

RADIOACTIVE WASTE

Low-Level Radioactive Waste Disposal

Low-level radioactive waste (LLW) includes items contaminated with radioactive material or exposed to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, medical waste, and laboratory animal carcasses and tissue. Some LLW is quite low in radioactivity—even as low as just above background levels found in nature. Some licensees, notably hospitals, store such waste on site until it has decayed and lost most of its radioactivity. Then it can be disposed of as ordinary trash. Other LLW, such as parts of a reactor vessel from a nuclear power plant, is more radioactive and requires special handling. Waste that does not decay fairly quickly is stored until amounts are large enough for shipment to an LLW disposal site in containers approved by DOT and the NRC.

Commercial LLW can be disposed of in facilities licensed by either the NRC or Agreement States. The facilities are designed, constructed, and operated to meet NRC and State safety standards. The facility operator analyzes how the facility will perform in the future based on the environmental characteristics of the site. Current LLW disposal uses shallow land disposal sites with or without concrete vaults (see Figure 33. Low-Level Radioactive Waste Disposal).

Determining the classification of waste can be a complex process. The NRC classifies LLW based on its potential hazards. The NRC has specified disposal and waste requirements for three classes of waste—Class A, B, and C—with progressively higher concentrations of radioactive material. Class A waste, the least radioactive, accounts for approximately 96 percent of the total volume of LLW in the United States. A fourth class of LLW, called "greater-than-Class-C waste," must be disposed of in a geological repository licensed by the NRC unless the Commission approves an alternative proposal. Under the Low-Level Radioactive Waste Policy Amendments Act of 1985, DOE is responsible for disposal of greater-than-Class-C waste.

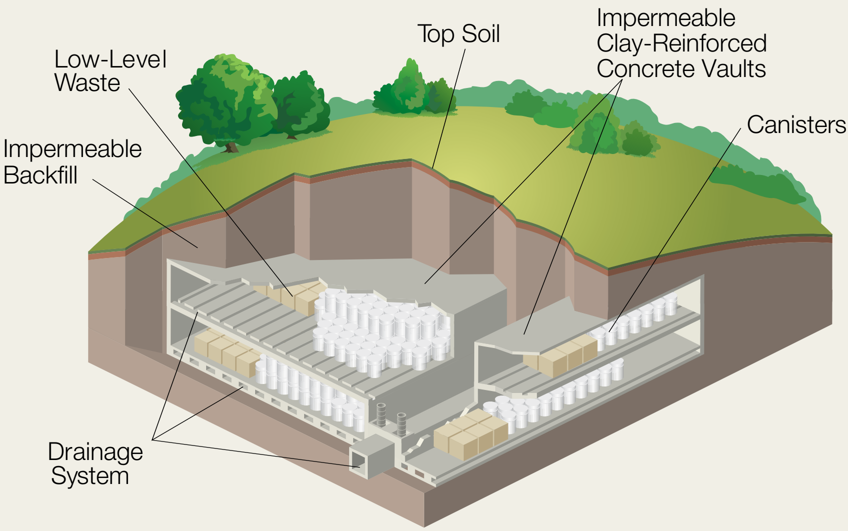
See Appendix P for regional compacts and closed LLW sites.

The volume and radioactivity of waste vary from year to year. Waste volumes currently include several million cubic feet each year from operating and decommissioning reactor facilities and from cleanup of contaminated sites.

The Low-Level Radioactive Waste Policy Amendments Act gave the States responsibility for LLW disposal. The Act authorized States to:

- form regional compacts, with each compact to provide for LLW disposal site access
- manage LLW import to, and export from, a compact
- exclude waste generated outside a compact

Figure 33. Low-Level Radioactive Waste Disposal



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

The States have licensed four active LLW disposal facilities:

- EnergySolutions' Barnwell facility, located in Barnwell, SC—Previously, Barnwell accepted LLW from all U.S. generators of LLW. Barnwell now accepts waste only from the Atlantic Compact States of Connecticut, New Jersey, and South Carolina. The State of South Carolina licensed Barnwell to receive Class A, B, and C waste.
- EnergySolutions' Clive facility, located in Clive, UT—Clive accepts waste from all regions of the United States. The State of Utah licensed Clive for Class A waste only.
- U.S. Ecology's Richland facility, located in Richland, WA, on the Hanford Nuclear Reservation—Richland accepts waste from the Northwest Compact States (Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming) and the Rocky Mountain Compact States (Colorado, Nevada, and New Mexico). The State of Washington licensed Richland to receive Class A, B, and C waste.
- Waste Control Specialists' Andrews facility, located in Andrews, TX—Andrews accepts waste from the Texas Compact, which consists of Texas and Vermont. It also accepts waste from out-of-compact generators on a case-by-case basis. The State of Texas licensed Andrews to receive Class A, B, and C waste.

High-Level Radioactive Waste Management

Spent Nuclear Fuel Storage

Commercial spent nuclear fuel, although highly radioactive, is stored safely and securely throughout the United States. Spent fuel is stored in pools and in dry casks at sites with operating nuclear power reactors. Several storage facilities do not have operating power reactors but are safely and securely storing spent fuel. Waste can be stored safely in pools or casks for 100 years or more. The NRC licenses and regulates the storage of spent fuel, both at commercial nuclear power plants and at separate storage facilities.

See Appendices N and O for information about dry spent fuel storage and licensees.

Most reactor facilities were not designed to store the full amount of spent fuel that the reactors would generate during their operational lives. Facilities originally planned to store spent fuel temporarily in deep pools of continuously circulating water, which cools the spent fuel assemblies. After a few years, the facilities were expected to send the spent fuel to a reprocessing plant. However, in 1977, the U.S. Government declared a moratorium on reprocessing spent fuel in the United States. Although the Government later lifted the restriction, reprocessing has not resumed in the United States.

See Glossary for information on fuel reprocessing (recycling).

As a result, facilities expanded their storage capacity by using high-density storage racks in their spent fuel pools. To provide supplemental storage, some fuel assemblies are stored in dry casks on site (see Figure 34. Spent Fuel Generation and Storage After Use). These facilities are called independent spent fuel storage installations (ISFSIs) and are licensed by the NRC. These large casks are typically made of leak-tight, welded, and bolted steel and concrete surrounded by another layer of steel or concrete. The spent fuel sits in the center of the cask in an inert gas. Dry cask storage shields people and the environment from radiation and keeps the spent fuel inside dry and nonreactive (see Figure 35. Dry Storage of Spent Nuclear Fuel).

Another type of ISFSI is called a Consolidated Interim Storage Facility (CISF). A CISF would store spent fuel from multiple commercial reactors, including those that have ceased operation, on a interim basis until a permanent disposal option is available. Additional information on consolidated interim storage is available on the NRC's Web site (see the Web Link Index).

The NRC regulates facilities that store spent fuel in two different ways. The NRC may grant site-specific licenses after a safety review of the technical requirements and operating conditions for an ISFSI. The NRC has issued a general license authorizing nuclear power reactor licensees to store spent fuel on site in dry storage casks

that the NRC has certified. Following a similar safety review, the NRC may issue a Certificate of Compliance and add the cask to a list of approved systems through a rulemaking. The agency issues licenses and certificates for terms not to exceed 40 years, but they can be renewed for up to an additional 40 years (see Figure 36. Licensed and Operating Independent Spent Fuel Storage Installations by State).

Public Involvement

The public can participate in decisions about spent nuclear fuel storage, as it can in many licensing and rulemaking decisions. The Atomic Energy Act of 1954, as amended, and the NRC's own regulations call for public meetings about site-specific licensing actions and allow the public to comment on Certificate of Compliance rulemakings. Members of the public may also file petitions for rulemaking. Additional information on ISFSIs is available on the NRC's Web site (see the Web Link Index).

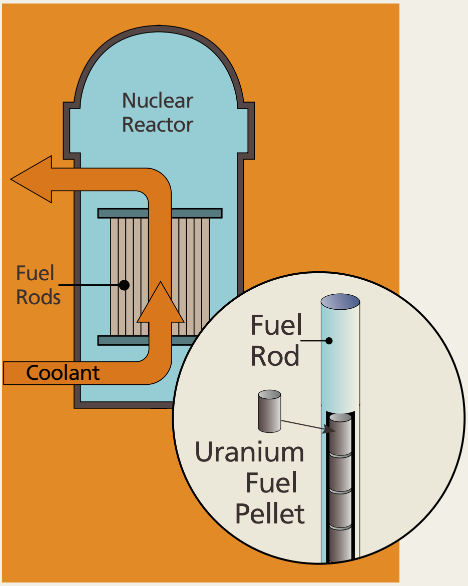
NRC Senior Resident Inspector James McGhee (right) takes time to discuss topics of interest at a public meeting held to discuss the performance of area nuclear power plants and their future decommissioning process.

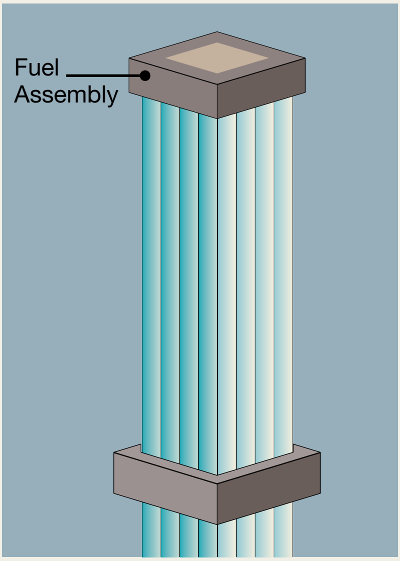
Spent Nuclear Fuel Disposal

The current U.S. policy governing permanent disposal of high-level radioactive waste is defined by the Nuclear Waste Policy Act of 1982, as amended, and the Energy Policy Act of 1992. These acts specify that high-level radioactive waste will be disposed of underground in a deep geologic repository licensed by the NRC. Because the timing of repository availability is uncertain, the NRC looked at potential environmental impacts of storing spent fuel over three possible timeframes: the short term, which includes 60 years of continued storage after a reactor's operating license has expired; the medium term, or 160 years after license expiration; and indefinite, which assumes a repository never becomes available. The NRC's findings—that any environmental impacts can be managed—appear in the 2014 report NUREG-2157, "Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel."

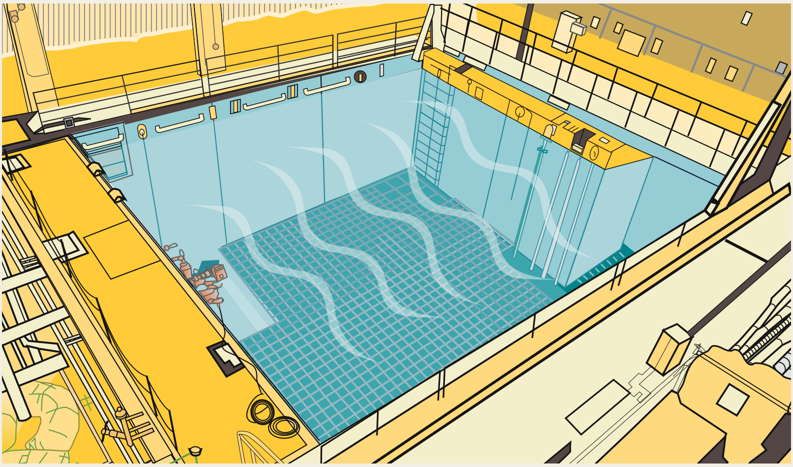
Figure 34. Spent Fuel Generation and Storage After Use

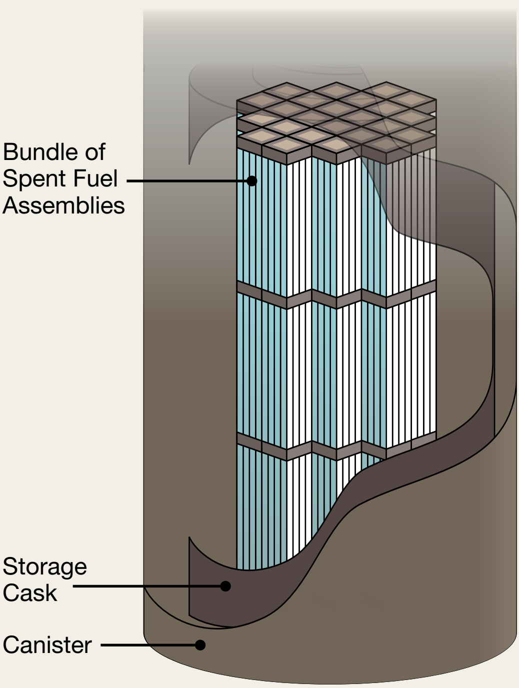
1 A nuclear reactor is powered by enriched uranium-235 fuel. Fission (splitting of atoms) generates heat, which produces steam that turns turbines to produce electricity. A reactor rated at several hundred megawatts may contain 100 or more tons of fuel in the form of bullet-sized pellets loaded into 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.



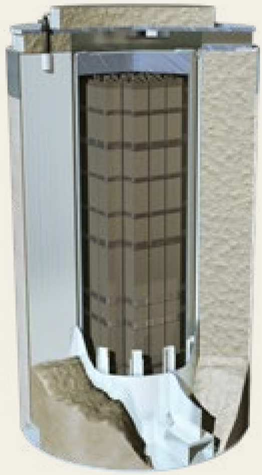


3 Commercial light-water nuclear reactors store spent radioactive fuel in a steel-lined, seismically designed concrete pool under about 40 feet (12.2 meters) of water that provides shielding from radiation. Pumps supply continuously flowing water to cool the spent fuel. Extra water for the pool is provided 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.

Figure 35. 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.

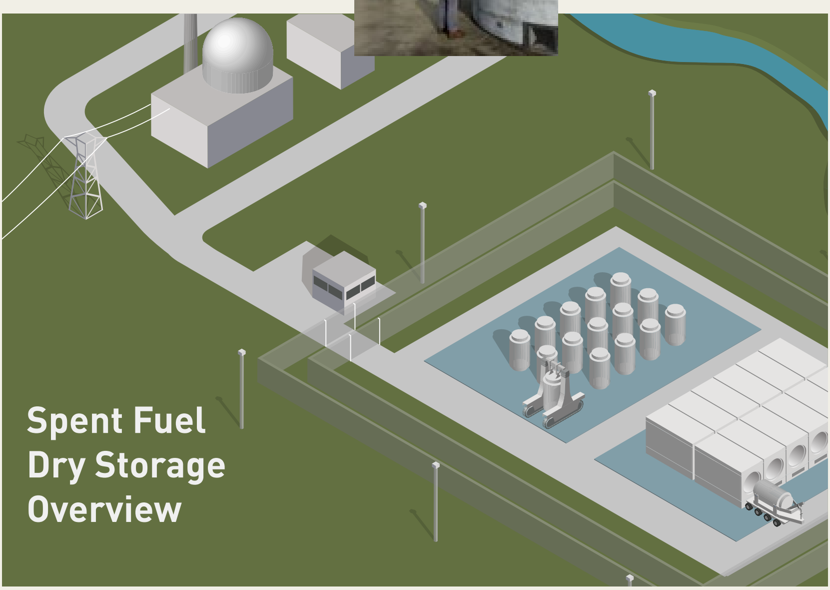
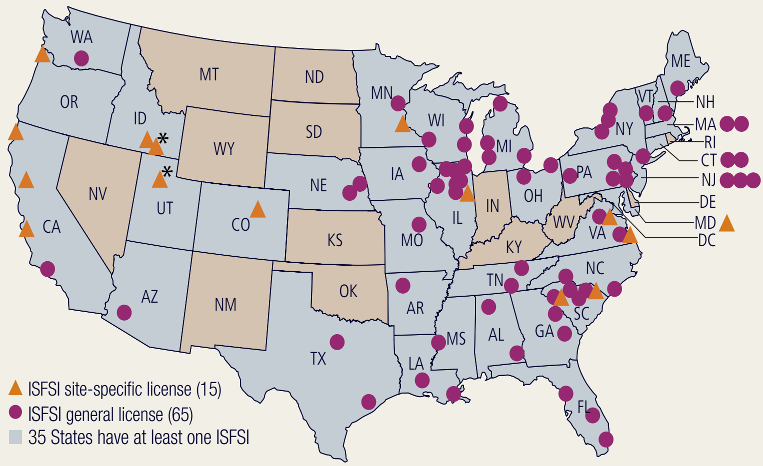


Figure 36. Licensed and Operating Independent Spent Fuel Storage Installations by State



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/*.

The NRC adopted those findings into NRC regulations in a continued storage rule. This rule provides an important basis for issuing new or renewed licenses for nuclear power plants and spent fuel storage facilities.

Transportation

The NRC regulates the transportation of spent nuclear fuel. The NRC establishes safety and security requirements in collaboration with DOT, certifies transportation cask designs, and conducts inspections to ensure that requirements are being met. Spent nuclear fuel transportation casks are designed to meet the following safety criteria under both normal and accident conditions:

- prevents the loss or dispersion of radioactive contents
- shields everything outside the cask from the radioactivity of the contents
- dissipates the heat from the contents
- prevents nuclear criticality (a self-sustaining nuclear chain reaction) from occurring inside the cask

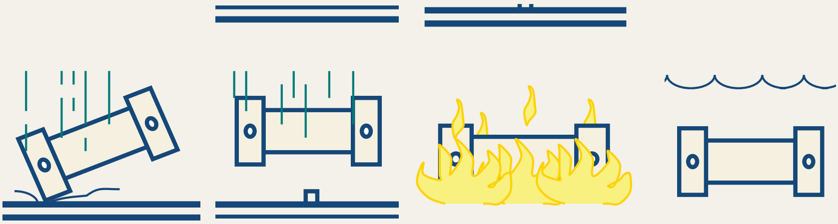
Transportation casks must be designed to survive a sequence of tests, including a 30-foot (9-meter) drop onto an unyielding surface, a puncture test, a fully engulfing fire at 1,475 degrees Fahrenheit (800 degrees Celsius) for 30 minutes, and immersion under water. This very severe test sequence, akin to the cask striking a concrete pillar along a highway at high speed and being engulfed in a severe and long-lasting fire and then falling into a river, simulates conditions more severe than 99 percent of vehicle accidents (see Figure 37. Ensuring Safe Spent Fuel Shipping Containers).

To ensure the safe transportation of spent nuclear fuel and other nuclear materials, each year the NRC takes the following actions:

- conducts transportation safety inspections of fuel, reactor, and materials licensees
- reviews, evaluates, and certifies new, renewed, or amended transportation package design applications
- conducts inspections of cask vendors and manufacturers to ensure the quality of dry cask design and fabrication

Additional information on materials transportation is available on the NRC's Web site (see the Web Link Index).

Figure 37. 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.

A transport package is placed inside a conveyance vehicle.

Decommissioning

Decommissioning is the safe removal of a nuclear facility from service and the reduction of residual radioactivity to a level that permits release of the property and termination of the license. NRC rules establish site-release criteria and provide for unrestricted and (under certain conditions) restricted release of a site. The NRC also requires all licensees to maintain financial assurance that funds will be available when needed for decommissioning.

See Appendices C, I, and Q for licensees undergoing decommissioning.

The NRC regulates the decontamination and decommissioning of nuclear power plants, materials and fuel cycle facilities, research and test reactors, and uranium recovery facilities, with the ultimate goal of license termination (see Figure 38. Reactor Phases of Decommissioning, and Figure 39. Power Reactor Decommissioning Status).

Reactor Decommissioning

When a nuclear power plant operator decides to cease operations, it must submit to the NRC a post-shutdown decommissioning activities report (PSDAR). This may be submitted before shutting down, or no later than 2 years following permanent cessation of operations. The PSDAR includes detailed plans for decommissioning the facility, as well as an estimate of what decommissioning will cost.

The first stage of decommissioning for a nuclear power plant is to transition from operating status to a permanently shutdown condition. The licensee must certify to the NRC that it has permanently ceased operation and that it has permanently removed the fuel from the reactor. At this point, the license no longer authorizes the plant to operate.

Licensees typically then apply for several exemptions from NRC requirements that apply to operating reactors but are no longer appropriate after permanent shutdown because a reactor accident can no longer occur. The exemptions are implemented through license amendments that change the plant's licensing basis to reflect its decommissioning status. These changes are in areas such as personnel, spent fuel management, physical and cybersecurity, emergency preparedness, and incident response. The NRC is developing new regulations to make this transition from operations to decommissioning more efficient.

The NRC allows a licensee up to 60 years to decommission a nuclear power plant. This may include extended periods of inactivity (called SAFSTOR), during which residual radioactivity is allowed to decay, making eventual cleanup easier and more efficient. A facility is said to be in DECON when active demolition and decontamination are underway. Active decommissioning of a nuclear power plant takes about 10 years on average.

NRC oversight and inspection continue throughout the entire process. Two years before decommissioning is completed, the plant operator must submit a license termination plan, detailing procedures for the final steps. The NRC inspects and verifies that the site is sufficiently decontaminated before terminating the license and releasing the site for another use.

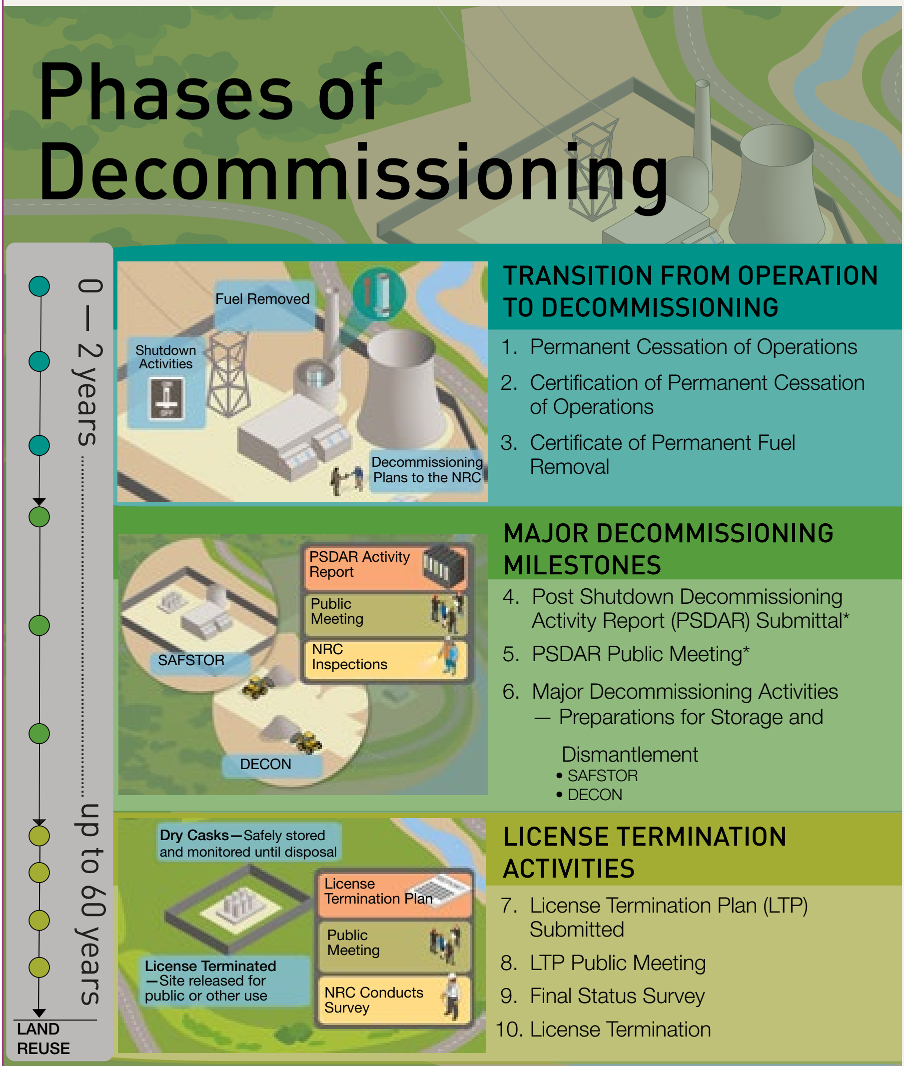
Public Involvement

Under Nuclear Energy Innovation and Modernization Act, the NRC is required to submit a report to Congress on best practices for community engagement panels in areas surrounding nuclear power plants that have ceased operations and begun decommissioning. The NRC plans to consult with host States, communities within the emergency planning zone of a nuclear power reactor, and existing local community advisory boards. This consultation also includes a minimum of 10 public meetings in locations that ensure geographic diversity across the United States, with priority given to States that have a nuclear power reactor currently undergoing the decommissioning process.

The best practices report is scheduled to be issued to Congress by June 2020 and will include a discussion of the composition of existing community advisory boards and best practices identified their during the establishment and operation, such as logistical considerations, frequency of meetings, and the selection of board members.

The NRC holds public meetings around the country, where NRC staff members provide information about the agency's role and mission and about the performance of area nuclear power plants and their future decommissioning process.

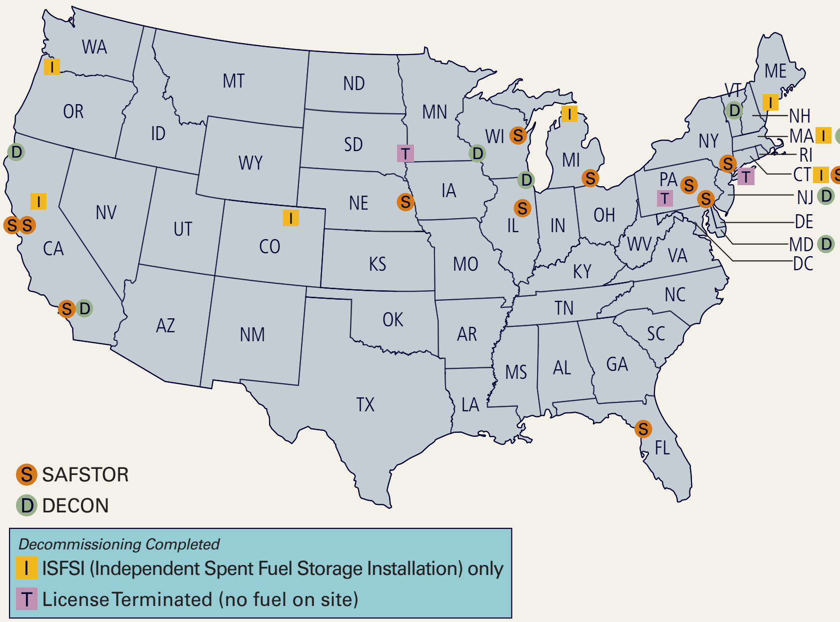
Figure 38. Reactor Phases of Decommissioning



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).

Figure 39. Power Reactor Decommissioning Status



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

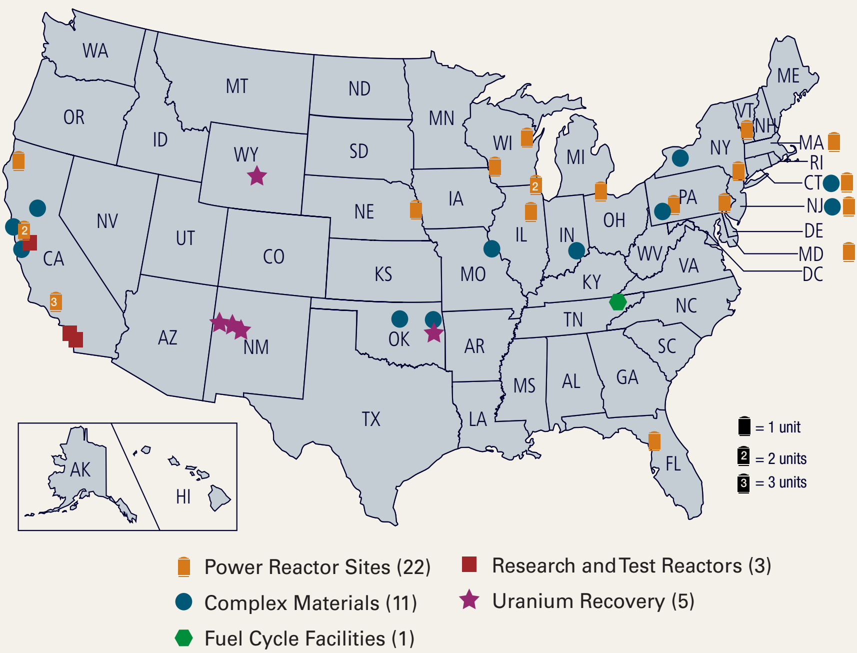
Alaska and Hawaii are not pictured and have no sites.
Notes: ISFSIs are also located at all sites undergoing decommissioning or in SAFSTOR. GE Bonus, Hallam, and Piqua decommissioned reactor sites are part of the DOE nuclear legacy. For more information, visit DOE's Office of Legacy Management LM Sites 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.

Decommissioning of Materials Licenses

The NRC terminates approximately 100 materials licenses each year. Most of these license terminations are routine, and the sites require little or no cleanup to meet the NRC's criteria for unrestricted access. The decommissioning program focuses on the termination of licenses for RTRs, uranium recovery facilities, fuel cycle facilities, and sites involving more complex decommissioning activities. These facilities typically were manufacturing or industrial sites that processed uranium, radium, or thorium or were military bases. They are required to begin decommissioning within 2 years of ending operations, unless the NRC approves an alternative schedule. (See Figure 40. Locations of NRC-Regulated Sites Undergoing Decommissioning.)

SECY-18-0119, "Status of the Decommissioning Program—2018 Annual Report," dated November 30, 2018 contains additional information on the decommissioning programs of the NRC and Agreement States. More information is on the NRC's Web site (see the Web Link Index).

Figure 40. Locations of NRC-Regulated Sites Undergoing Decommissioning



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Dismantling activities during the decommissioning process of the Elk River Station in Minnesota.

Image of preparation steps toward demolition of reinforced concrete containment of the building dome that once housed the nuclear reactor.

NRC Region III staff provide presentations about the plant performance, decommissioning, and environmental monitoring at an open house for the Michigan-based Palisades nuclear plant.