacy. For more information, visit DOE's Office of Legacy Management LM Sites Web page at *https://www.energy.gov/lm/sites/*. CVTR, Elk River, and Shippingport decommissioned reactor sites were either decommissioned before the formation of the NRC or were not licensed by the NRC. Licensees have announced their intention to permanently cease operations for Three Mile Island (2019), Davis Besse (2020), Perry (2021), Indian Point (2020 and 2021), Beaver Valley (2021), Palisades (2022), and Diablo Canyon (2024 and 2025). NRC-abbreviated reactor names are listed. For the most recent information, go to the Dataset Index Web page at *https://www.nrc.gov/reading-rm/doc-collections/datasets/*. Data are current as of July 2019.


As of August 2019

# U.S. Nuclear Research and Test Reactors




RTRs Licensed/Currently Operating (31)

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

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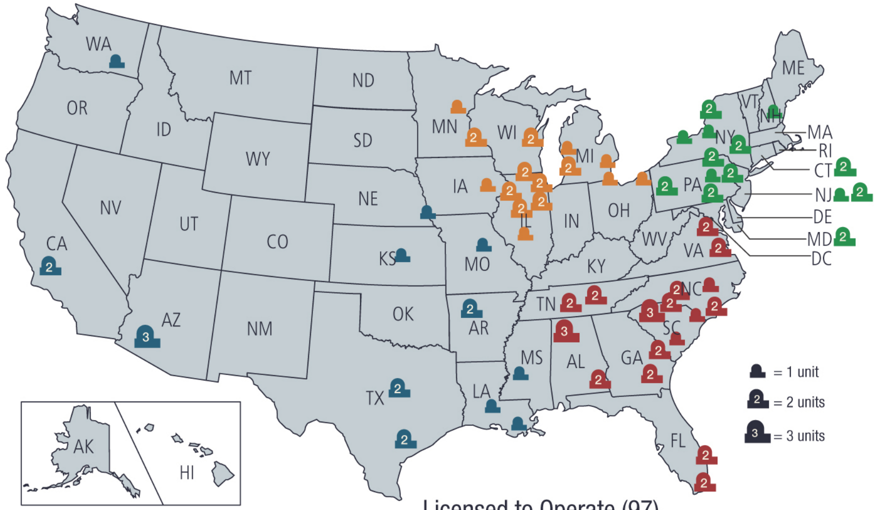
## U.S. Operating Commercial Nuclear Power Reactors




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/*.

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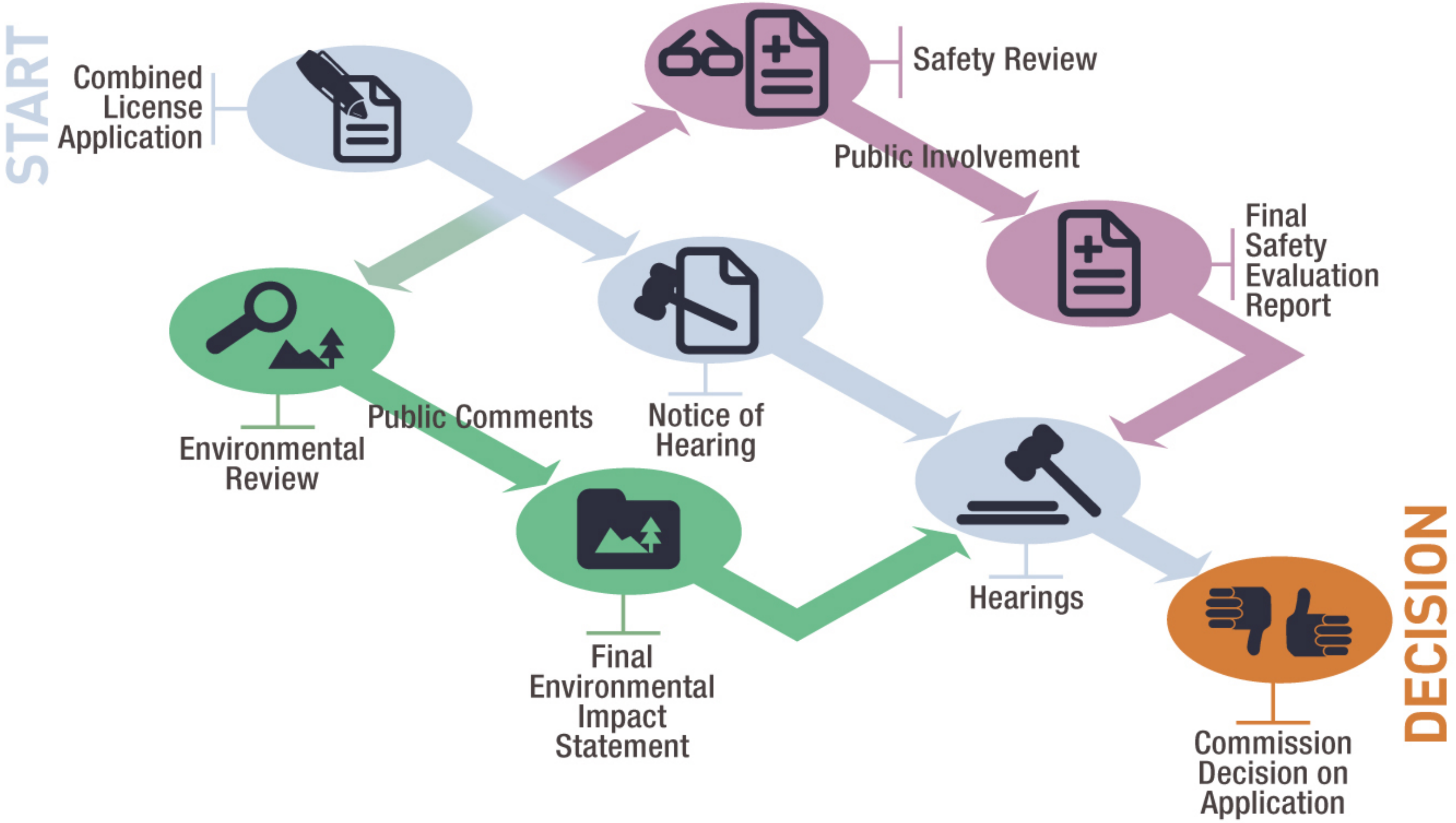
## New Reactor Licensing Process



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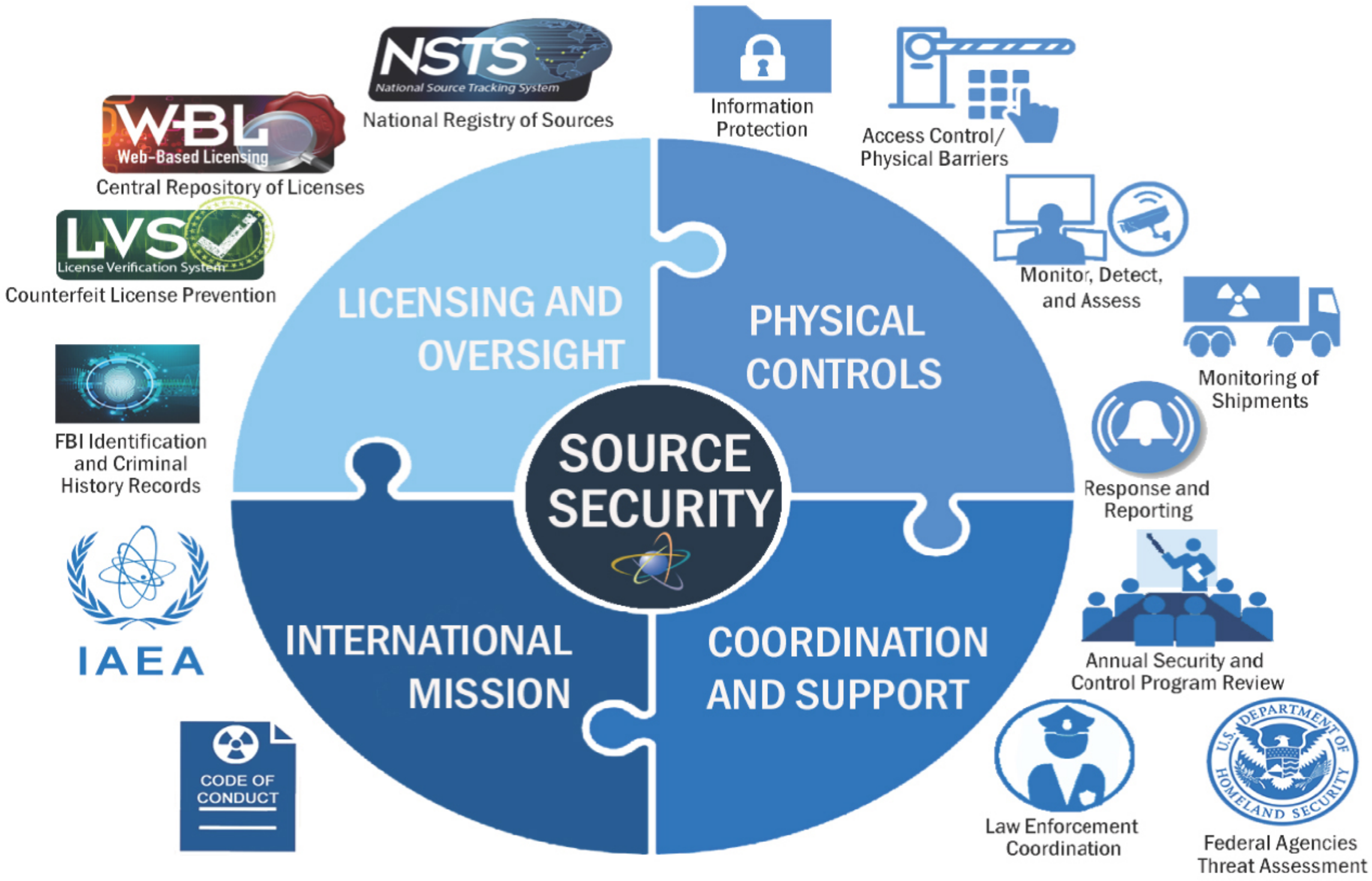
# NRC Approach to Source Security



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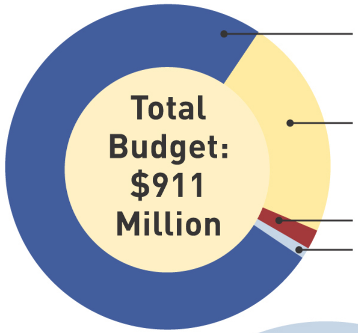
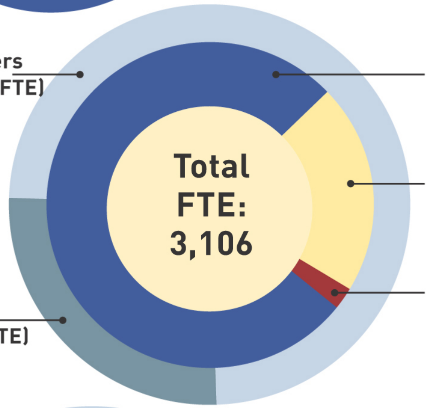
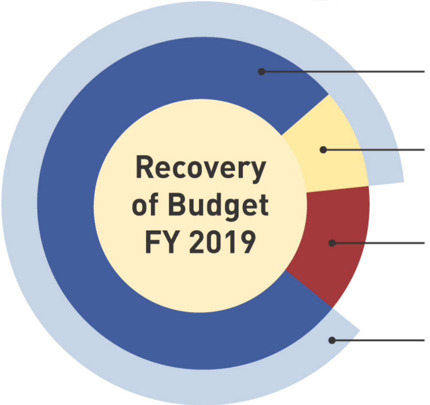
## NRC FY 2019 Distribution of Enacted Budget Authority; Recovery of NRC Budget




* Recovered fees do not include the use of prior-year carryover where fees were previously collected.
Notes: The NRC incorporates corporate and administrative costs proportionately within programs.
Numbers are rounded. Enacted budget for FY 2019.

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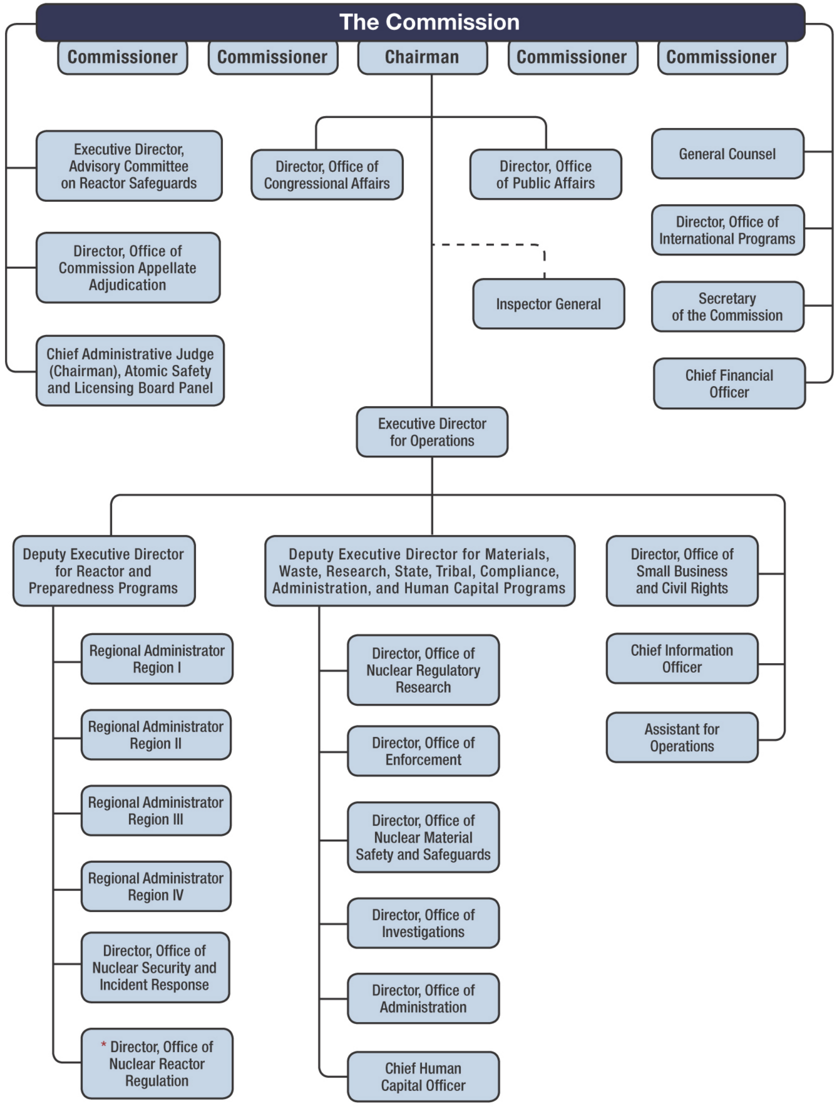
## NRC Organizational Chart




Note: For the most recent information, go to the NRC Organization Chart at *https://www.nrc.gov/about-nrc/organization.html*.
*Effective October 1, 2019, the Office of New Reactors will merge with the Office of Nuclear Reactor Regulation.

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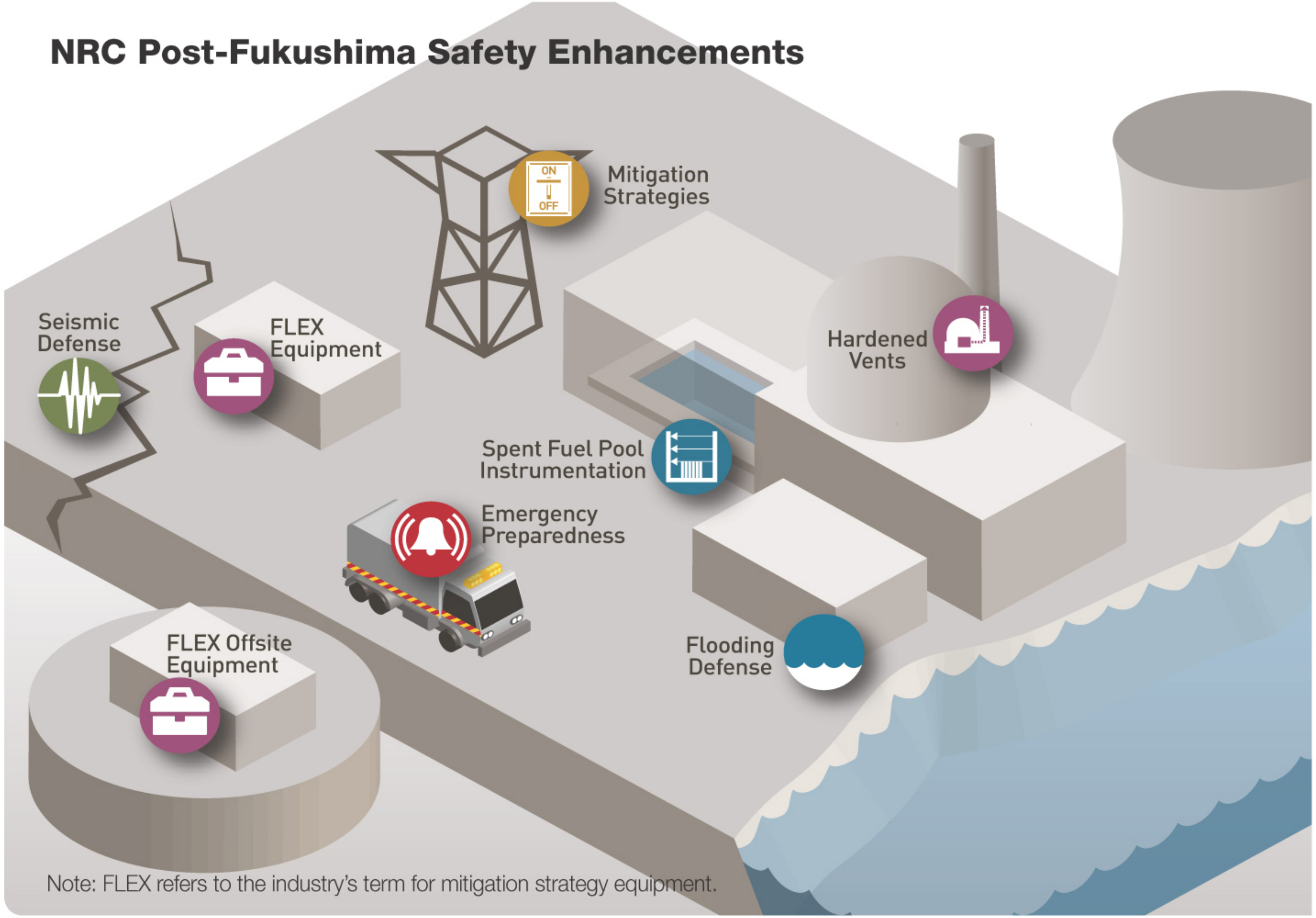
# NRC Post-Fukushima Safety Enhancements




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

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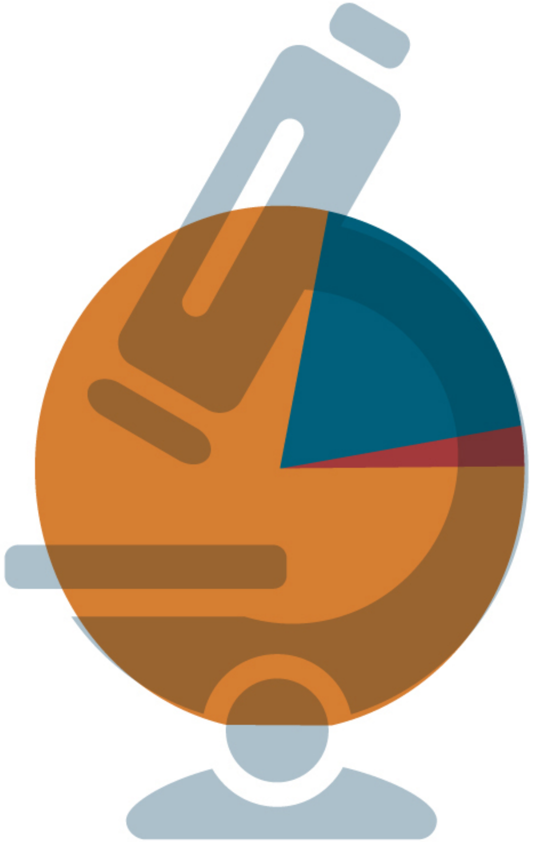
## NRC Research Funding, FY 2019



### 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.

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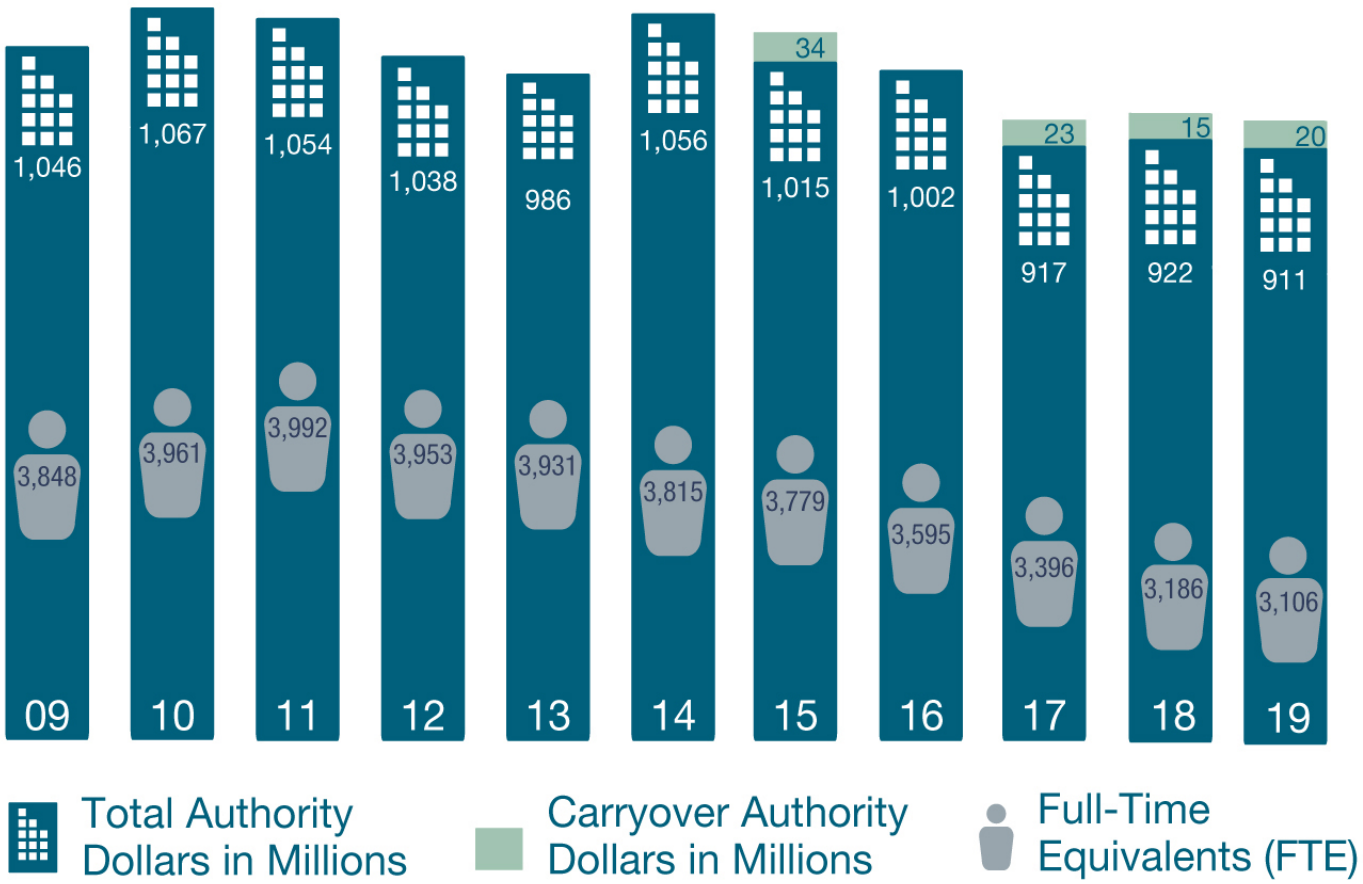
# NRC Total Authority, FYs 2009–2019




Note: Dollars are rounded to the nearest million.

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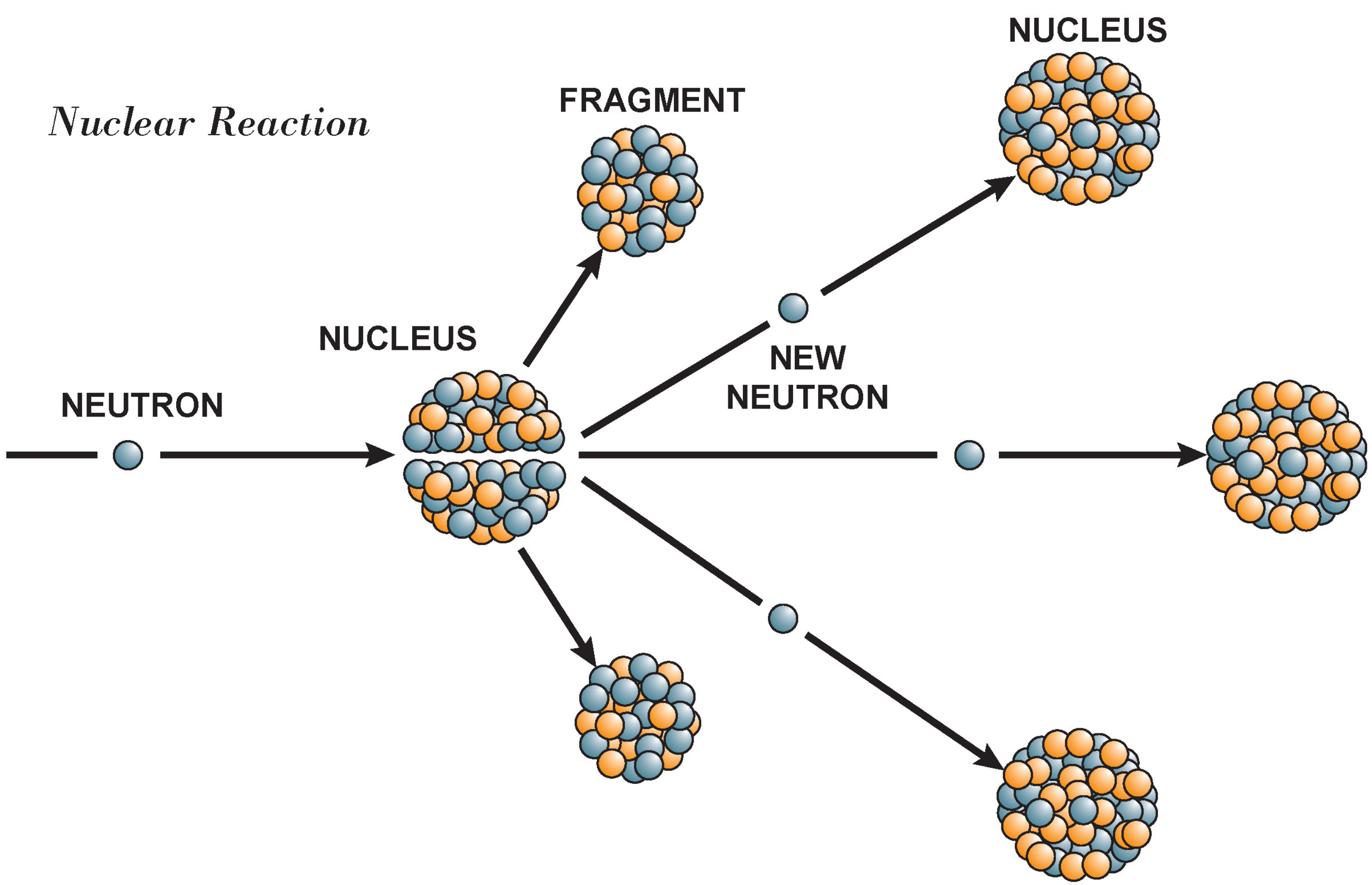
*Nuclear Reaction*

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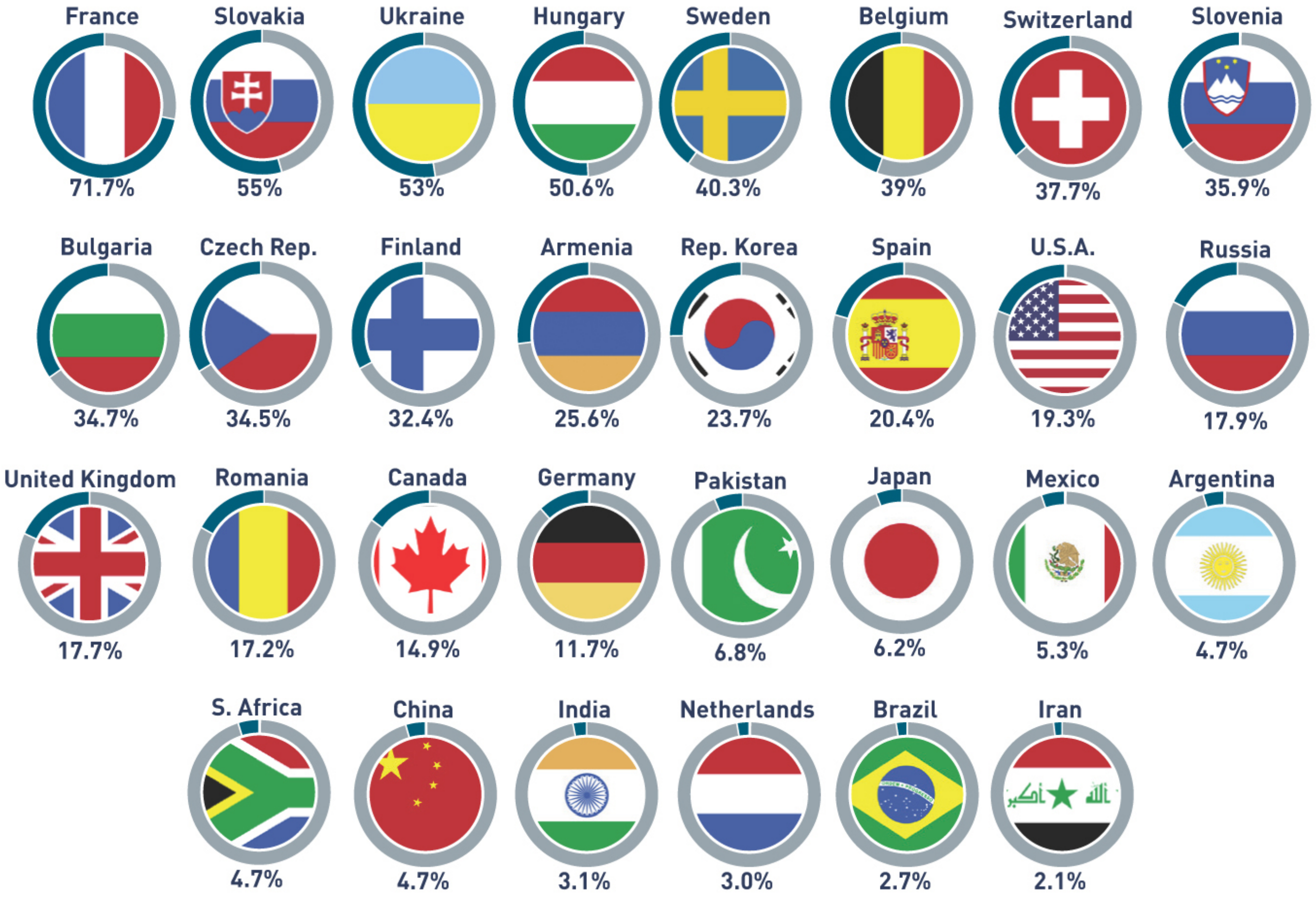
## Nuclear Share of Electricity Generated by Country




Note: Each country's short-form name is used.
Source: IAEA, Power Reactor Information System database, as of May 2019 for 2018

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## Principles of Good Regulation

| | |
|---|---|
| ***Independence:*** | *Nothing but the highest possible standards of ethical performance and professionalism should influence regulation.* |
| ***Openness:*** | *Nuclear regulation is the public's business, and it must be transacted publicly and candidly.* |
| ***Efficiency:*** | *The highest technical and managerial competence is required and must be a constant agency goal.* |
| ***Clarity:*** | *Regulations should be coherent, logical, and practical. Agency positions should be readily understood and easily applied.* |
| ***Reliability:*** | *Regulations should be based on the best available knowledge from research and operational experience.* |

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# Reactor Oversight Action Matrix Performance Indicators

## Performance Indicators

GREEN | WHITE | YELLOW | RED

INCREASING SAFETY SIGNIFICANCE →

## Inspection Findings

GREEN | WHITE | YELLOW | RED

INCREASING SAFETY SIGNIFICANCE →

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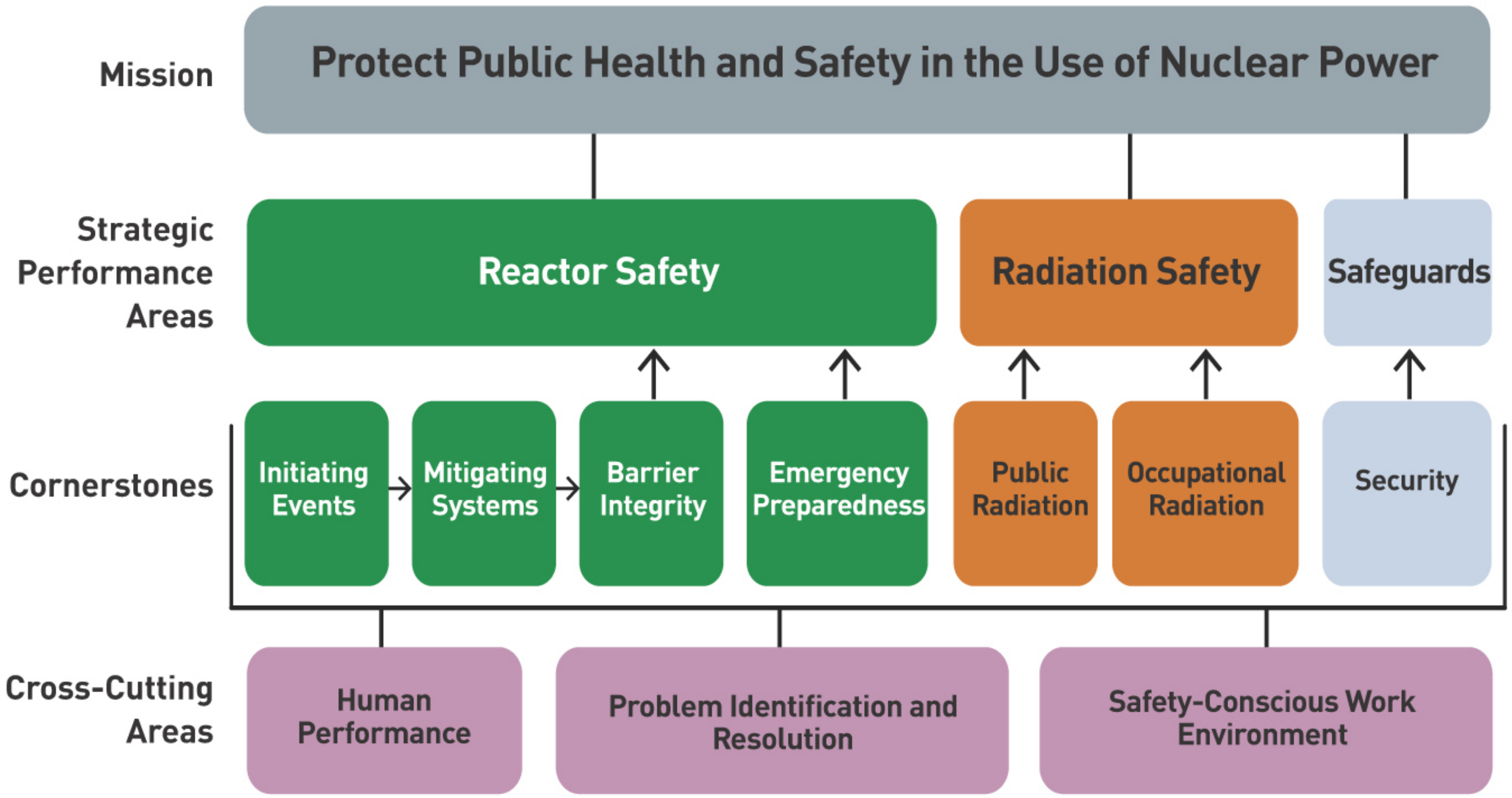
## Reactor Oversight Framework

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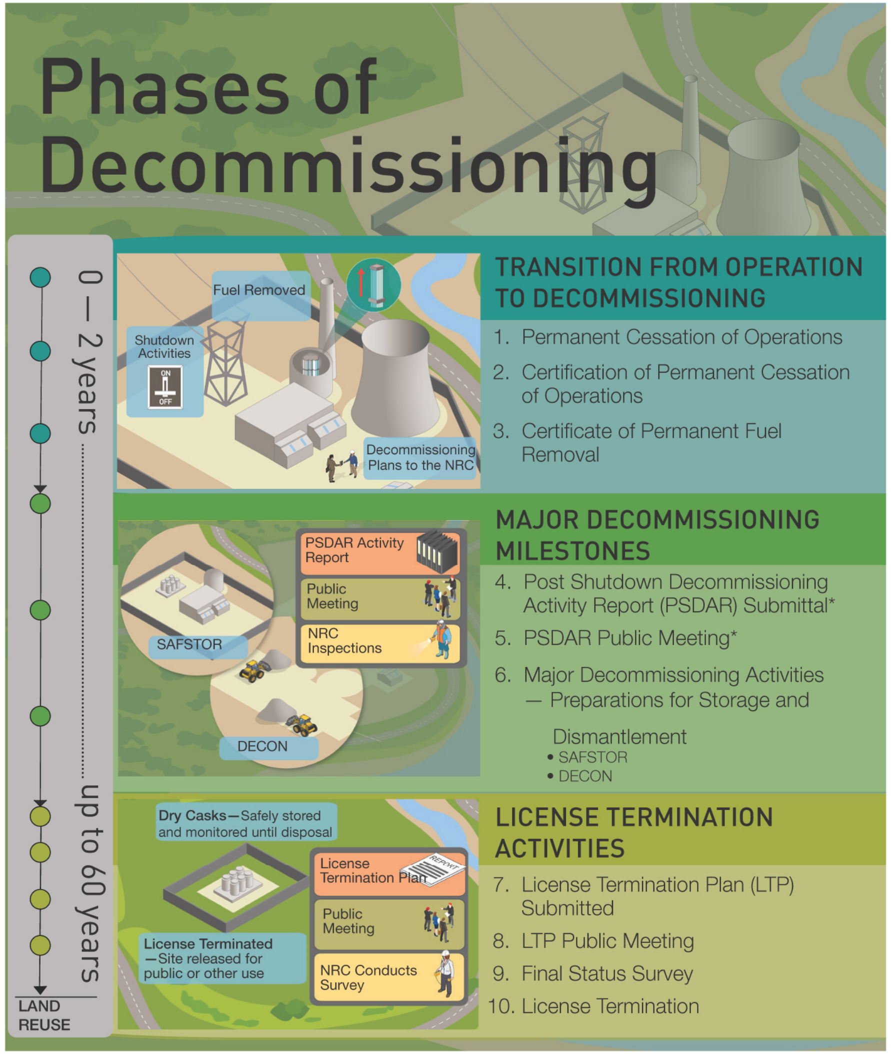
## Reactor Phases of Decommissioning




| | |
|---|---|
| SAFSTOR | Under SAFSTOR, a nuclear power plant is maintained and monitored in a condition that allows the radioactivity to decay; afterwards, the plant shifts to DECON as the facility is dismantled and the property decontaminated. |
| DECON | Under DECON, equipment, structures and portions of the facility containing radioactive contaminants are removed or decontaminated to a level that permits release of the property and termination of the NRC license. |

*Under DECON some licensees have submitted the PSDAR before shutdown (license transfer model).

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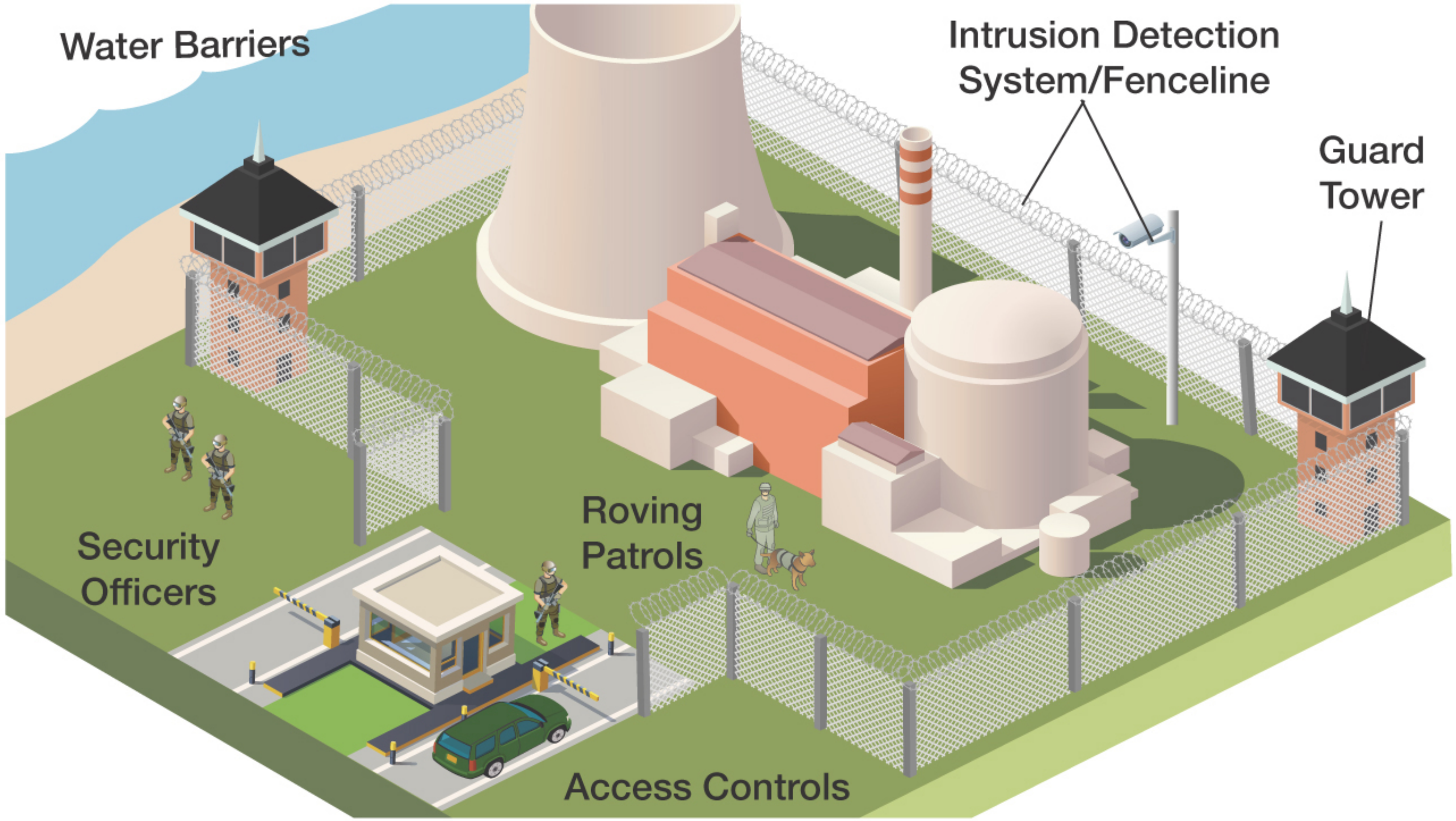
## Security Components




*Protecting nuclear facilities requires all of the security features to come together and work as one.*

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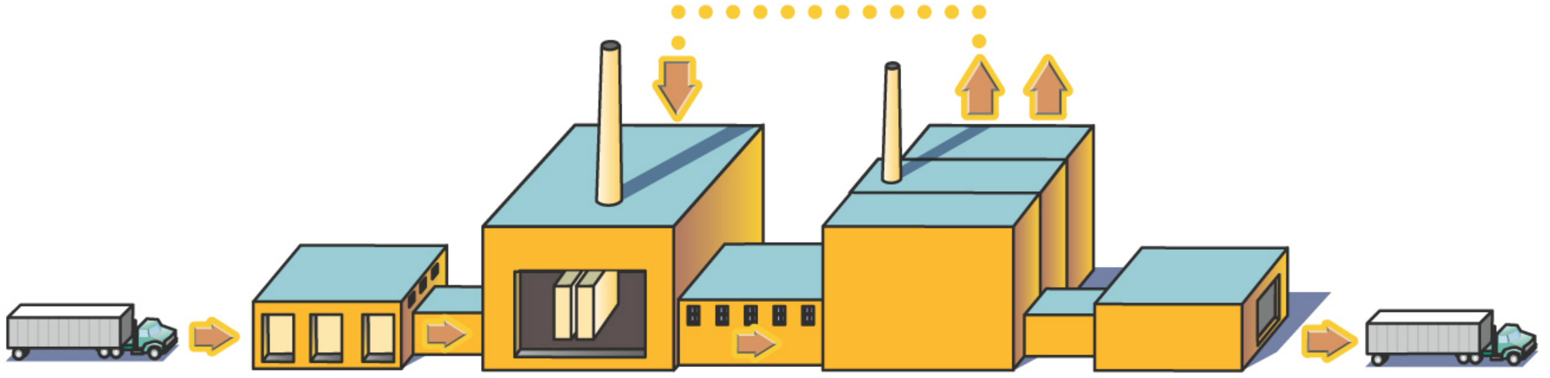
# Simplified Fuel Fabrication Process




Fabrication of commercial light-water reactor fuel consists of the following three basic steps:

(1) the chemical conversion of $UF_6$ to $UO_2$ powder

(2) a ceramic process that converts $UO_2$ powder to small ceramic pellets

(3) a mechanical process that loads the fuel pellets into rods and constructs finished fuel assemblies

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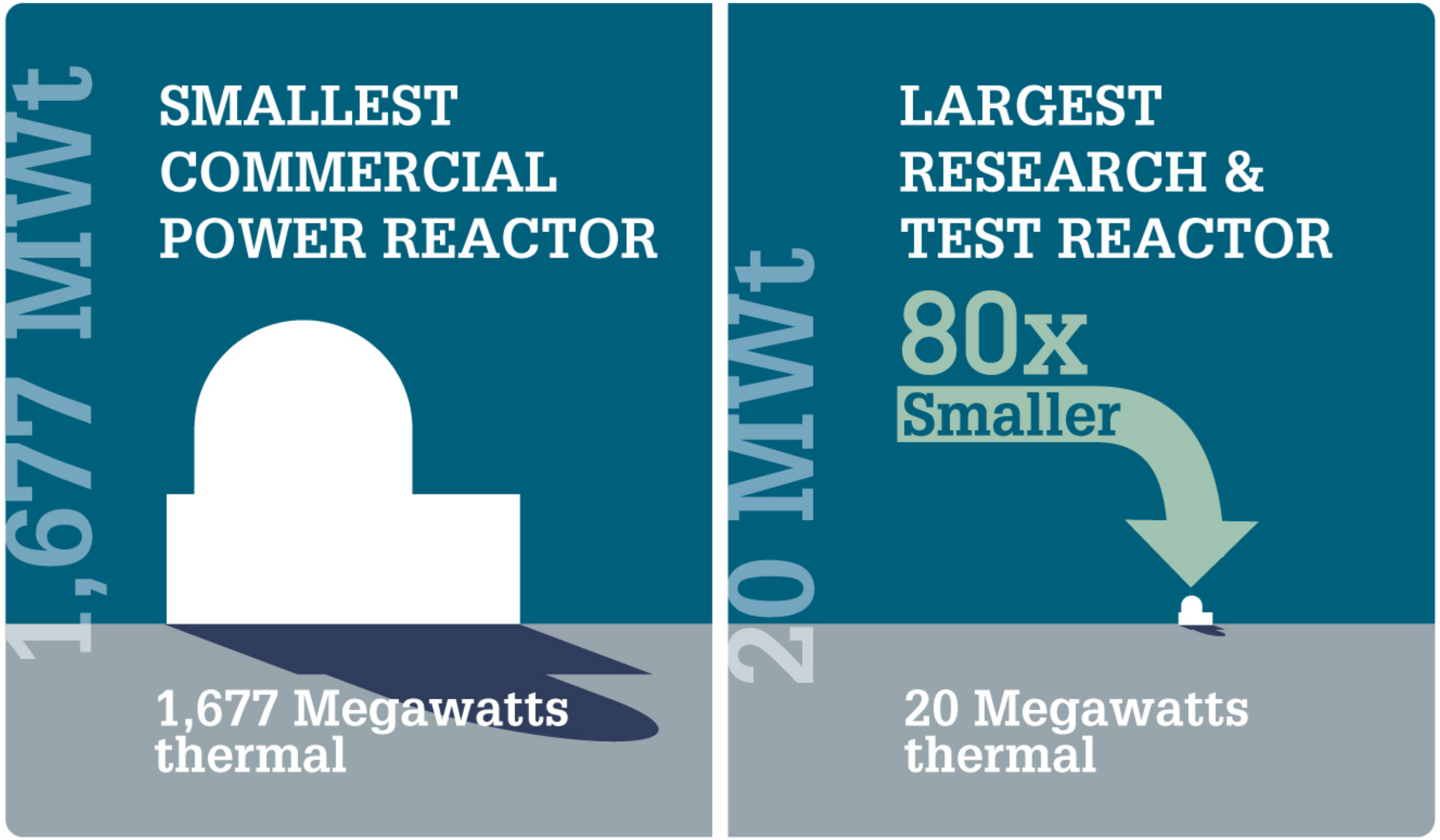
## Size Comparison of Commercial and Research Reactors




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

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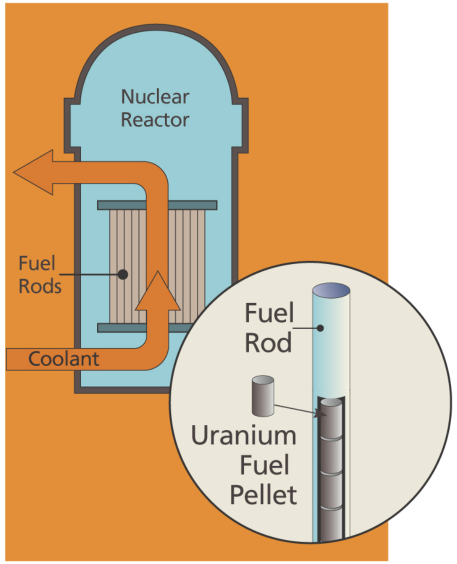
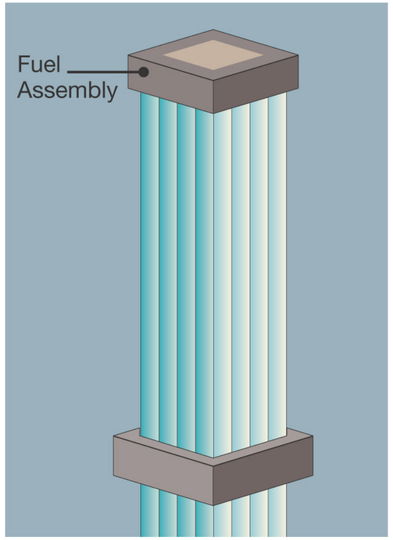
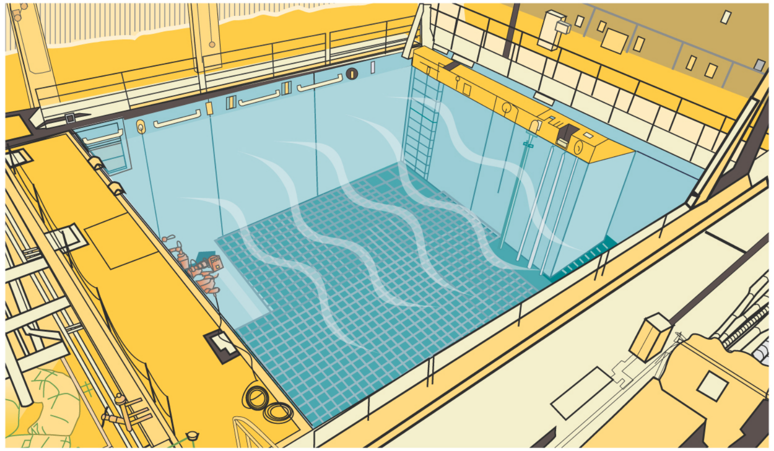
## Spent Fuel Generation and Storage After Use

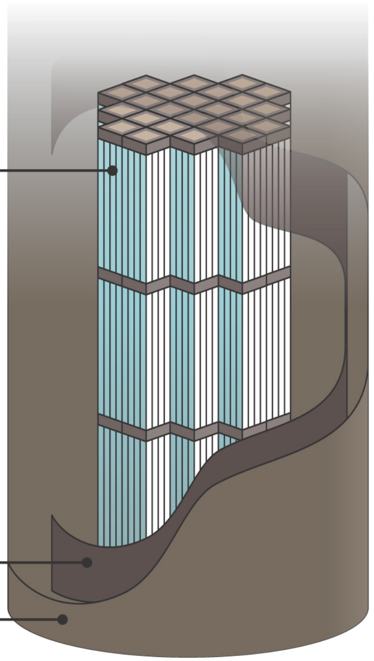
*1* A nuclear reactor is powered by enriched uranium-235 fuel. Fission (splitting of atoms) generates heat, which produces steam that turns turbines to produce electricity. A reactor rated at several hundred megawatts may contain 100 or more tons of fuel in the form of bullet-sized pellets loaded into long metal rods that are bundled together into fuel assemblies. Pressurized-water reactors (PWRs) contain between 120 and 200 fuel assemblies. Boiling-water reactors (BWRs) contain between 370 and 800 fuel assemblies.




*2* After 5–6 years, spent fuel assemblies (which are typically 14 feet [4.3 meters] long and which contain nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs) are removed from the reactor and allowed to cool in storage pools. At this point, the 900-pound (409-kilogram) assemblies contain only about one-fifth the original amount of uranium-235.






*3* Commercial light-water nuclear reactors store spent radioactive fuel in a steel-lined, seismically designed concrete pool under about 40 feet (12.2 meters) of water that provides shielding from radiation. Pumps supply continuously flowing water to cool the spent fuel. Extra water for the pool is provided by other pumps that can be powered from an onsite emergency diesel generator. Support features, such as water-level monitors and radiation detectors, are also in the pool. Spent fuel is stored in the pool until it is transferred to dry casks on site or transported off site for interim storage or disposal.



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## 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.

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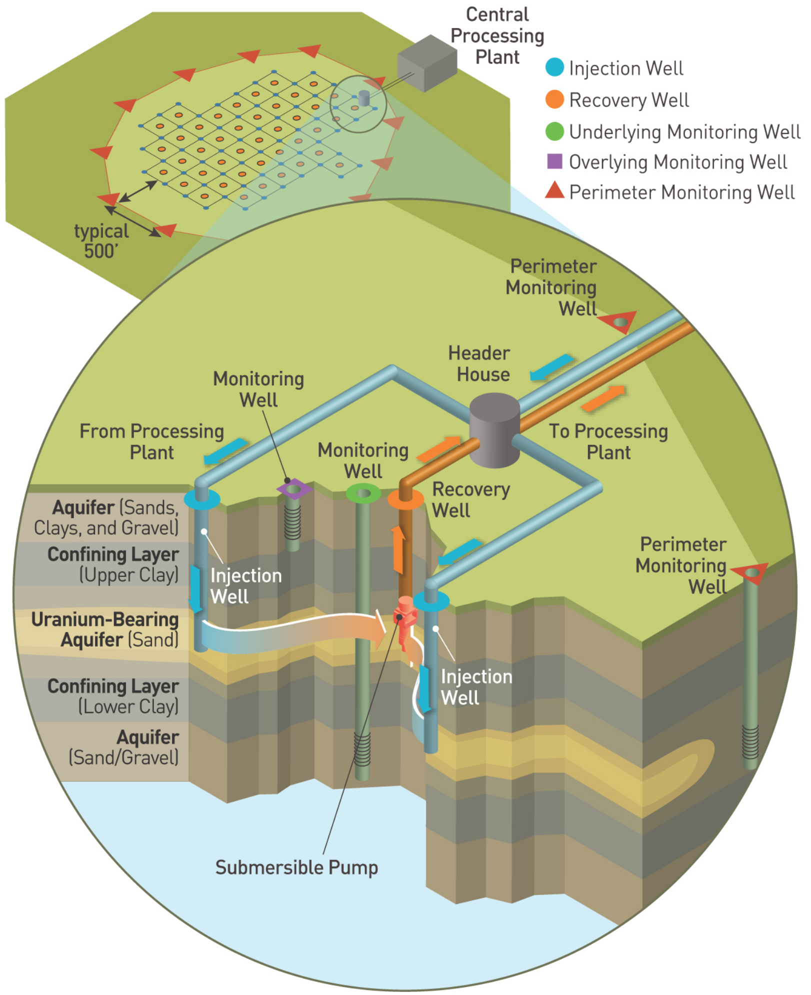
## The In Situ Uranium Recovery Process




Injection wells ● pump a solution of native groundwater, typically mixed with oxygen or hydrogen peroxide and sodium bicarbonate or carbon dioxide, into the aquifer (groundwater) containing uranium ore. The solution dissolves the uranium from the deposit in the ground and is then pumped back to the surface through recovery wells ●, all controlled by the header house. From there, the solution is sent to the processing plant. Monitoring wells ● ■ ▲ are checked regularly to ensure the injection solution is not escaping from the wellfield. Confining layers keep groundwater from moving from one aquifer to another.

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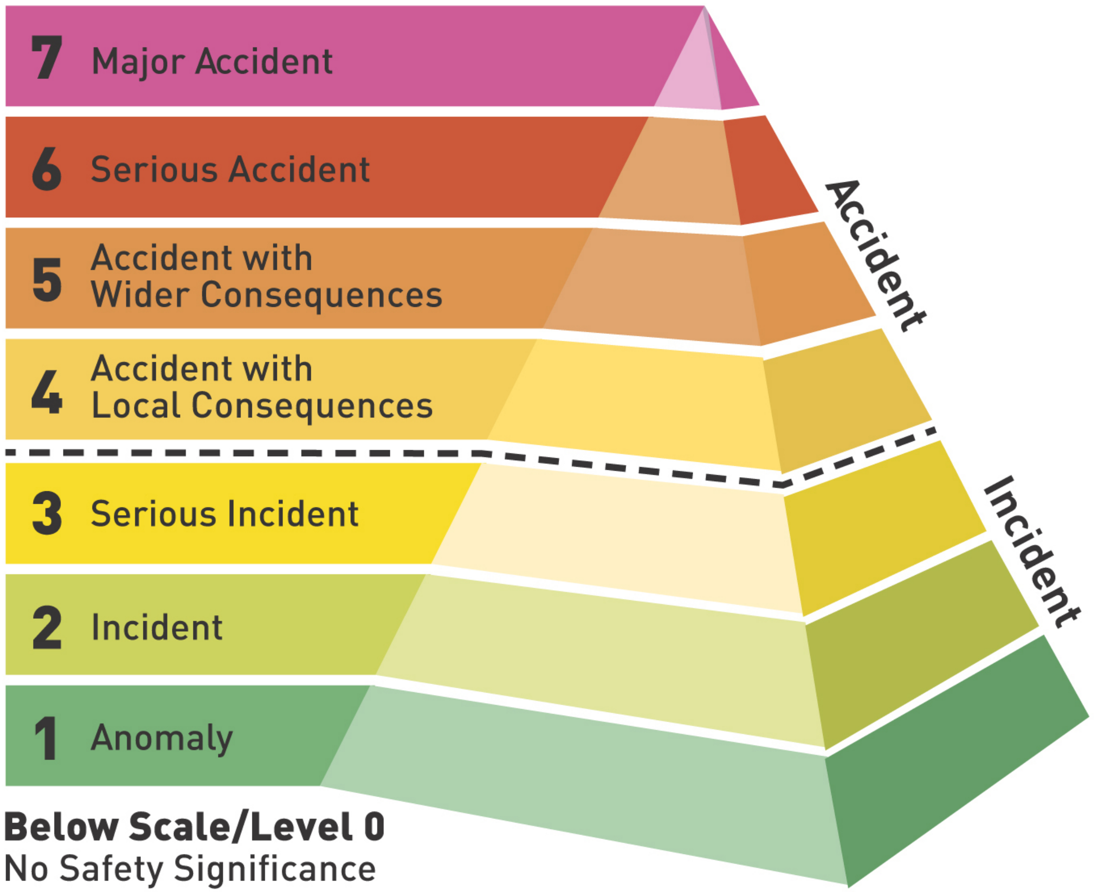
## The International Nuclear and Radiological Event Scale




INES events are classified on the scale at seven levels. Levels 1–3 are called incidents, and Levels 4–7 are called accidents. The scale is designed so that the severity of an event is about 10 times greater for each increase in level on the scale. Events without safety significance are called deviations and are classified as Below Scale or at Level 0.

Source: *https://www.iaea.org/topics/emergency-preparedness-and-response-epr/international-nuclear-radiological-event-scale-ines*

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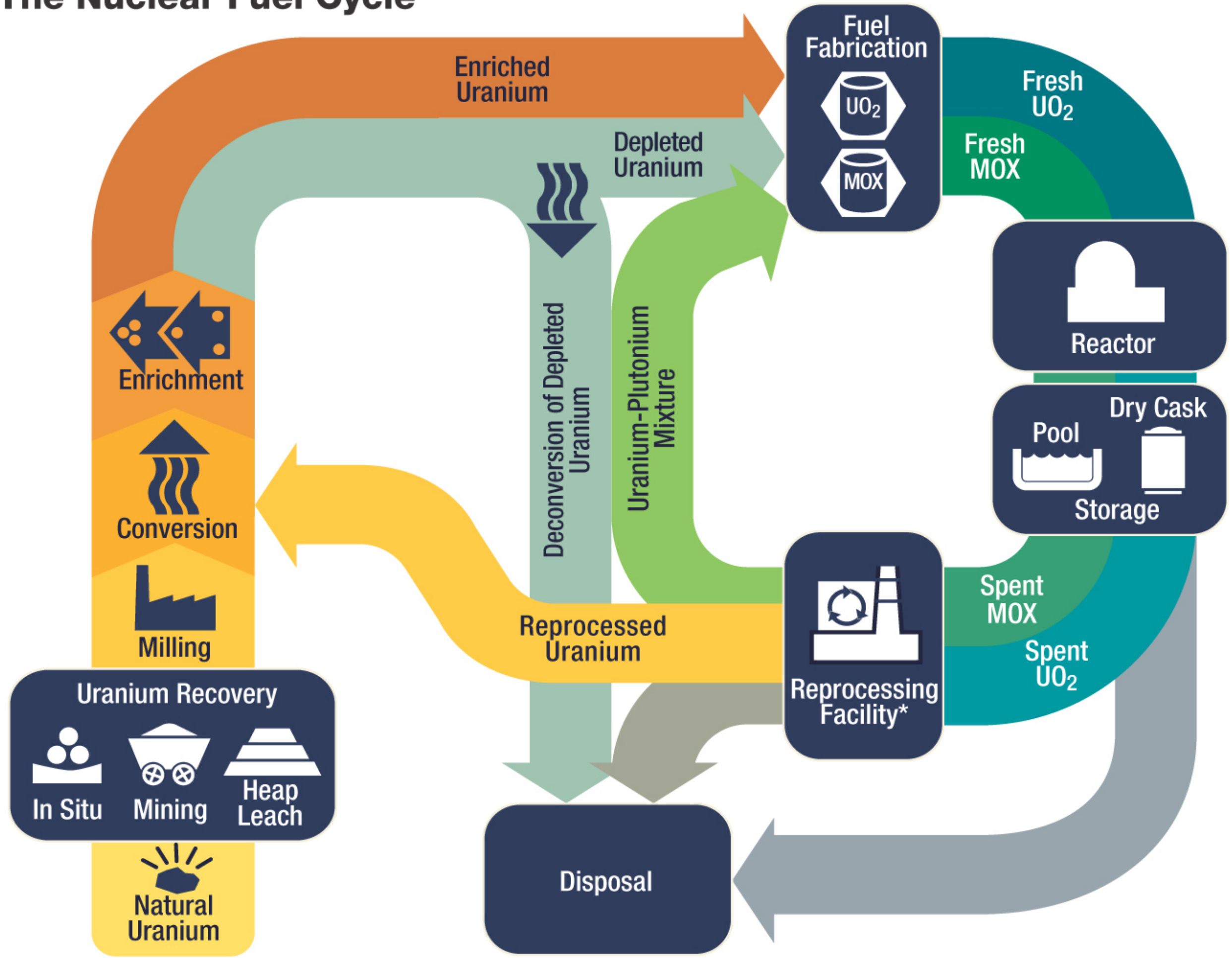
## The Nuclear Fuel Cycle




* Reprocessing of spent nuclear fuel, including mixed-oxide (MOX) fuel, is not practiced in the United States.
Note: The NRC has no regulatory role in mining uranium.

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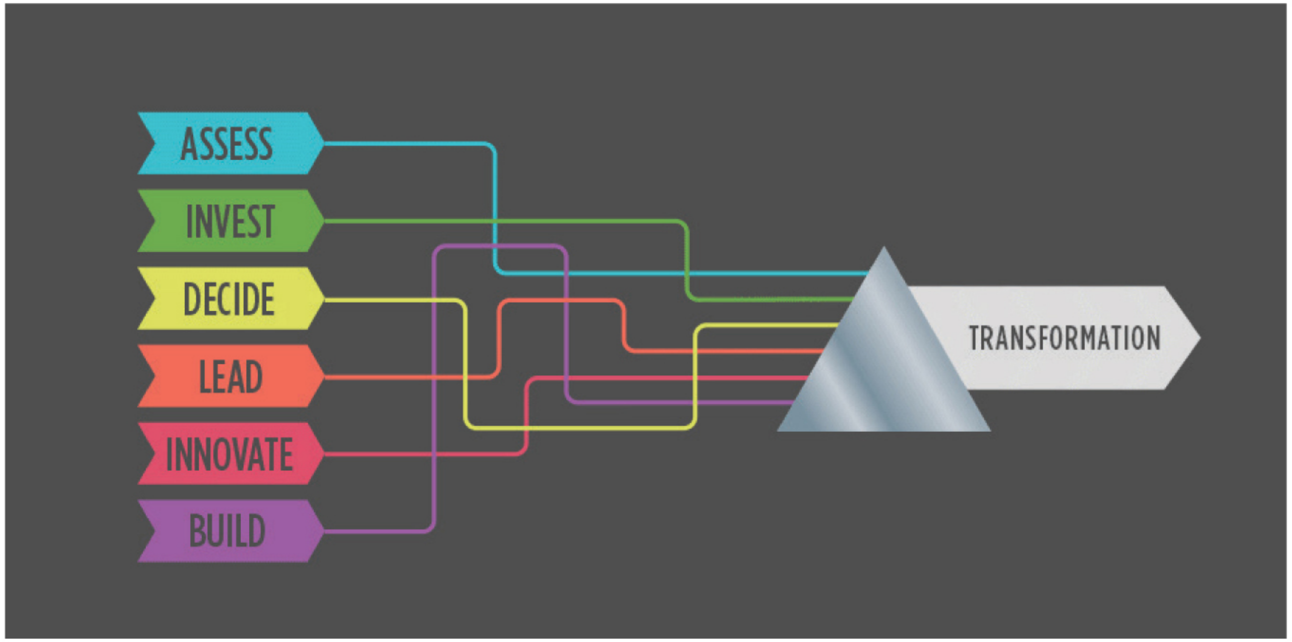
## Transforming the NRC

***Investing in people, innovating processes, and building partnerships by—***

- *Assessing the Future*
- *Investing in Our People*
- *Modernizing NRC Decision-Making*
- *Fostering a Culture of Change*
- *Innovating How We Work*
- *Building Strong Partnerships*

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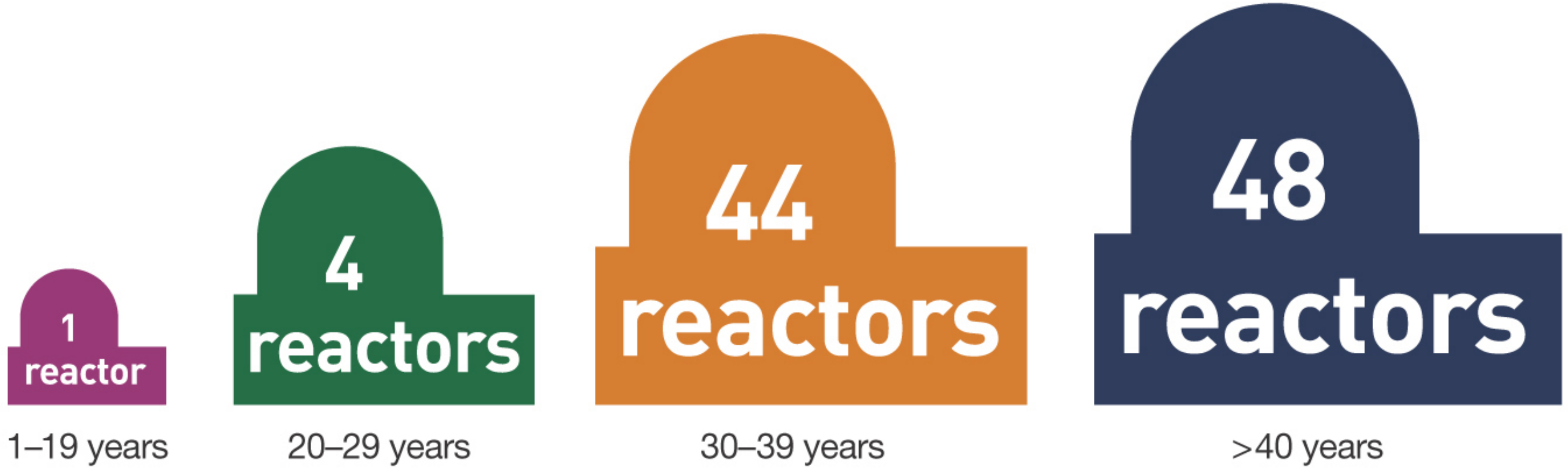
## U.S. Commercial Nuclear Power Reactors—Years of Operation by the End of 2019




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/*.

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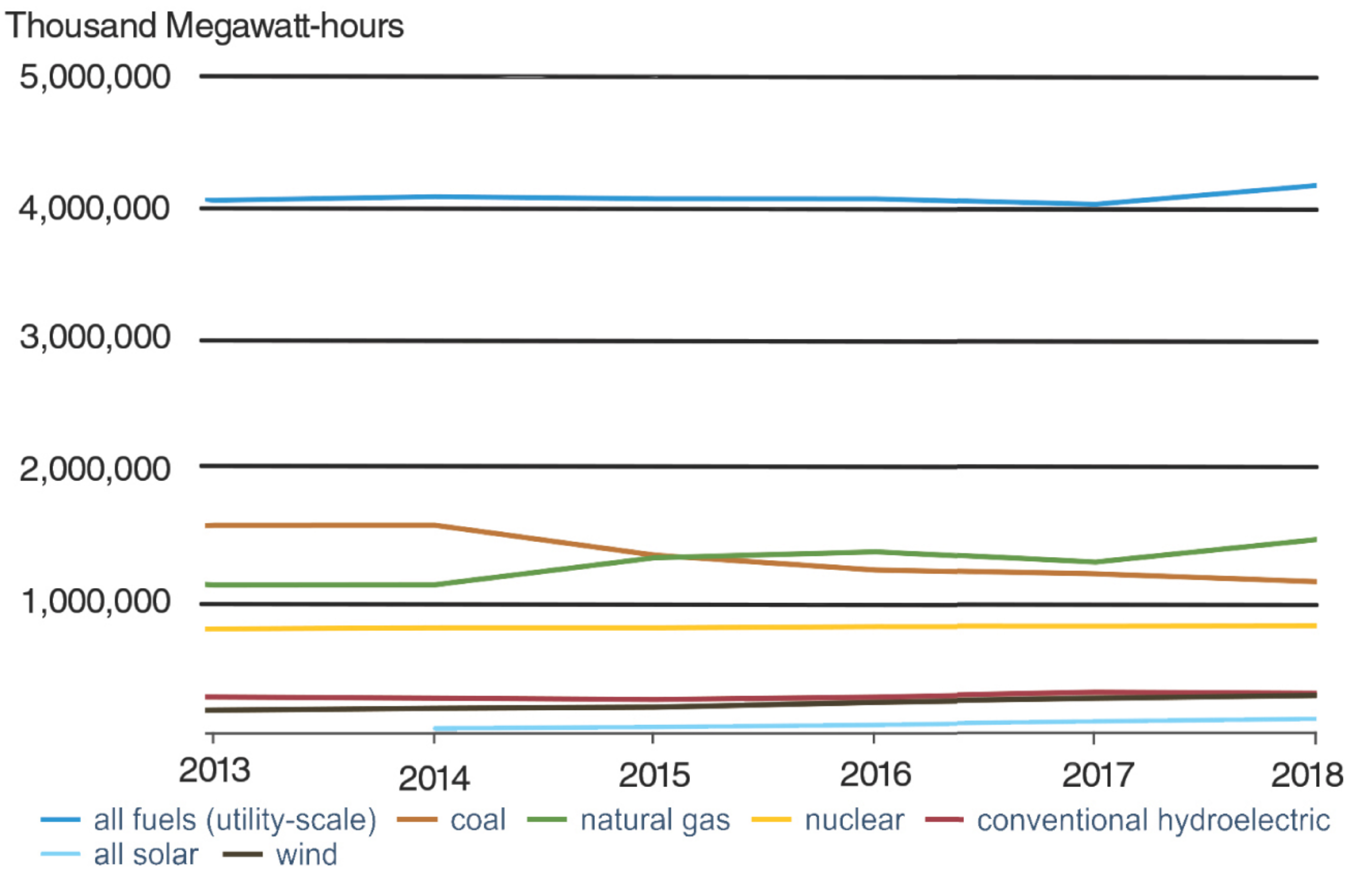
## U.S. Electricity Generation by Energy Source, 2013–2018




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)

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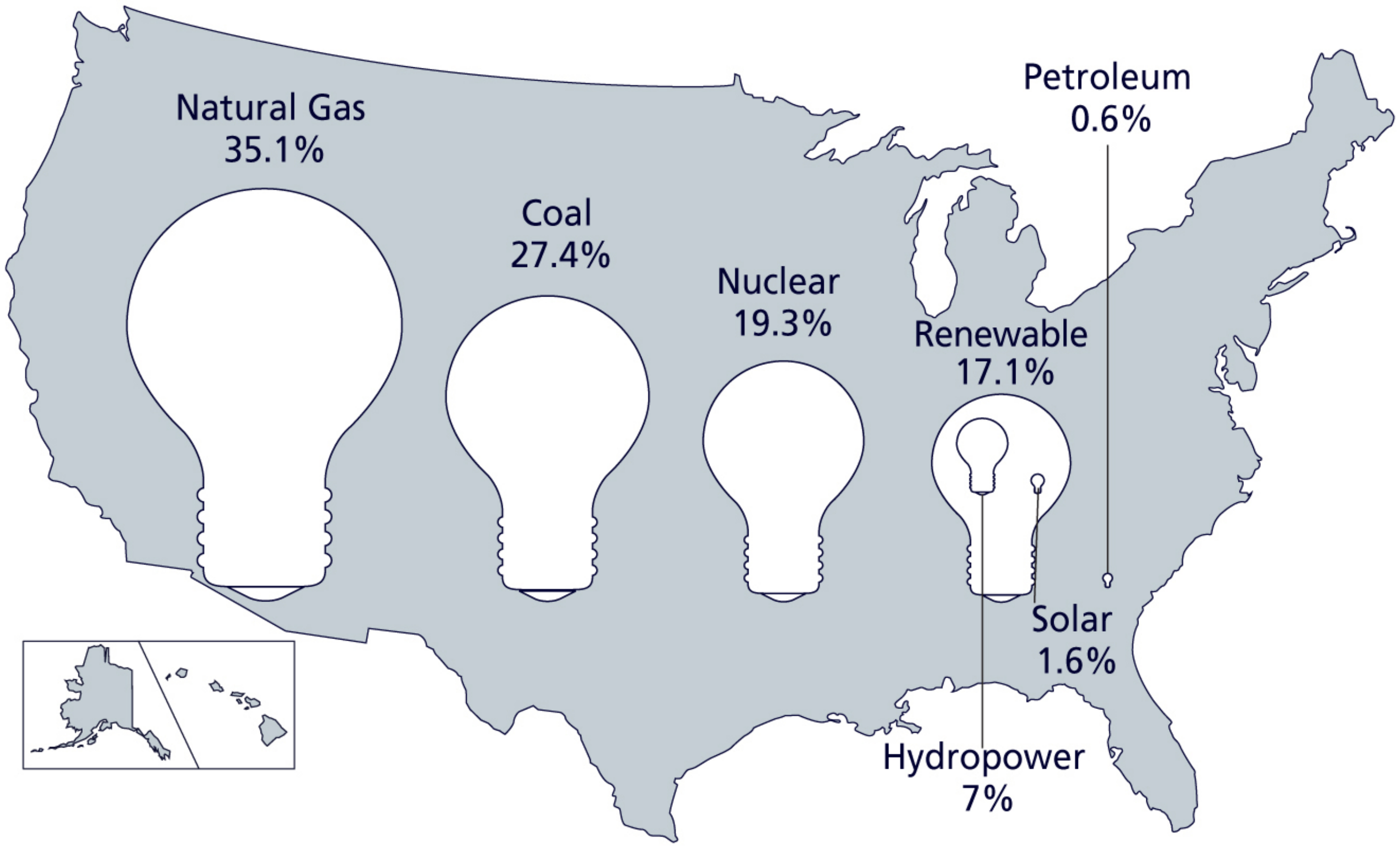
## U.S. Gross Electricity Share by Energy Source, 2018




Note: Figures are rounded.

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

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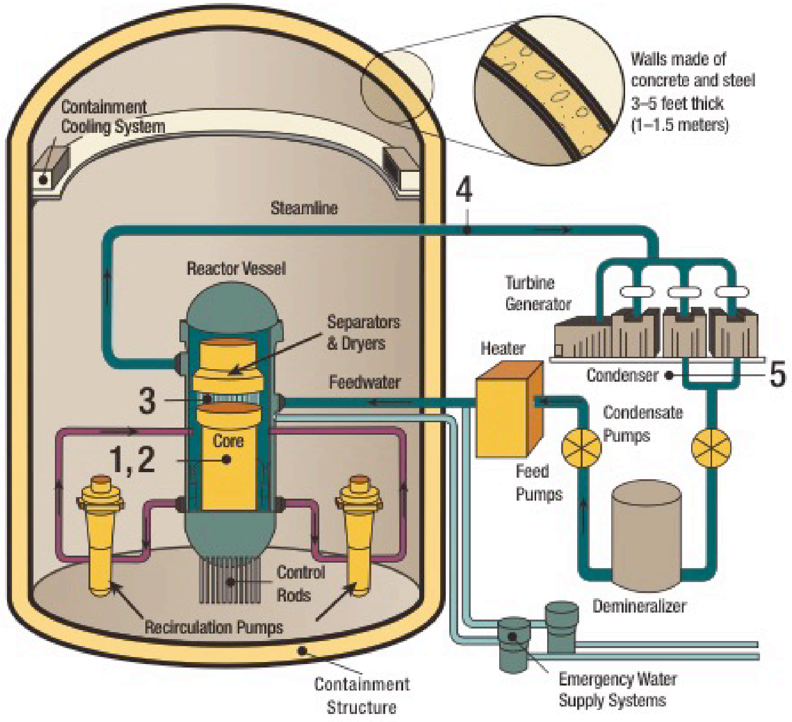
# A Typical Boiling-Water Reactor




**How Nuclear Reactors Work**

In a typical design concept of a commercial BWR, the following process occurs:

1. The nuclear fuel core inside the reactor vessel creates heat from nuclear fission.
2. A steam-water mixture is produced when very pure water (reactor coolant) moves upward through the core, absorbing heat.
3. The steam-water mixture leaves the top of the core and enters the two stages of moisture separation where water droplets are removed before the steam is allowed to enter the steamline.
4. The steam is piped to the main turbine, causing it to turn the turbine generator, which produces electricity.
5. The steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps and pumped back to the reactor vessel.

The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other operating systems in the plant receive their power from the electrical grid. If offsite power is lost, cooling water is supplied by other pumps, which can be powered by onsite diesel generators or steam generated by the core. Other safety systems, such as the containment cooling system, also need electric power. BWRs contain between 370–800 fuel assemblies.

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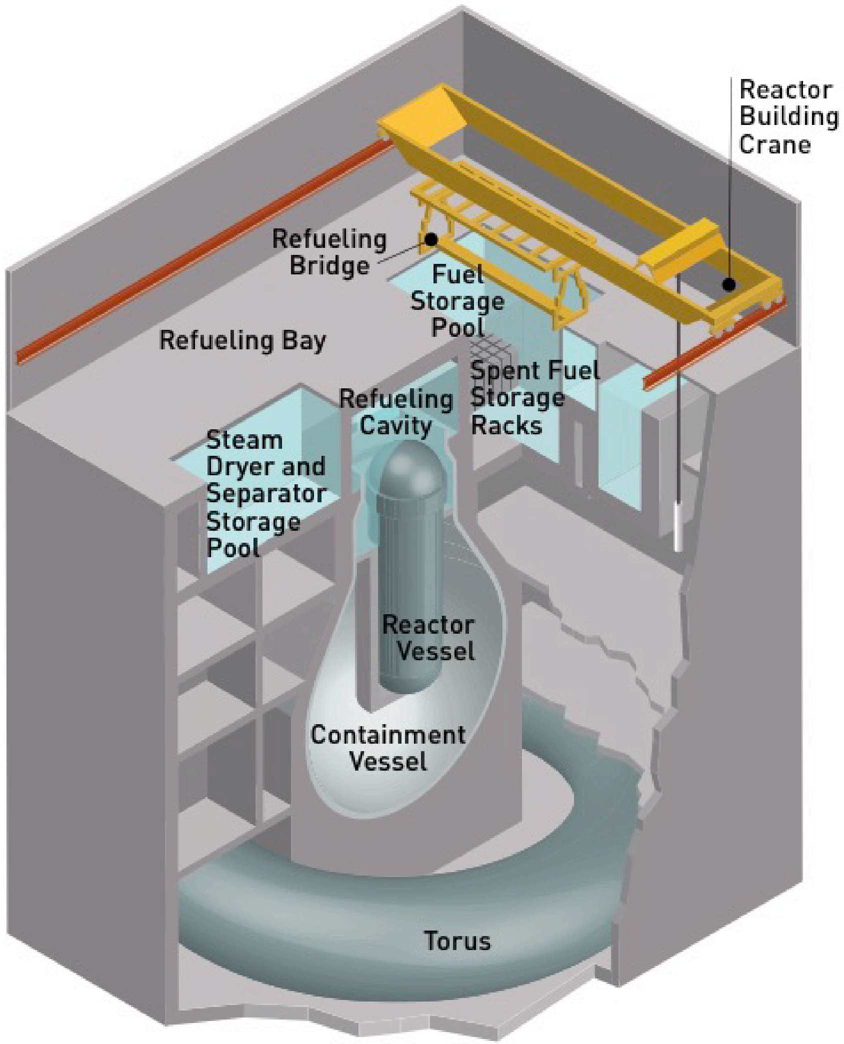
# Boiling-Water Reactor Refueling

**BWR refueling**
As new fuel shipping canisters arrive in the reactor building, the reactor building crane lifts them to the refueling floor, where the fuel is removed from the canister and inspected for defects. The fuel can then be stored in either the new fuel storage area (which is dry) or in the refueling pool, depending upon the needs of the site. Fuel in the new fuel storage area is moved into the fuel pool before refueling begins. To refuel the reactor, the containment vessel lid and the reactor vessel head are removed, the refueling cavity above the reactor vessel is flooded, and the gates between the reactor cavity and fuel pool are removed. The refueling bridge removes one fuel bundle at a time from the reactor and transfers it to the spent fuel storage racks until about a third of the fuel is removed. The process is reversed when fuel is removed from the fuel pool and placed in the reactor. In BWRs, the fuel remains in a vertical position throughout the process.



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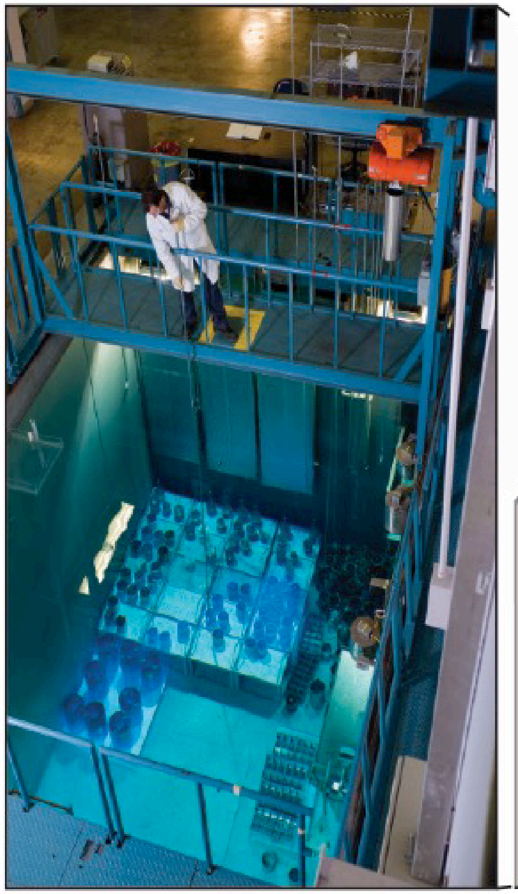
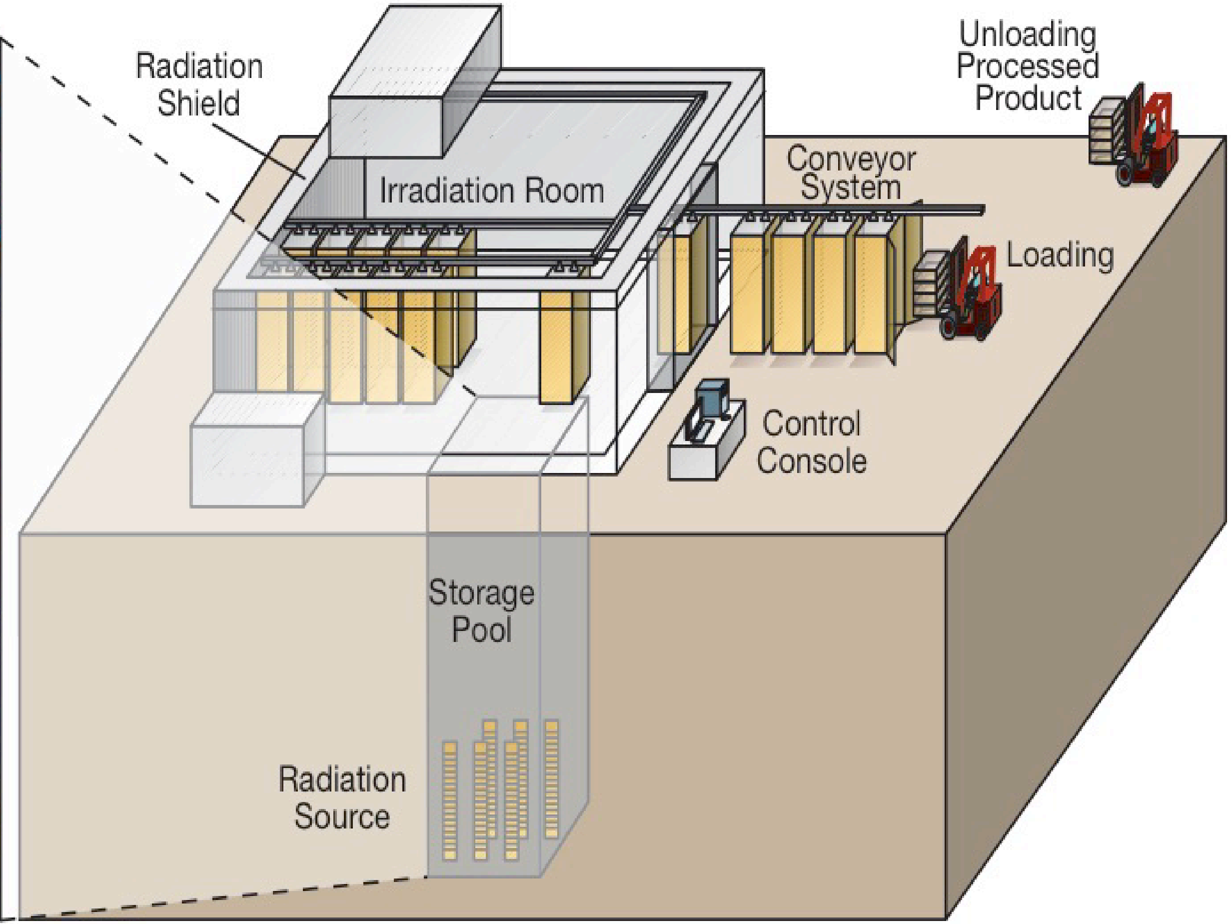
# Commercial Irradiator









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# Dry Cask Storage



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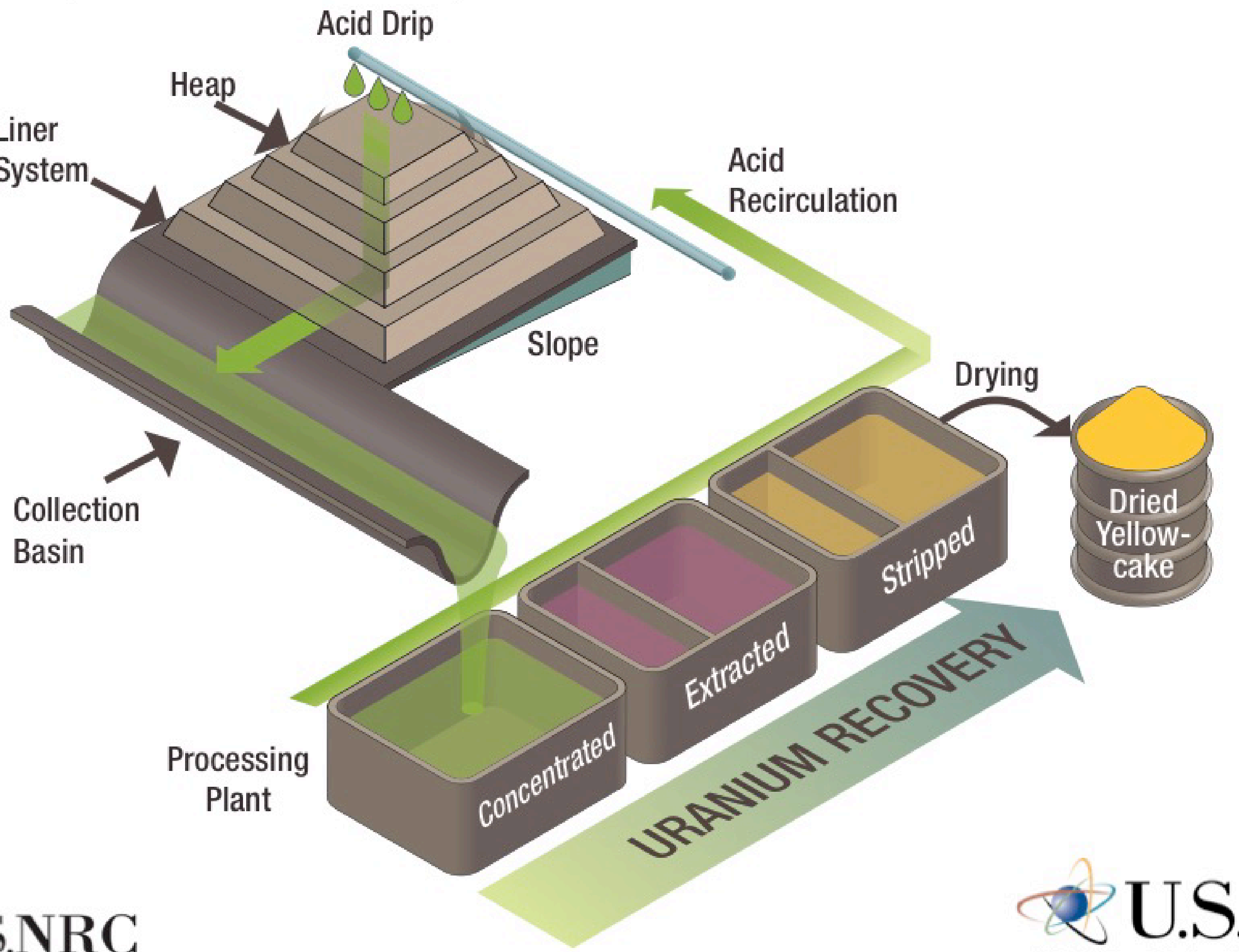
# Heap Leach Recovery Process

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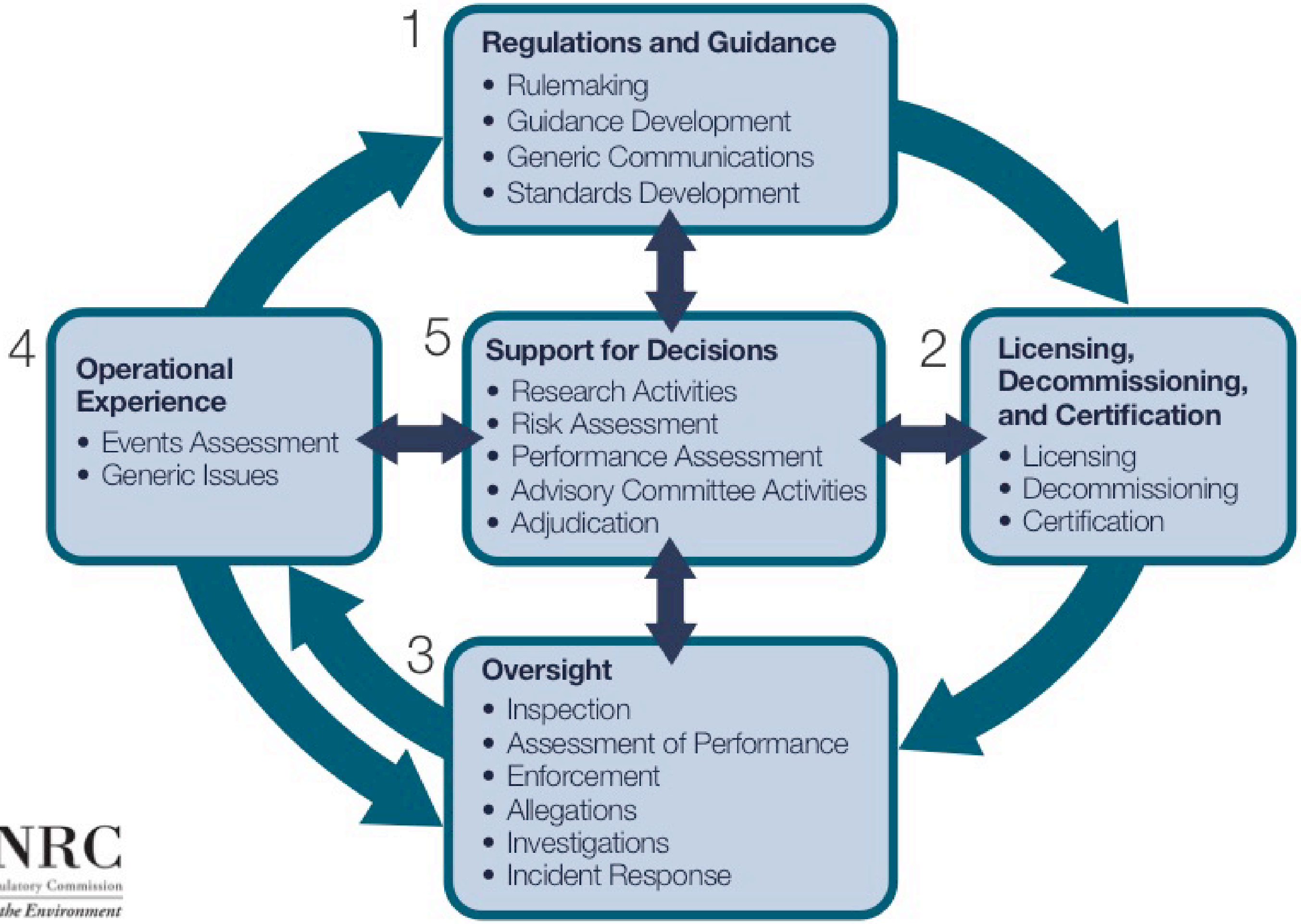
# How We Regulate

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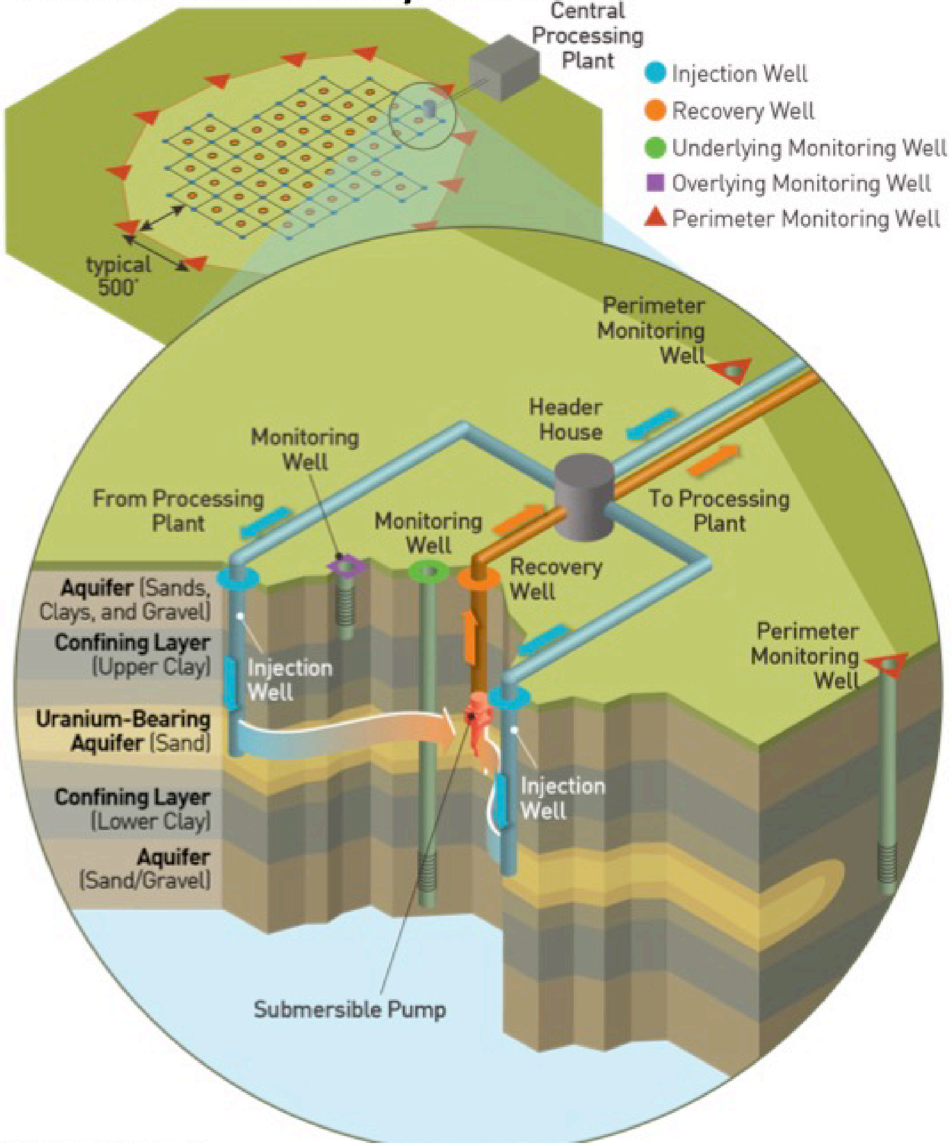
# The In Situ Uranium Recovery Process

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# Gauging Devices

Figure 31. Moisture Density Guage

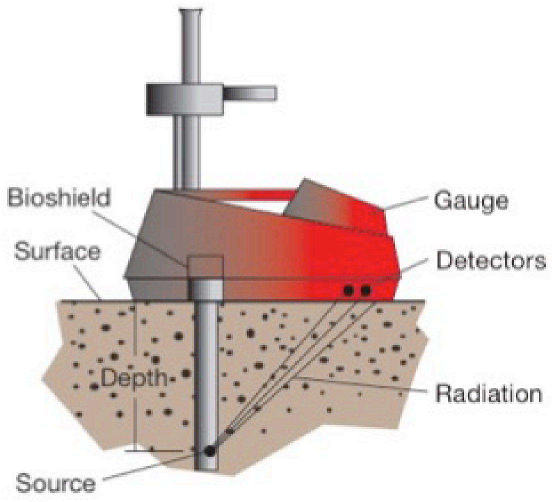
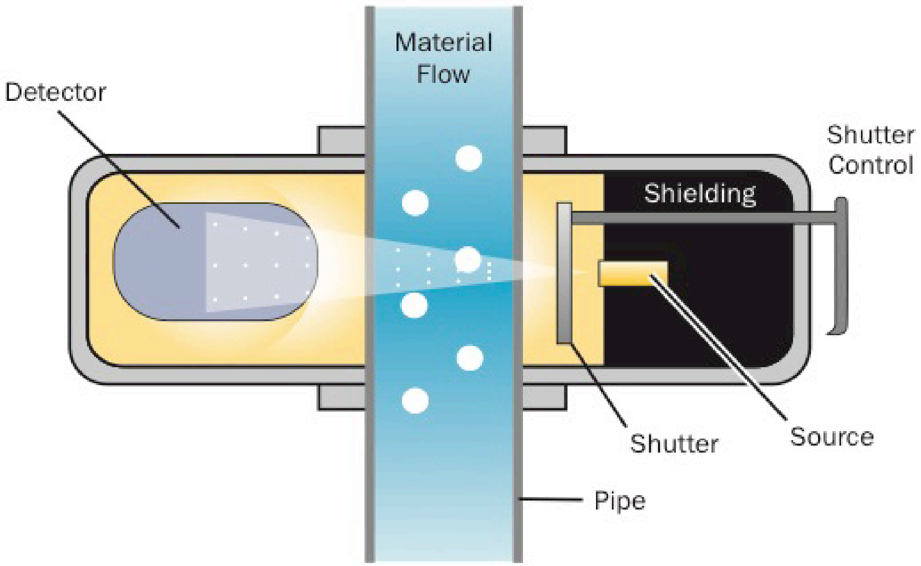



**Figure 35.** Cross-Section of Fixed Fluid Gauge

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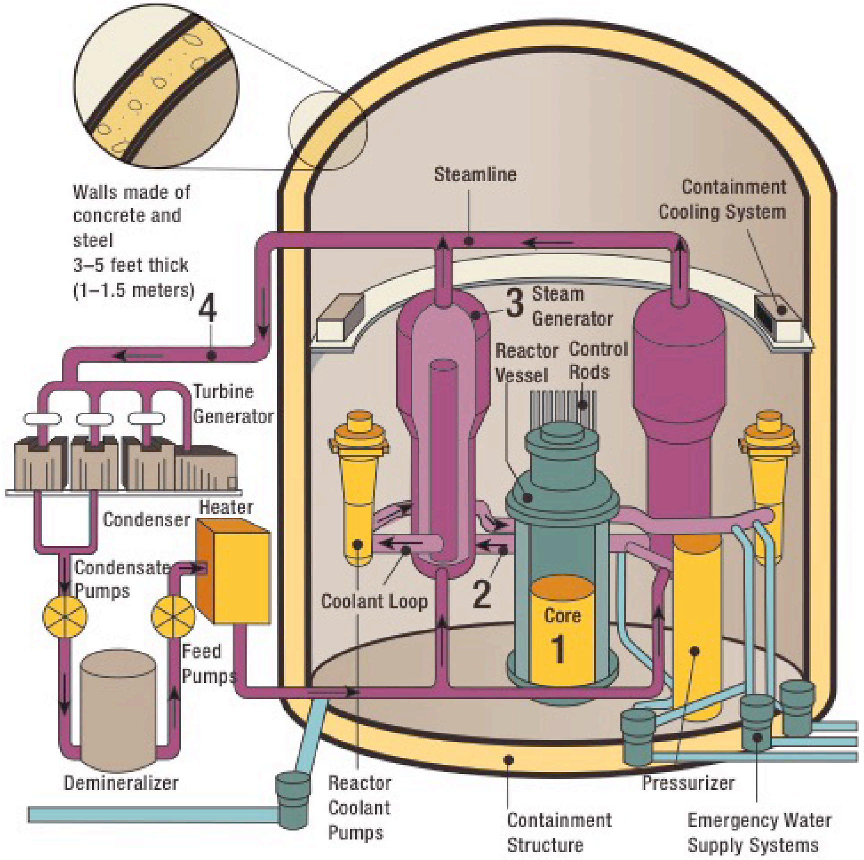
# A Typical Pressurized-Water Reactor




**How Nuclear Reactors Work**

In a typical design concept of a commercial PWR, the following process occurs:

1. The core inside the reactor vessel creates heat.
2. Pressurized water in the primary coolant loop carries the heat to the steam generators.
3. Inside the steam generators, heat from the primary coolant loop vaporizes the water in a secondary loop, producing steam.
4. The steamline directs the steam to the main turbine, causing it to turn the turbine generators, which produces electricity.

The steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the steam generators. The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other systems in the plant receive their power from the electrical grid. If offsite power is lost, cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power. PWRs contain between 120–200 fuel assemblies.

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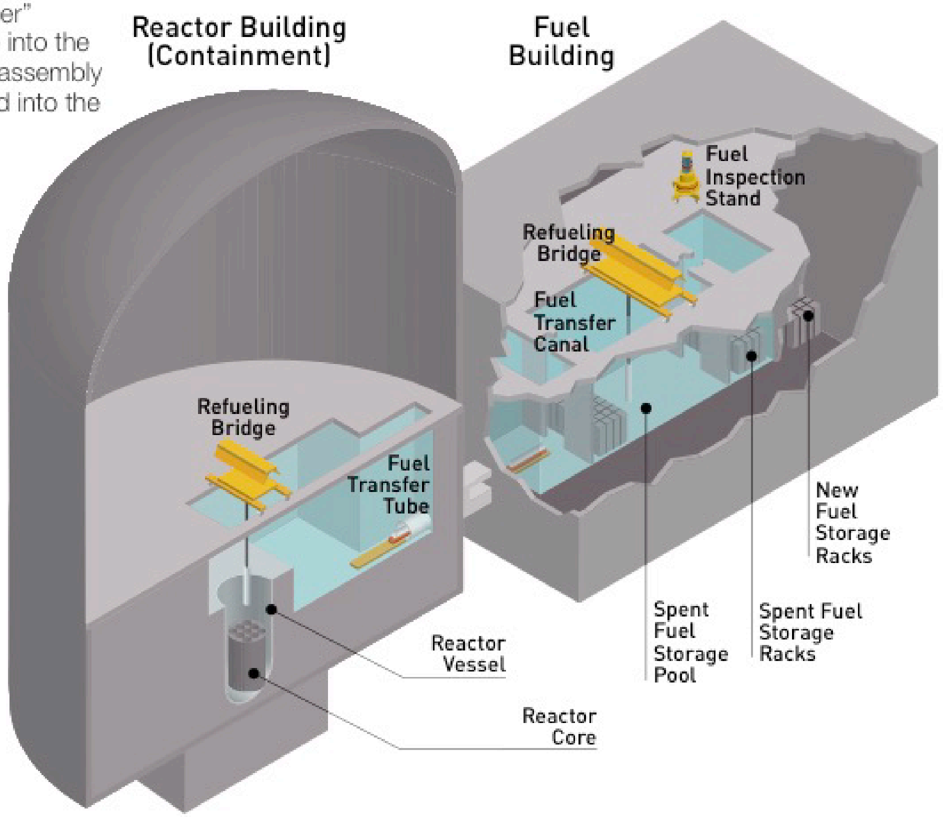
# Pressurized-Water Reactor Refueling

**PWR refueling**

As new fuel shipping canisters arrive in the fuel building, the reactor building crane (not shown) lifts them to the fuel inspection stand, where the fuel is removed from the canister and inspected for defects. Fuel in the new fuel storage area is moved into the fuel pool before refueling begins. The fuel can then be stored in either the new fuel storage racks (which are dry) or in the refueling pool, depending upon the needs of the site. Fuel in the new fuel storage area is moved into the fuel pool before refueling begins. To refuel the reactor, the vessel head is removed, the fuel transfer canals and transfer tube areas are flooded, and removable gates are opened in order to connect the refueling canal to the fuel pool. The reactor building refueling bridge is used to remove a fuel assembly from the reactor vessel and transfer it to the "up-ender" basket, which is then tilted until it is horizontal, sent through the transfer tube into the fuel building, and returned upright. The refueling bridge then moves the fuel assembly into the spent fuel storage racks. This process is reversed when fuel is loaded into the reactor.

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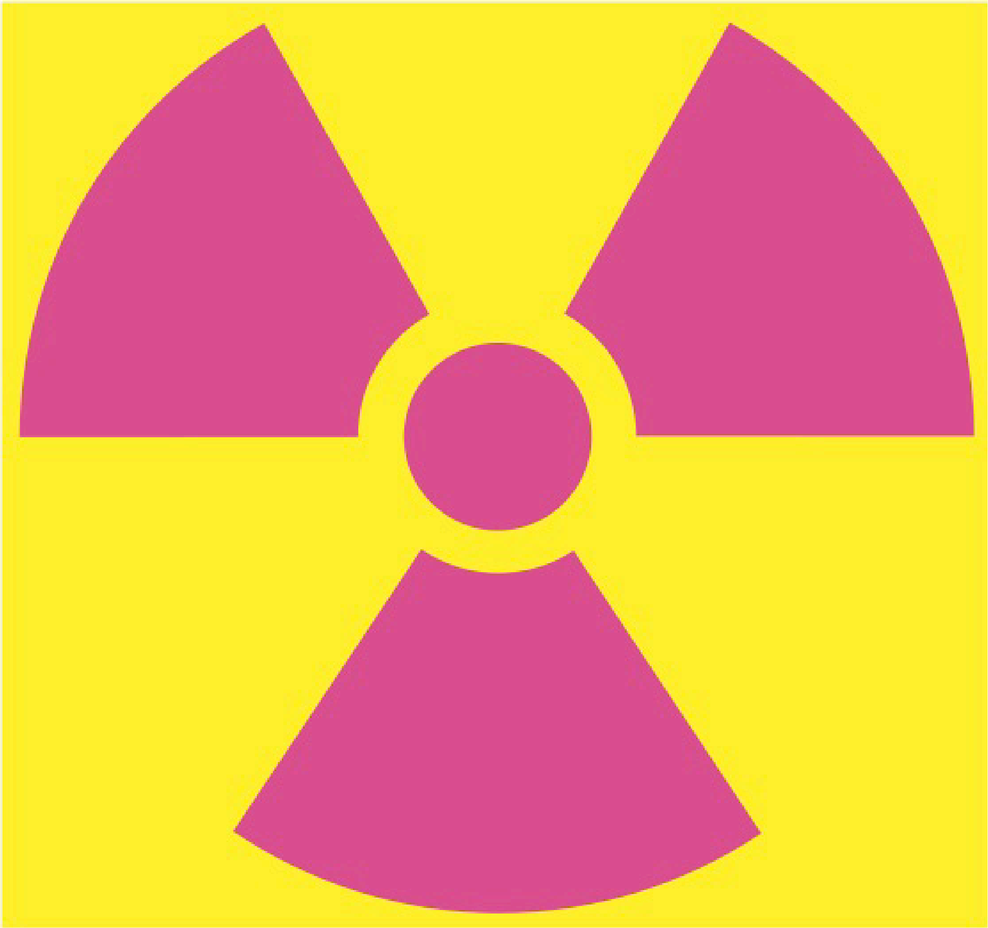
# Radiation Warning Symbol





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