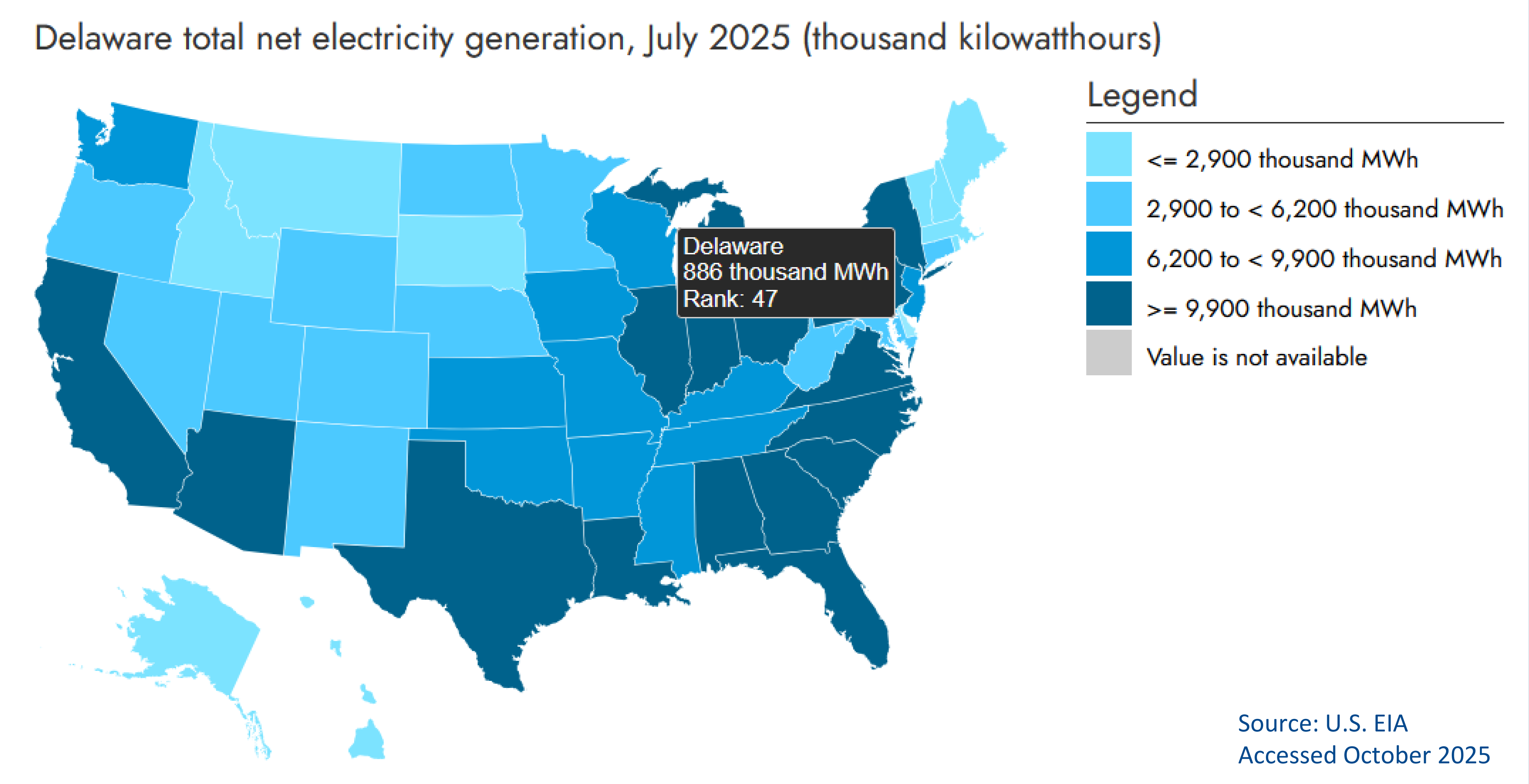
Nuclear Energy 101: Technology, Policy, and Status of the Resource

Prepared for the Delaware Nuclear Energy Feasibility Task Force
27 October 2025

Kathryn Lienhard, Energy Research Associate
Delaware Sea Grant, University of Delaware

Why discuss electricity generation?

Delaware imports approximately 60% percent of its electricity



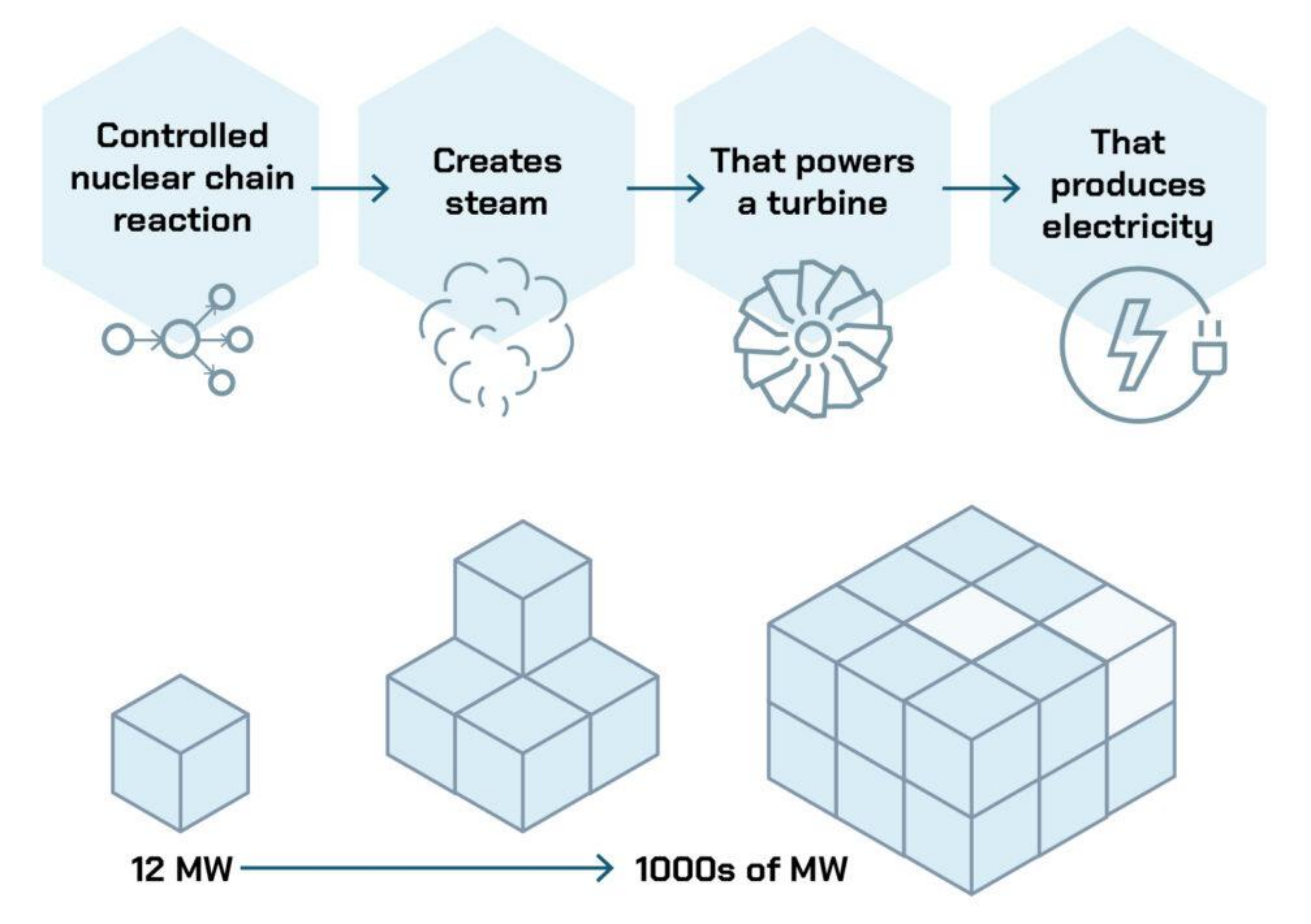
Source: U.S. EIA
Accessed October 2025

Agenda

- Technology overview
  - Nuclear fission, power plant types, nuclear fuel, comparing technologies
- Nuclear power in the U.S. and abroad
  - Status of existing plants, planned construction, federal responsibilities, nuclear waste management
- Current and future directions of nuclear power
  - Federal directives and incentives, proposed SMR designs

Technology Overview

How nuclear power generates electricity



Graphic: Idaho National Laboratory (INL)

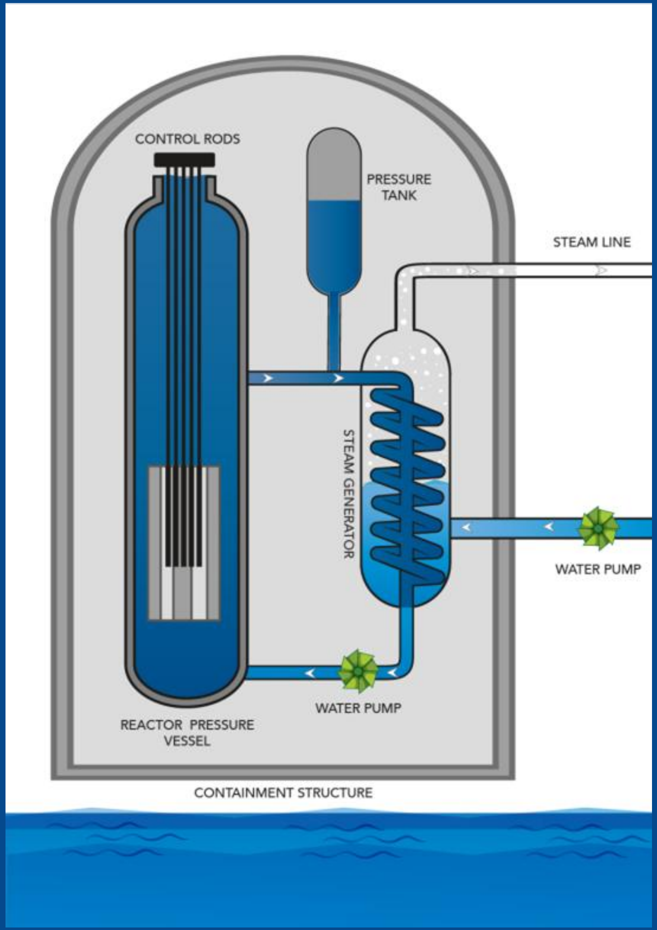
Traditional nuclear power plant

- Nameplate capacity: 1 GW+
- Two types of commercial reactors in the U.S.
  - Pressurized water reactors (PWRs)
  - Boiling water reactors (BWRs)
- Commercial reactors first licensed in the U.S. in the 1950s

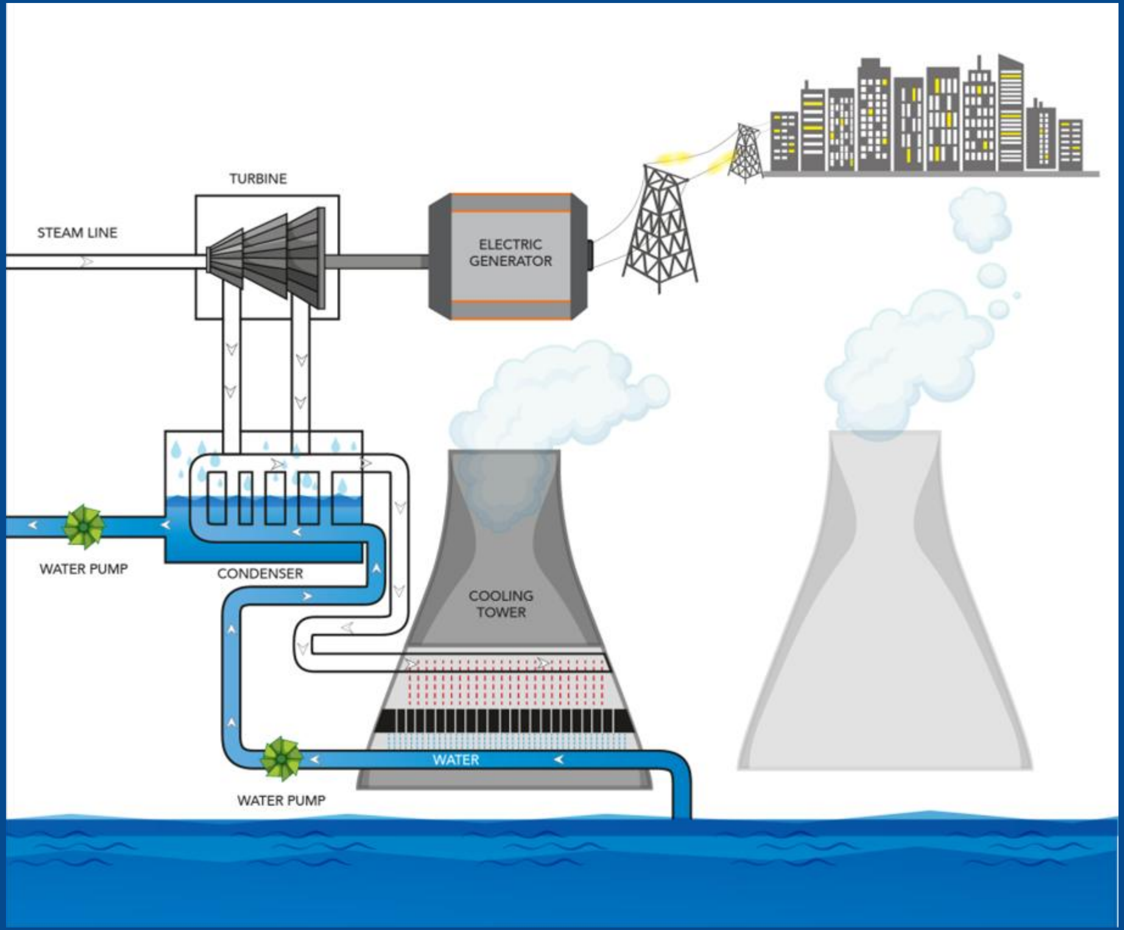
Hope Creek Nuclear Generating Station, NJ

Two types of commercial reactors in the U.S.

Pressurized Water Reactor (PWR)



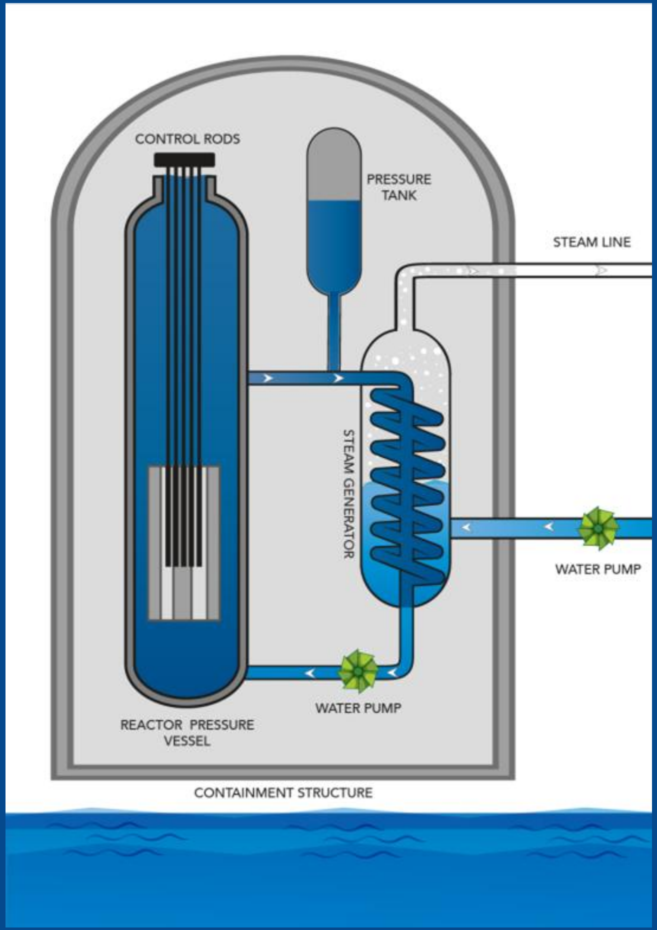
Power plant components of both reactor types



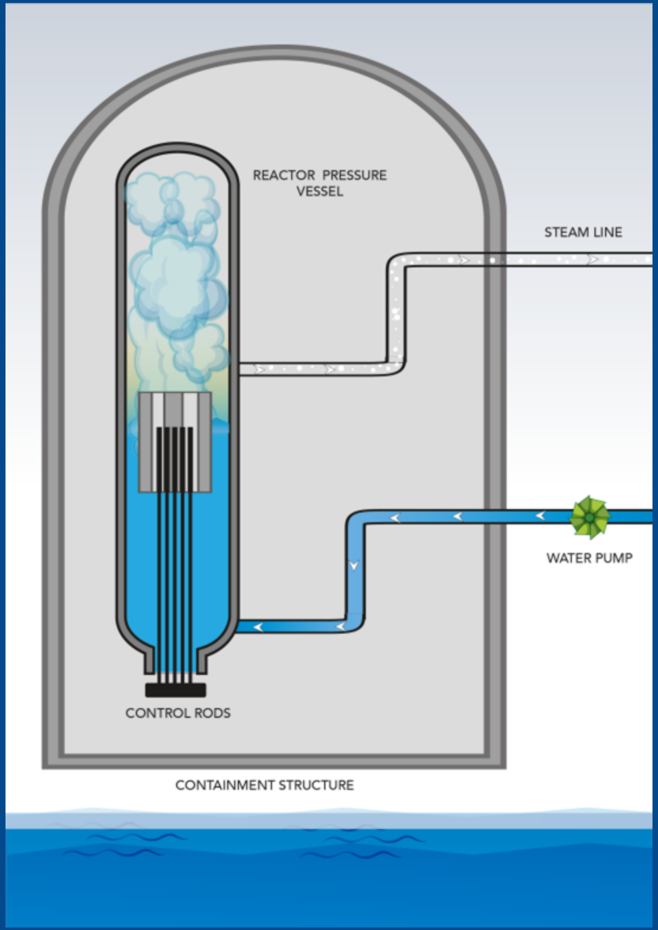
Source: Office of Nuclear Energy, U.S. DOE

Two types of commercial reactors in the U.S.

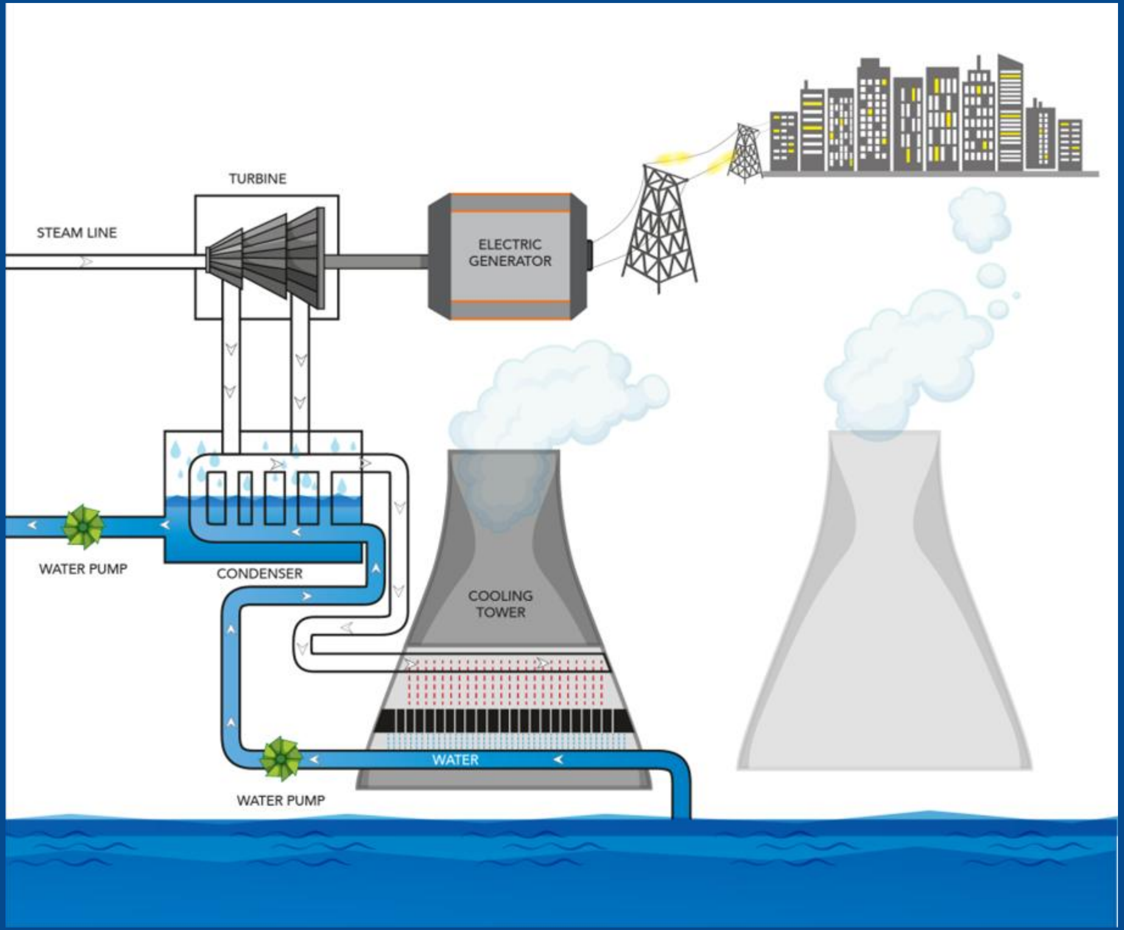
Pressurized Water Reactor (PWR)



Boiling Water Reactor (BWR)



Power plant components of both reactor types



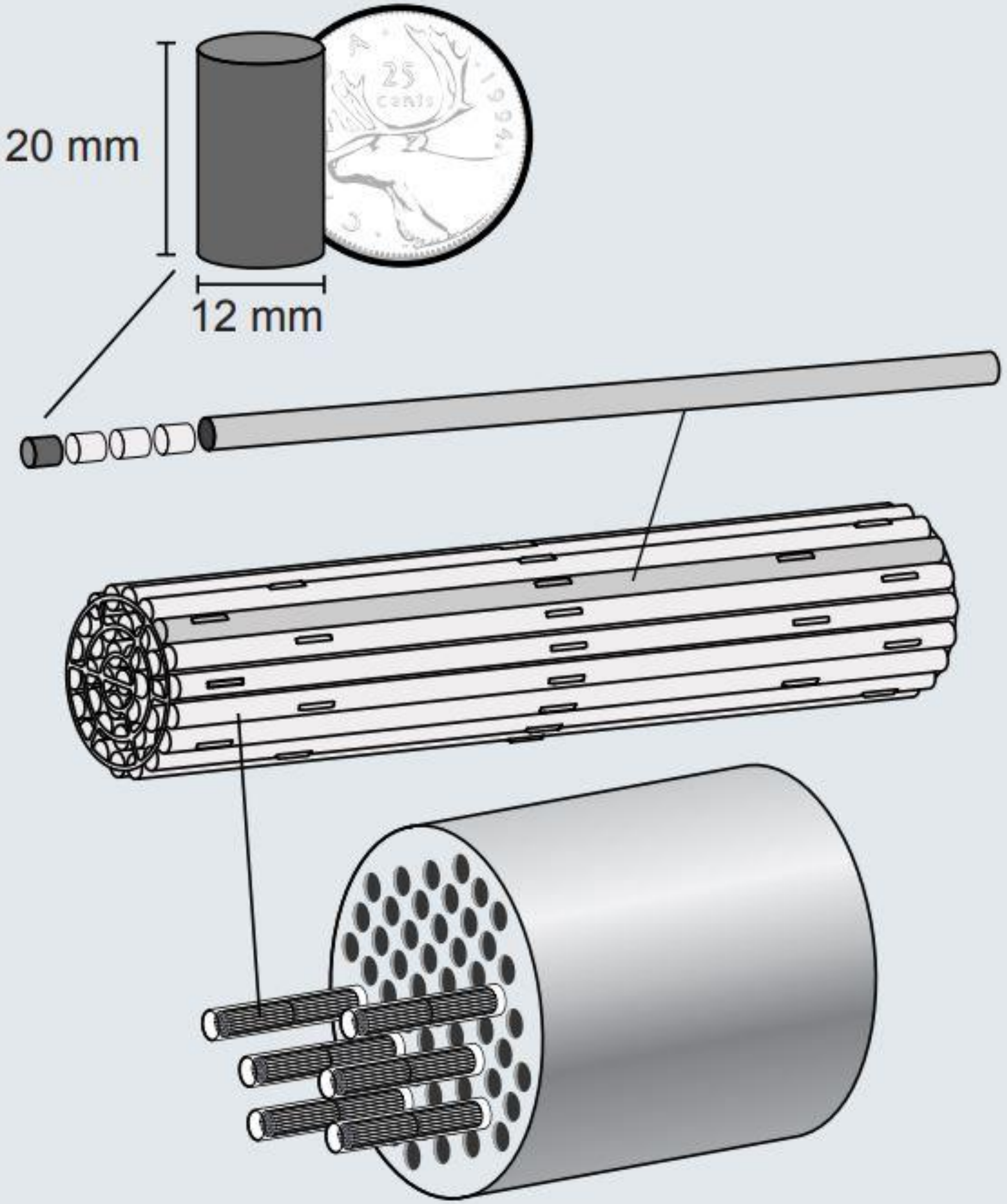
Source: Office of Nuclear Energy, U.S. DOE

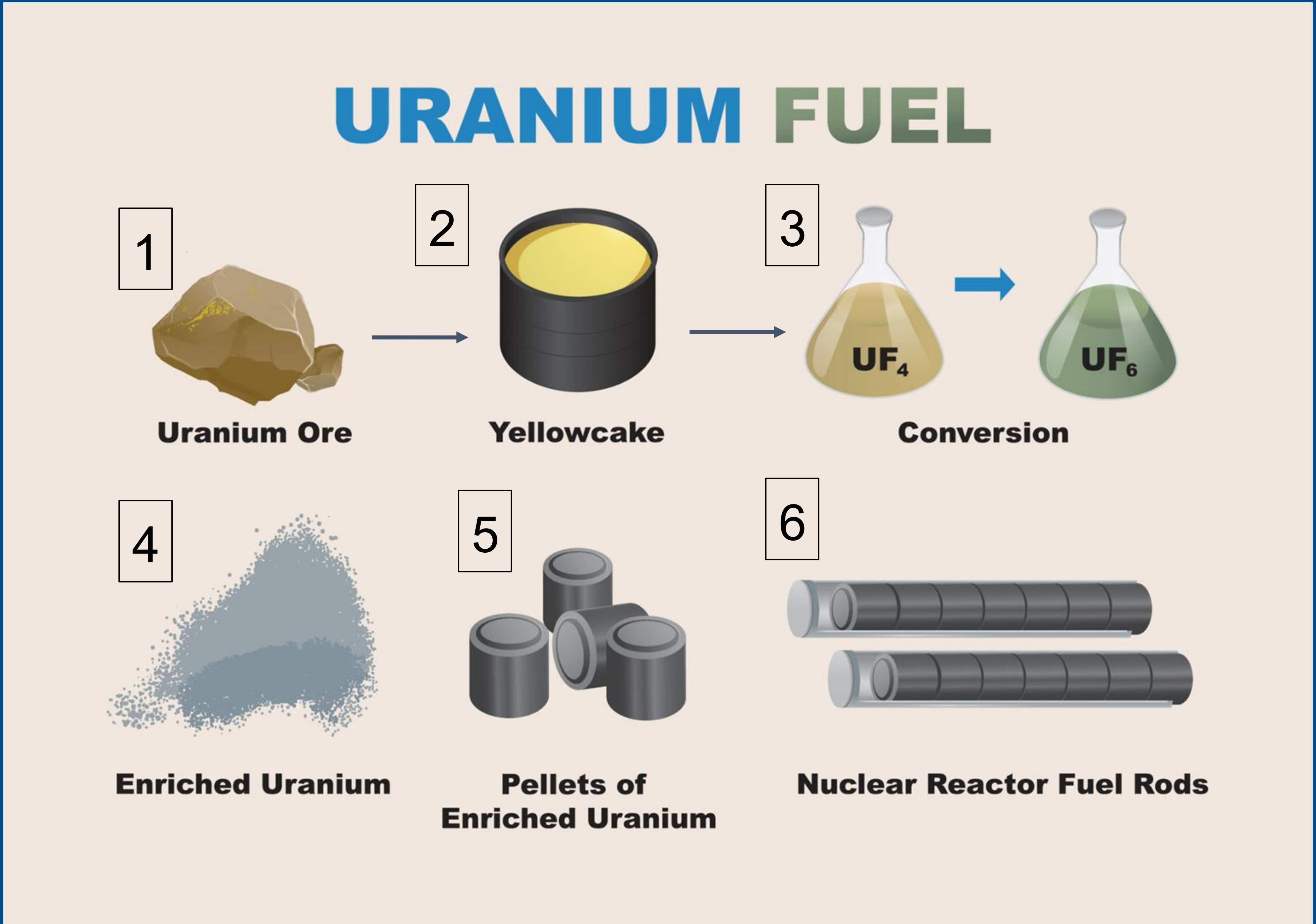
FUEL PELLET

FUEL PENCIL

FUEL BUNDLE

NUCLEAR REACTOR




URANIUM FUEL
1
Uranium Ore
2
Yellowcake
3
UF4
UF6
Conversion
4
Enriched Uranium
5
Pellets of
Enriched Uranium
6
Nuclear Reactor Fuel Rods

Small modular reactor (SMR)

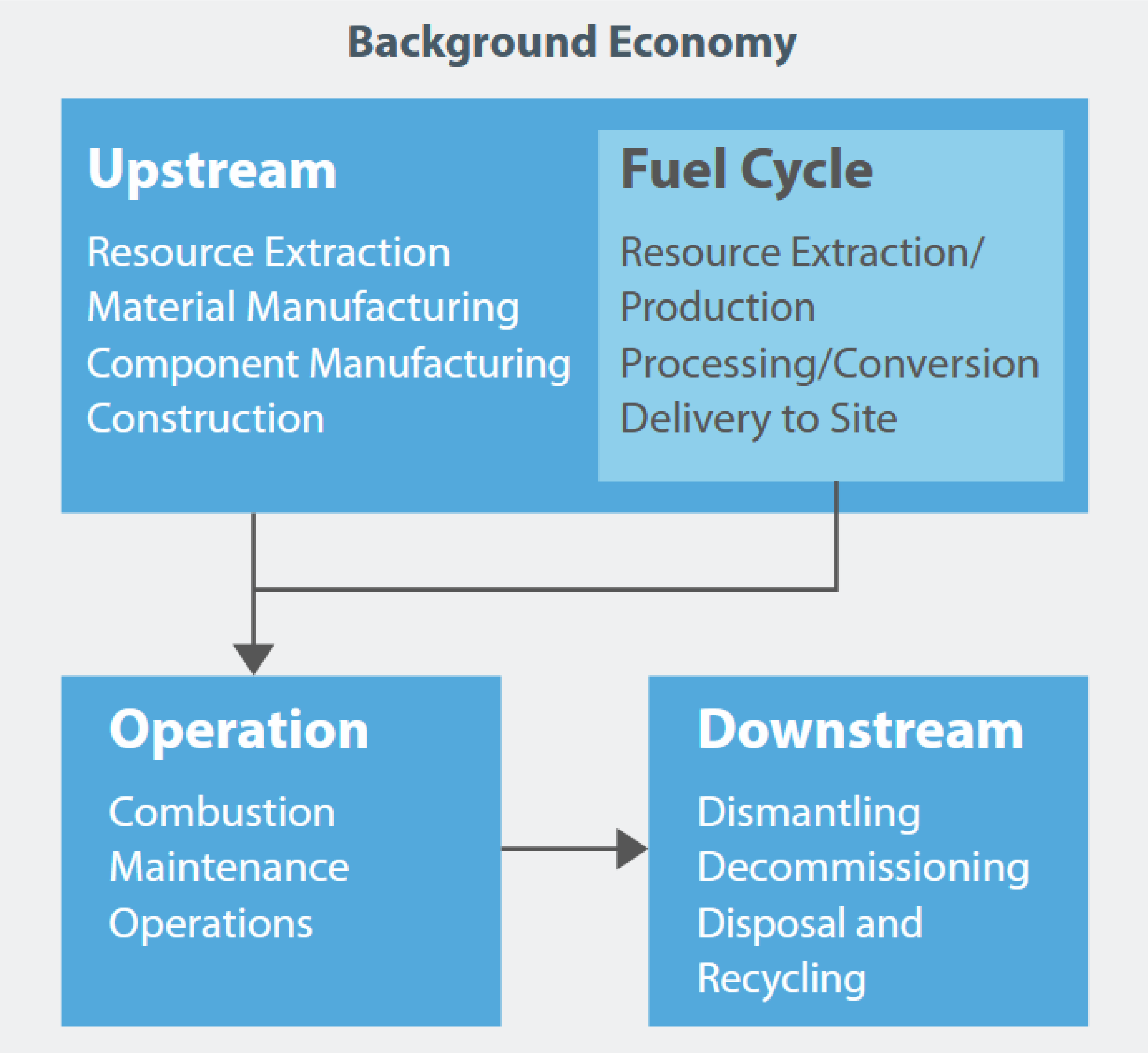
- Nameplate capacity: up to 300 MW
- Many potential designs with varying reactor technologies, and therefore different fuels and waste products
- No operating commercial reactors in the U.S., however, test/demonstration reactors are undergoing planning and construction
    - First test reactor to receive construction approval from the NRC is the Hermes Low Power Demonstration Reactor (TN) by Kairos Power. It is expected to be operational in 2027, but will not produce electricity.

NuScale Power SMR
Upper Module Mockup

Source: Office of Nuclear Energy, U.S. DOE

Comparing Technologies

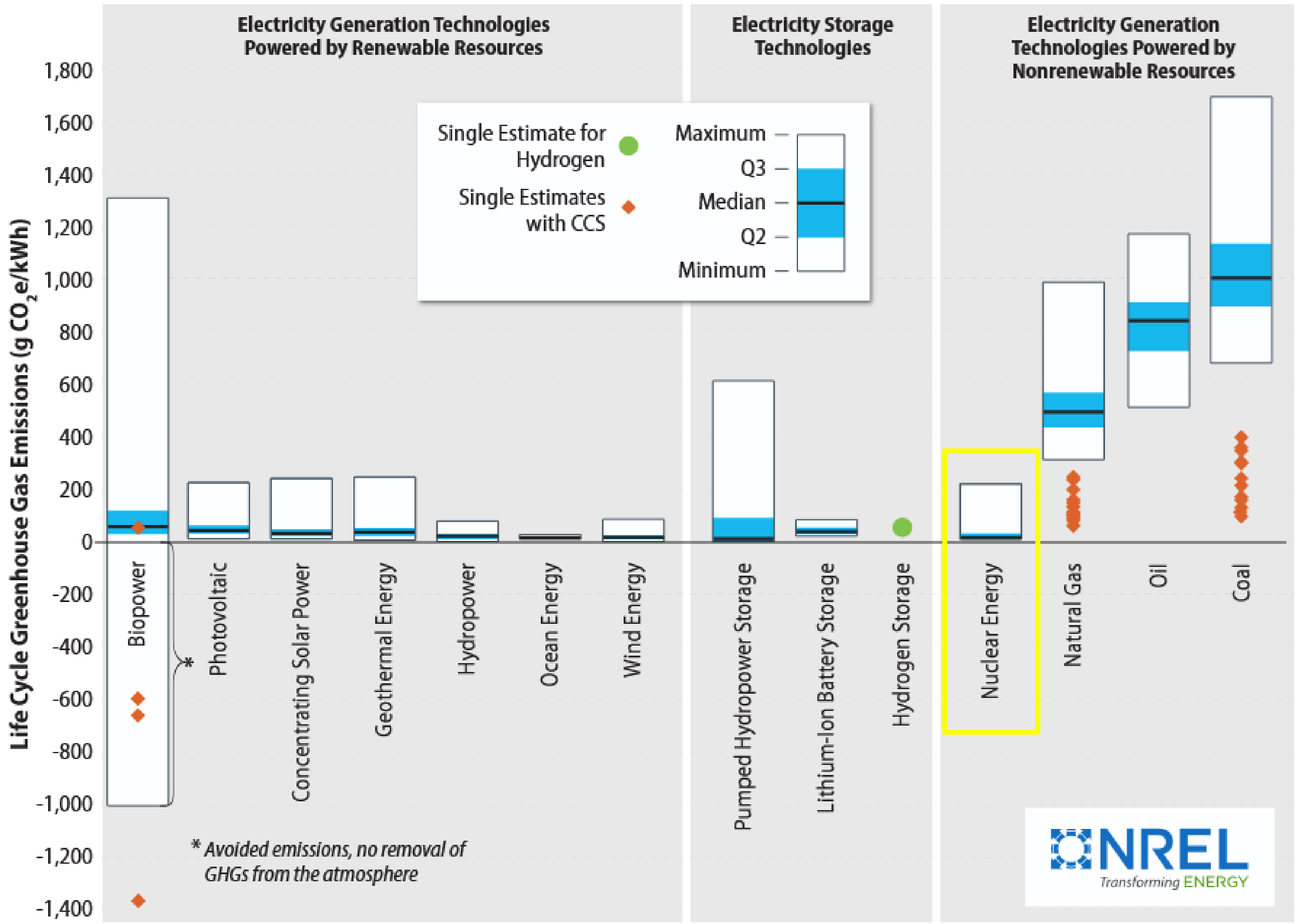
Figure 1. Generalized life cycle stages for energy technologies



Source: Sathaye et al. 2011

Graphic: NREL

Figure 2. Life cycle greenhouse gas emission estimates for selected electricity generation and storage technologies, and some technologies integrated with carbon capture and storage (CCS).



	Biopower	Photovoltaic	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Pumped Hydropower Storage	Lithium-Ion Battery Storage	Hydrogen Storage	Nuclear Energy	Natural Gas	Oil	Coal
Estimates	276 (+4)	46	36	35	149	10	186	16	29	1	99	80 (+13)	24	164 (+11)
References	57 (+2)	17	10	15	22	5	69	4	3	1	27	47 (+11)	10	53 (+9)

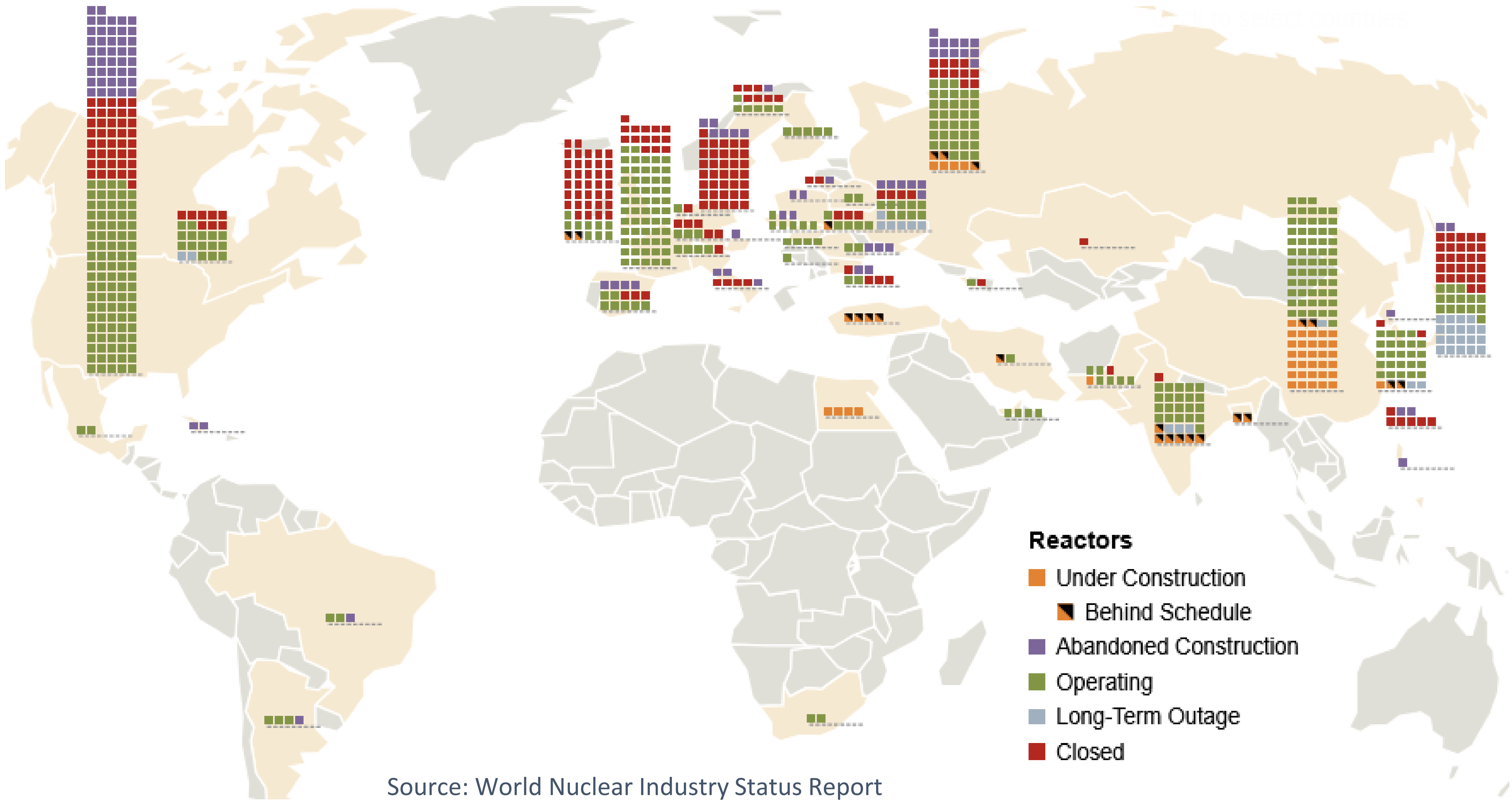
Notes for Figure 2: The number of estimates is greater than the number of references because many studies considered multiple scenarios. Numbers reported in parentheses pertain to additional references and estimates that evaluated technologies with CCS.

Graphic: NREL

Nuclear Power in the U.S.

Nuclear Power Reactors in the World

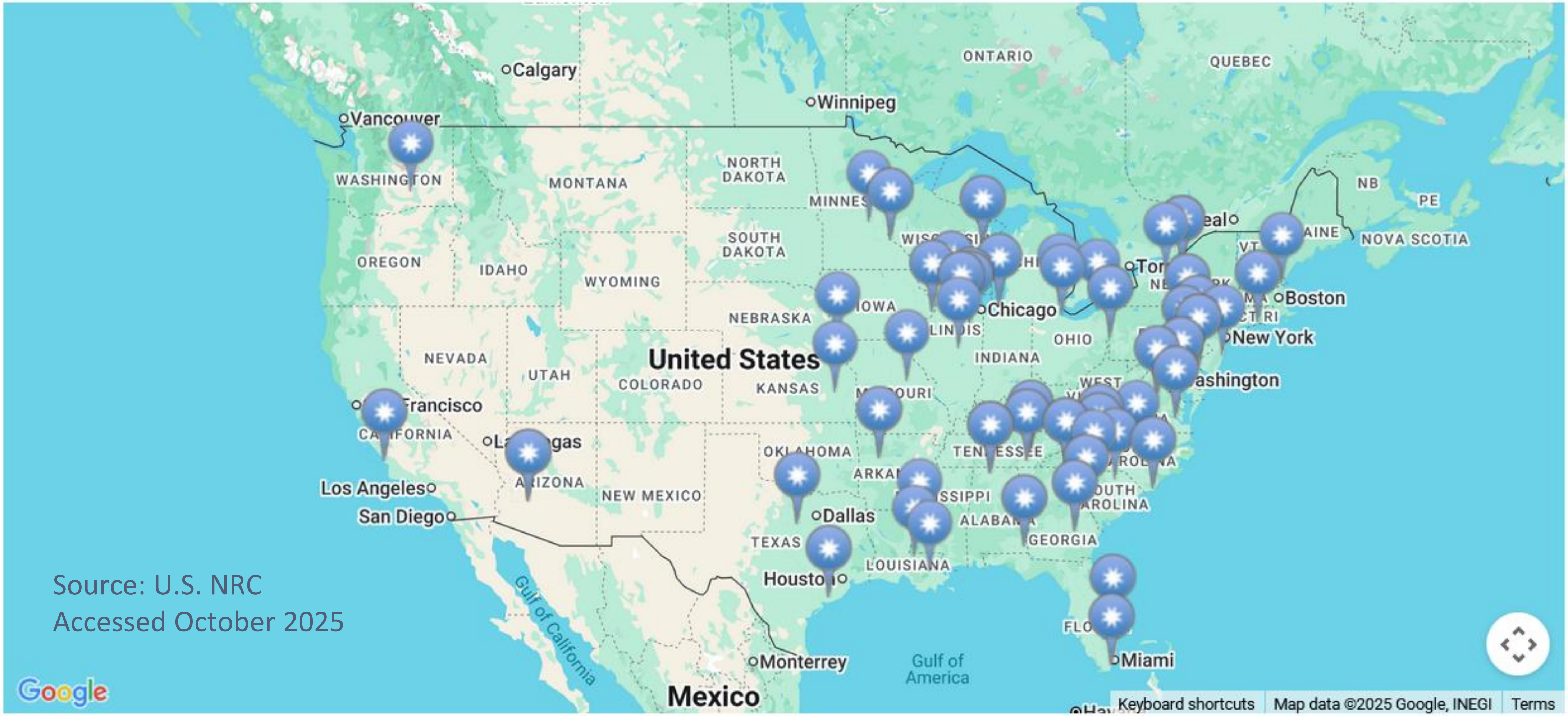
by Status, as of 30 September 2025.



Source: World Nuclear Industry Status Report
Accessed October 2025

Operating Nuclear Power Reactors (by Location or Name)

An operating nuclear power reactor is designed to produce heat for electric generation. Power reactors are distinguished from nonpower reactors which are reactors used for research, training, and test purposes, and for the production of radioisotopes for medical, industrial, and academic uses. To find information about a particular operating nuclear power reactor that NRC regulates, select that reactor from the map below, or from the [Alphabetical List of Operating Nuclear Power Reactors by Name](#).



Source: U.S. NRC
Accessed October 2025

Nuclear power in the U.S.

Oldest operating reactor:

Nine Mile Point, Unit 1 (NY), began operation in 1969

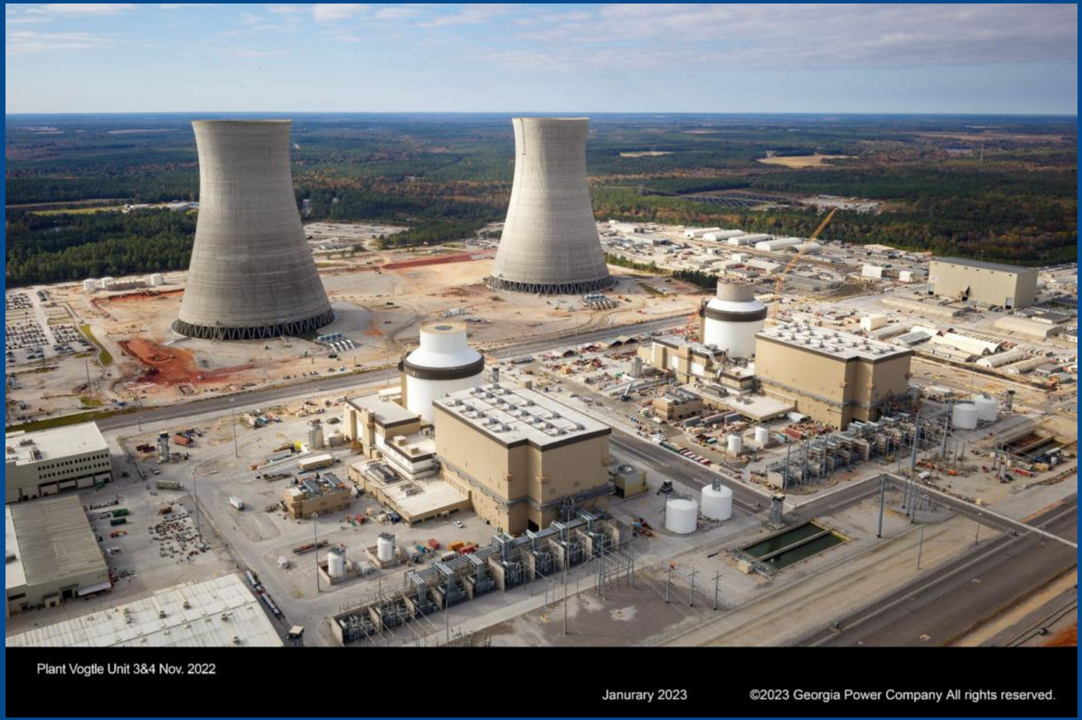
Source: U.S. EIA

Photo: U.S. DOE

Most recent construction:

Plant Vogtle (GA)
Unit 3: 2013-2023
Unit 4: 2013-2024

Source: U.S. EIA



Nuclear power in the U.S.

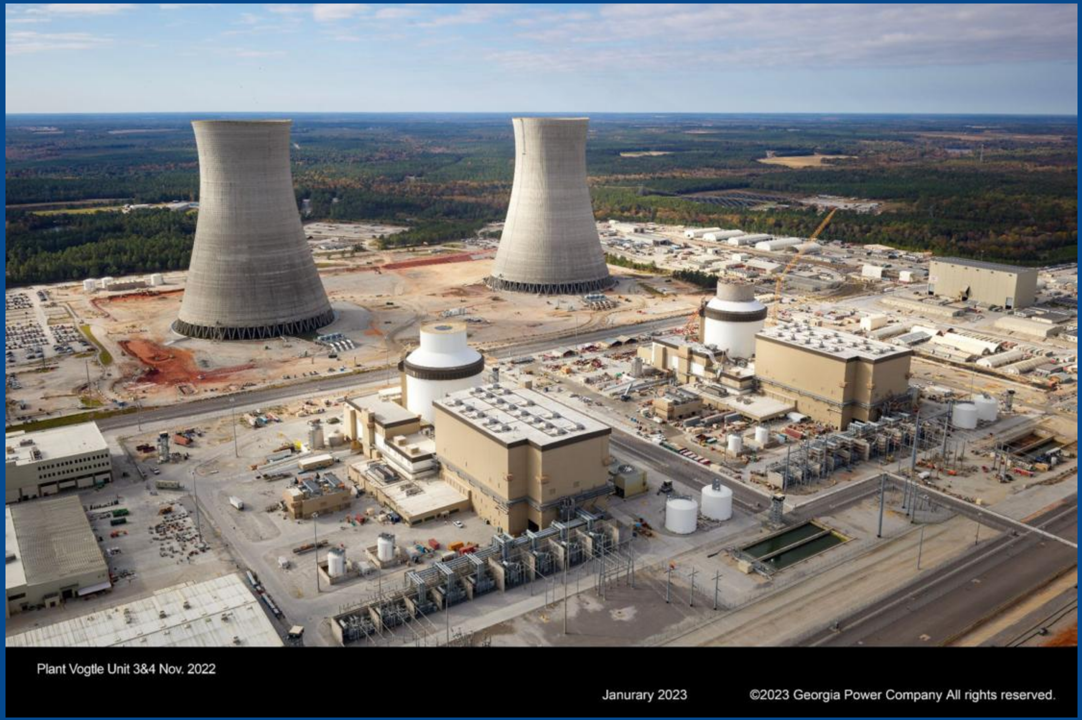
The most recent construction prior to Vogtle Units 3 & 4 began in the 1970s with the Watts Bar Nuclear Plant (TN) and was completed in the 1990s

Photo: TVA

Most recent construction:

Plant Vogtle (GA)
Unit 3: 2013-2023
Unit 4: 2013-2024

Source: U.S. EIA



Nuclear power in the U.S.

There are no reactors currently under construction, but permits have been submitted for planned reactors funded by the U.S. Advanced Reactor Demonstration Program

TerraPower Natrium reactor project (WY)

- 345 MW sodium fast reactor with molten salt energy storage
- TerraPower submitted the Natrium application in March 2024
- The NRC reports that the review is expected to be completed in 2026

Source: TerraPower

Long Mott Xe-100 project (TX)

- Four 80-MW high-temperature gas-cooled reactors with fuel of graphite and TRIstructural ISOtropic (TRISO) particle fuel
- Permit application to NRC submitted in March 2025
- The reactors would provide power and process heat to an existing Dow chemical facility

Source: U.S. NRC

Clinch River Nuclear Site (TN)

- Technology undecided
- Application for construction permit to NRC is in progress

Source: U.S. NRC

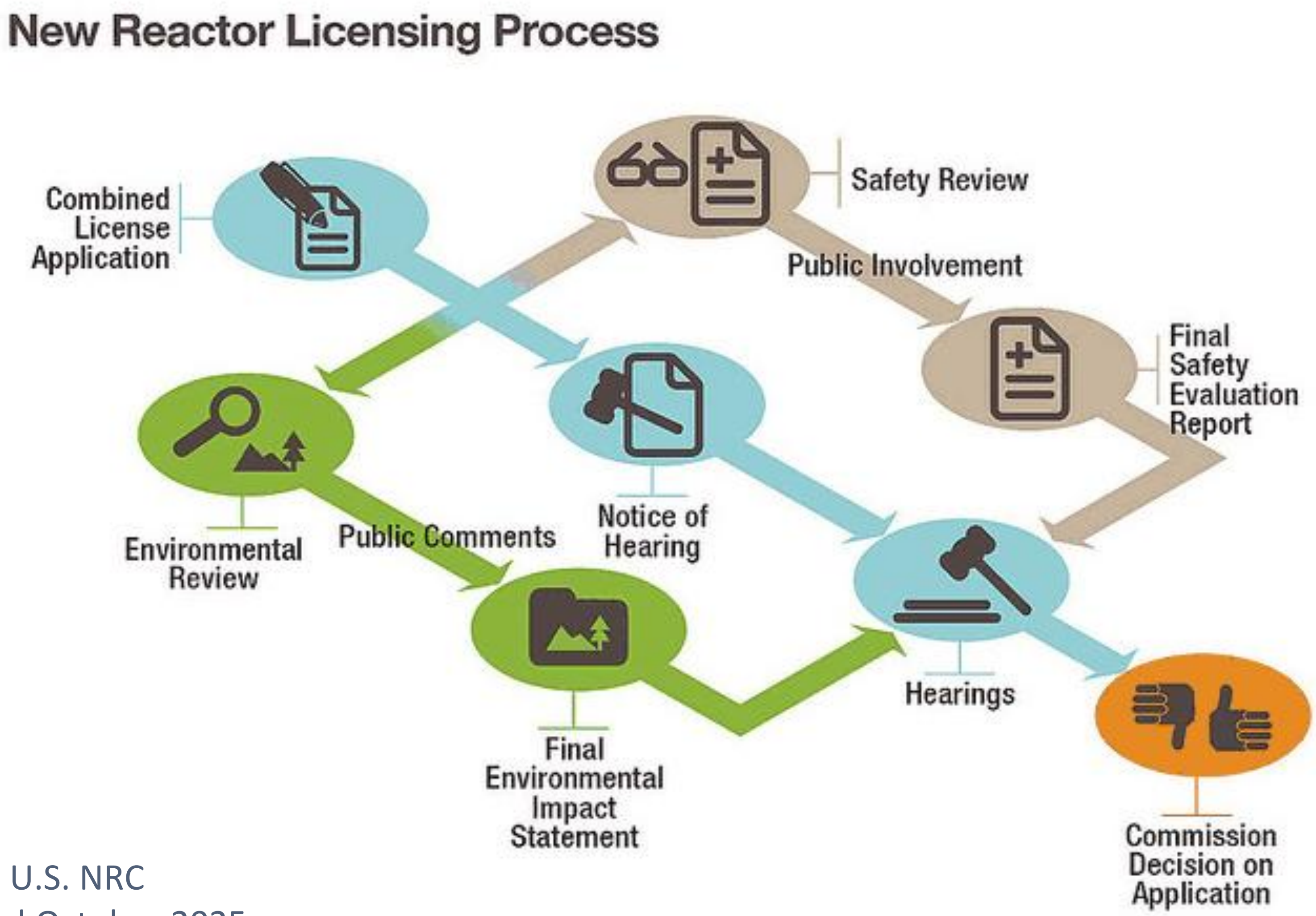
Federal agency responsibilities

Nuclear Regulatory Commission (NRC)
→ formulates policies, develops regulations governing nuclear reactor and nuclear material safety, issues orders to licensees, and adjudicates legal matters

Department of Energy (DOE) Office of Nuclear Energy

→ advances nuclear energy science and technology to meet U.S. energy, environmental, and economic needs

NRC Licensing



Source: U.S. NRC
Accessed October 2025

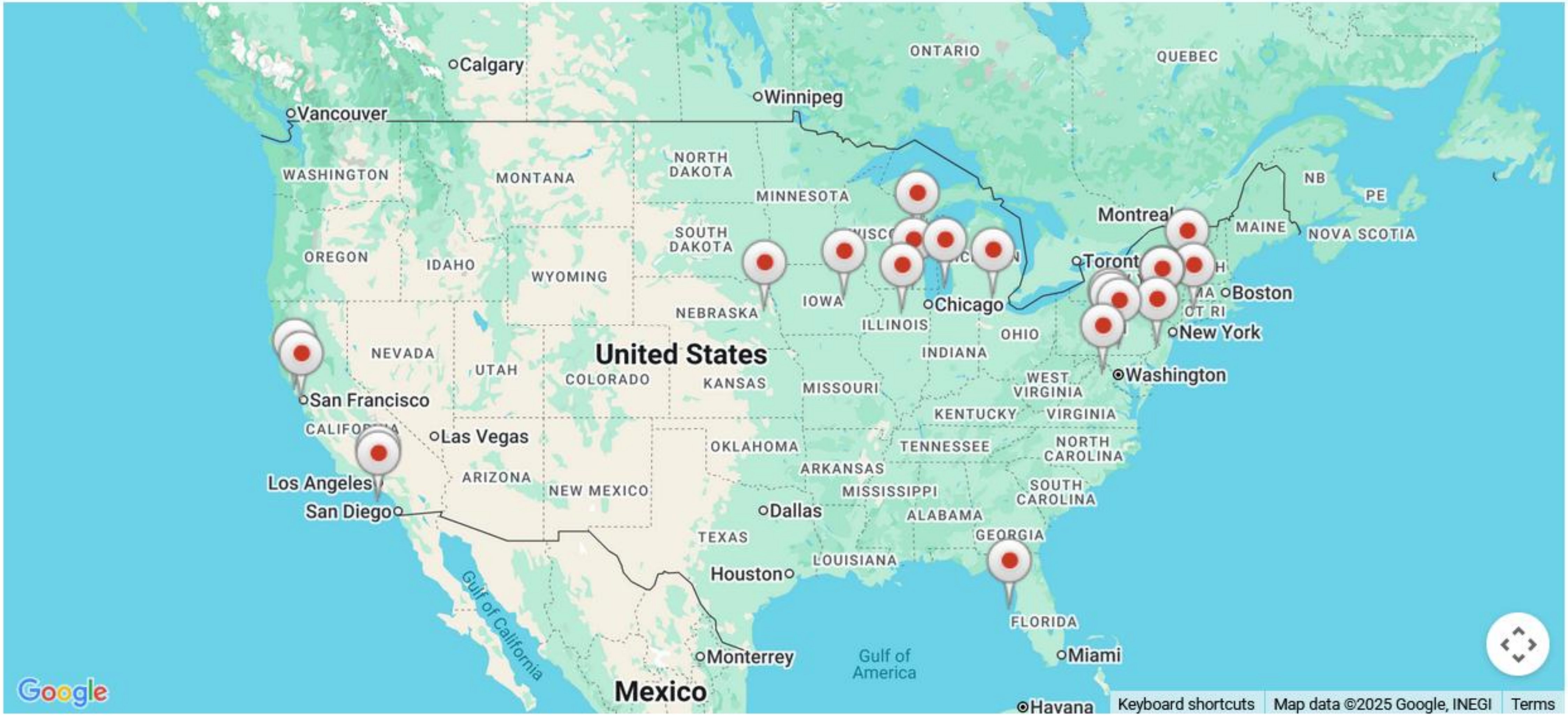
Sites Undergoing Decommissioning (by Location or Name)

- Complex Materials
- Power Reactors
- Research & Test Reactors
- Uranium Recovery Sites
- Fuel Cycle Facilities

Source: U.S. NRC
Accessed October 2025

Locations of Power Reactor Sites Undergoing Decommissioning

The NRC's Office of Nuclear Material Safety and Safeguards (NMSS) has project management responsibilities for power reactors undergoing decommissioning.



●	Power Reactors

Source: U.S. NRC
Accessed October 2025

Safety Considerations and Nuclear Waste

Reactor Oversight Process (ROP)

NRC program to inspect, measure, and assess the safety and security performance of operating commercial nuclear power plants, and to respond to any decline in their performance

- Reactor safety (avoiding accidents and reducing the consequences of accidents if they occur)
- Radiation safety for plant workers and the public during routine operations
- Protection of the plant against security threats

Source: U.S. NRC
Accessed October 2025

Nuclear waste

Low-level waste: items contaminated with radioactive material

- Protective shoe covers and clothing
- Equipments and tools

High-level waste: highly radioactive byproducts of the reactions that occur inside nuclear reactors

- **Spent reactor fuel** when it is accepted for disposal
- Waste materials remaining after spent fuel is reprocessed (if reprocessing occurs)

Source: U.S. NRC
Accessed October 2025

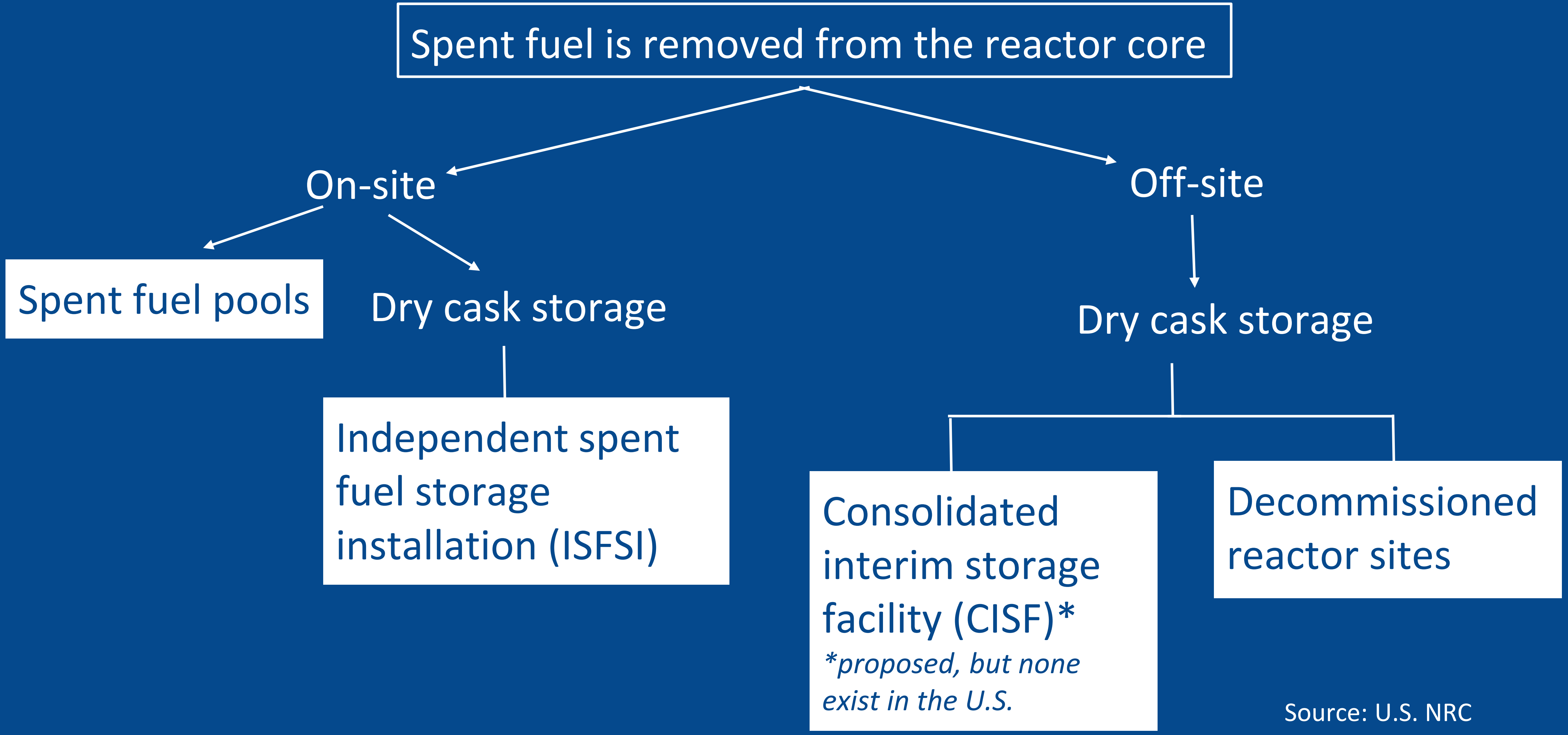
Spent nuclear fuel

Spent nuclear fuel (SNF): used fuel from a reactor that is no longer efficient in creating electricity

- Thermally hot, highly radioactive, and potentially harmful
- Licensees must safely store this fuel until a permanent disposal repository for spent nuclear fuel is built

Source: U.S. NRC
Accessed October 2025

Spent nuclear fuel storage



Source: U.S. NRC
Accessed October 2025

Spent fuel storage

Spent fuel pools

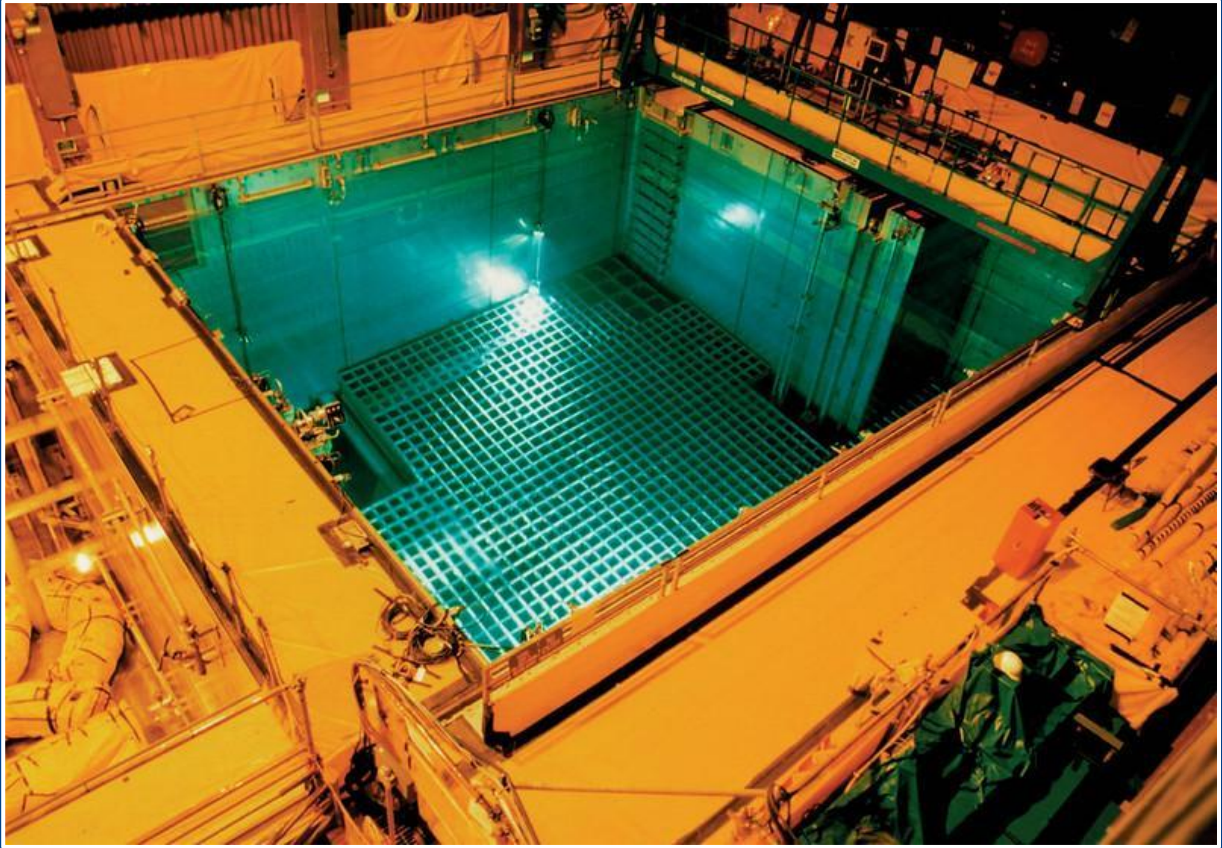


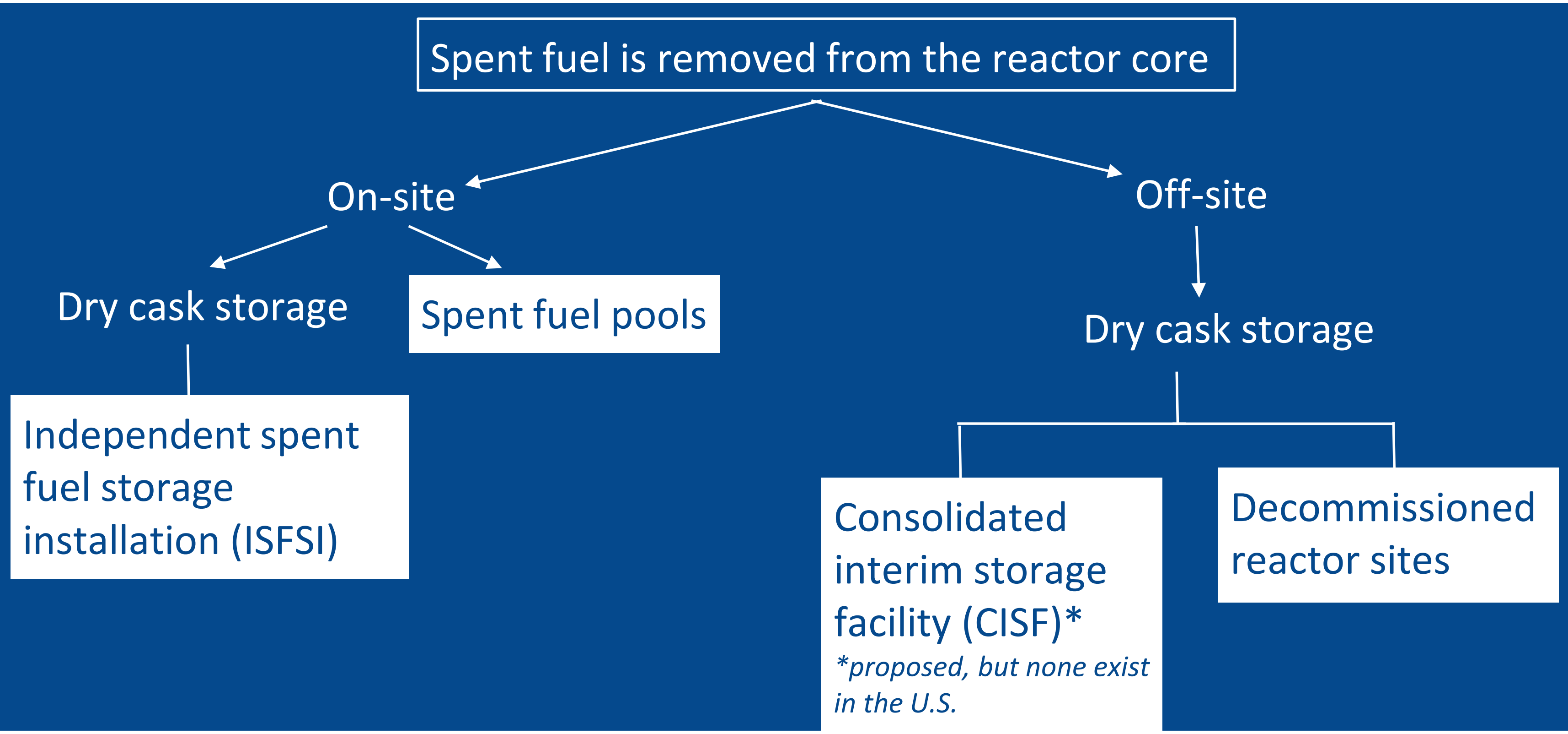
Photo: NRC

Dry cask storage

Photo: Westinghouse

Spent nuclear fuel storage

Short-term



Long-term

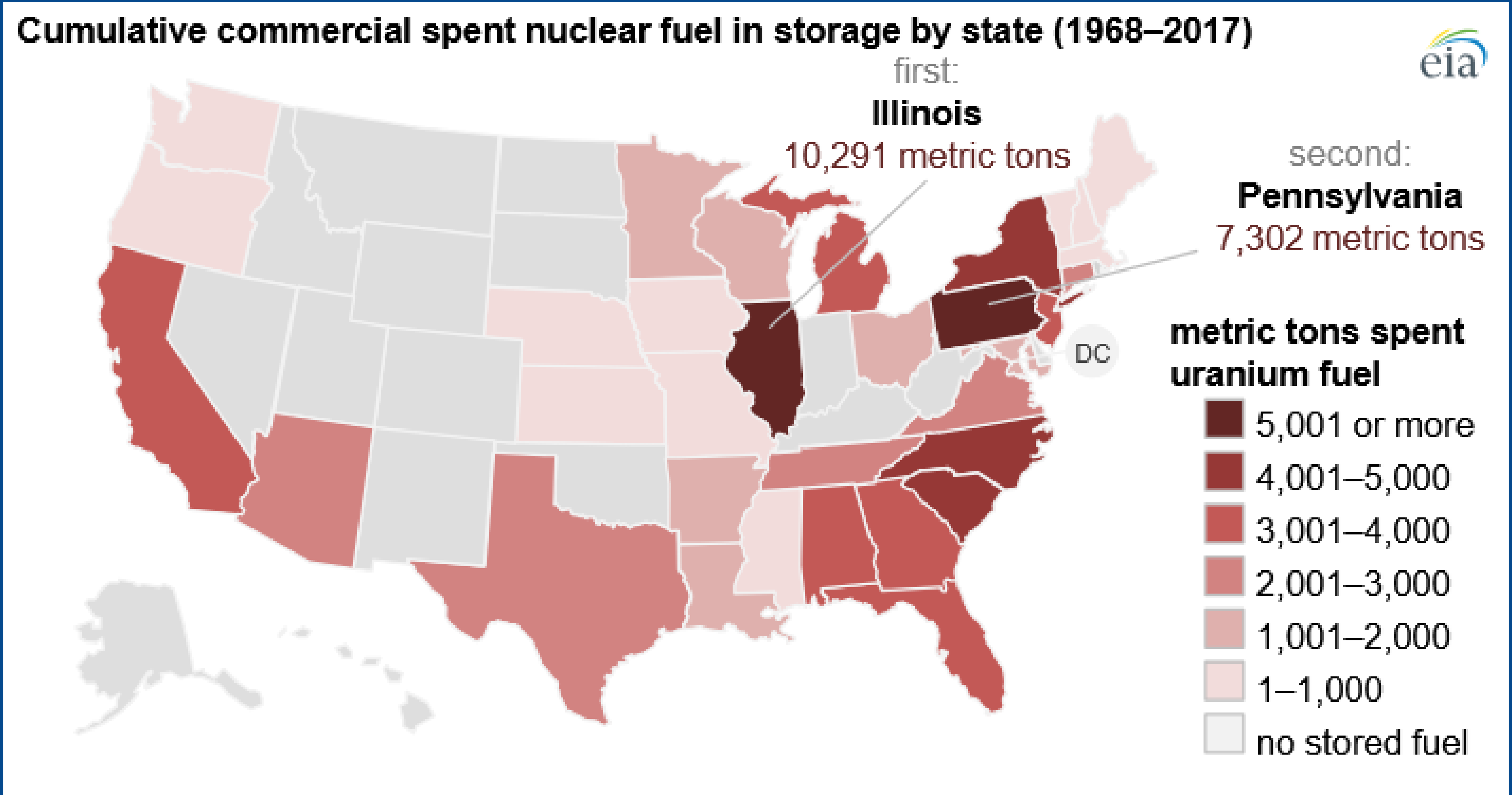
- Deep geological repository for long-term high-level nuclear waste yet to be sited
- Spent fuel reprocessing is not conducted in the U.S.

Source: U.S. NRC
Accessed October 2025

Spent fuel transport

- Spent uranium fuel may be stored on-site, or transported to a different temporary storage facility
- NRC and the Department of Transportation (DOT) jointly manage transportation standards within the U.S. to ensure safety
  - NRC: establishes requirements for the design and manufacturing of packages for radioactive materials
  - DOT: regulates shipments while in transit; sets standards for labeling and smaller quantity packages

Source: U.S. NRC
Accessed October 2025



Source: U.S. EIA
Accessed October 2025

Current and Future Directions of Nuclear Power

Federal incentives enacted prior to 2025

- Inflation Reduction Act: Nuclear Power Production Tax Credit (Nuclear PTC): subsidies to nuclear reactors built prior to August 2022
- Clean Electricity Production Tax Credit (CE PTC) and Clean Electricity Investment Credit (CE ITC): tax credits to new clean generation sources
- Clean Hydrogen Production Tax Credit (H_2 PTC): tax credits for producing hydrogen with low GHG emissions methods

Source: The World Nuclear Industry Status Report 2025, Mycle Schneider Consulting, September 2025

2025 Executive Orders on nuclear power

- Deploying Advanced Nuclear Reactor Technologies for National Security (EO 14299)
  - Develop and deploy the use of advanced nuclear technologies
  - Establish a program for nuclear energy across Department of Defense sites
  - Designate AI data centers in the U.S. that are located near Department of Energy (DOE) facilities as "support for national security missions, critical defense facilities, where appropriate"
  - Consider applying or creating new exclusions under the National Environmental Policy Act (NEPA) for advanced nuclear reactor technologies on federal lands

- Ordering the Reform of the Nuclear Regulatory Commission (EO 14300)
  - Reestablish the U.S. as the global leader in nuclear energy
  - Restructures the Nuclear Regulatory Commission to expedite license processing and adopt innovative technology; reduce staff
  - Reconsider the model for radiation exposure standards, the standard currently being exposure "as low as reasonably achievable"

2025 Executive Orders on nuclear power (continued)

- Reforming Nuclear Reactor Testing at the Department of Energy (EO 14301)
  - Revise the “regulations, guidance, and procedures and practices” of DOE and National Laboratories to expedite deployment of advanced nuclear reactors (ANRs)
    →led to the creation of the Nuclear Reactor Pilot Program
  - Eliminate or expedite environmental reviews for approvals of nuclear development applications

- Reinvigorating the Nuclear Industrial Base (EO 14302)
  - Produce a report on recommended policy for managing nuclear waste, legislative changes necessary to implement favorable policies for nuclear energy, and evaluation of current spent fuel reprocessing efforts
  - Develop a plan to expand uranium conversion programs for naval propulsion and nuclear weapons
  - Directs DOE to work with the nuclear energy industry to make power upgrades to existing reactors and have 10 new reactors under construction by 2030
  - Appropriate funds to develop nuclear energy-related workforce opportunities

Closed plants working to reopen

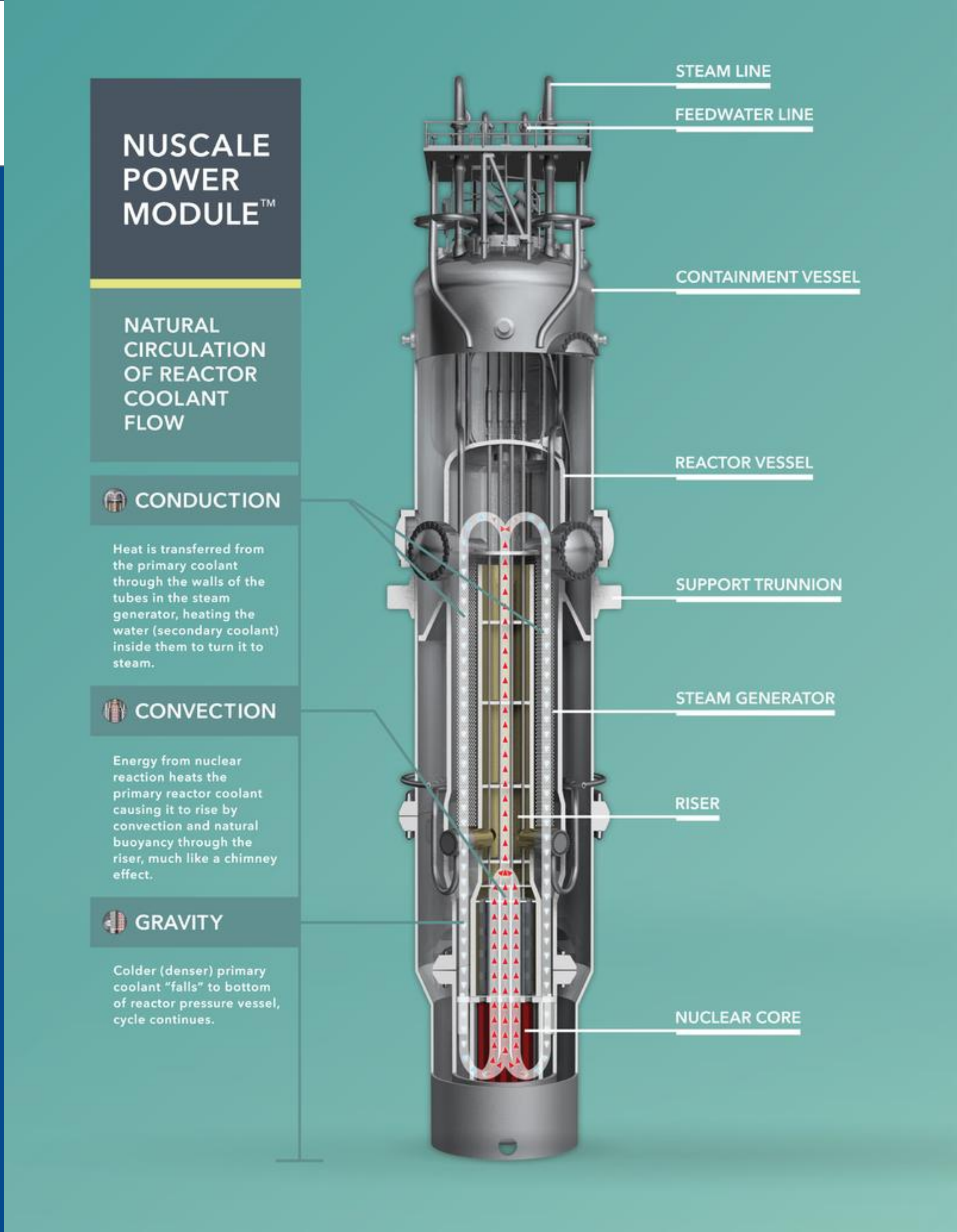
- Palisades Nuclear Plant (MI) (Source: U.S. DOE)
  - Shut down in May 2022 after 50 years of operation
  - Purchased by Holtec, with intention and investments to restart
  - Funding: $300 million from State of Michigan, $1.52 billion loan from DOE for upgrades and paying 200 remaining workers
- Three Mile Island/Crane Clean Energy Center (PA) (Source: U.S. DOE)
  - Reactor shut down in 2019 due to economics
  - September 2024: Microsoft made a deal with power plant owner Constellation Energy to purchase power over a 20-year contract to power data centers
  - Investments to restore Unit 1 reactor: update turbine, generator, cooling and control systems, main power transformer
  - Estimated reopening: 2027
  - Received accelerated approval from PJM to integrate into grid
  - NRC Restart Panel will oversee licensing and regulatory filings

Source: MIT Technology Review

Status of SMRs

There are no commercial SMRs operating in the U.S.

- NuScale Power has obtained NRC approval for several versions of their design



OPTIONS

Standard Plant Models

12 Modules **6 Modules** **4 Modules**

12 Modules

A 12-module plant can generate up to 924 MWe of carbon-free electricity. It can be used to power data centers, provide process heat, replace retiring coal plants, or power emergency micro-grids. Following a catastrophic loss of infrastructure, a 12-module plant can power a mission critical facility micro-grid at 154 MWe for 12 years without new fuel.

Thank you!

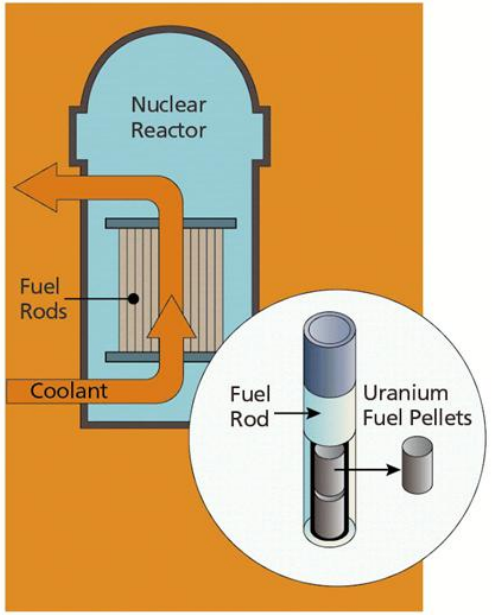
Kathryn Lienhard
Energy Research Associate
Delaware Sea Grant
lienhard@udel.edu

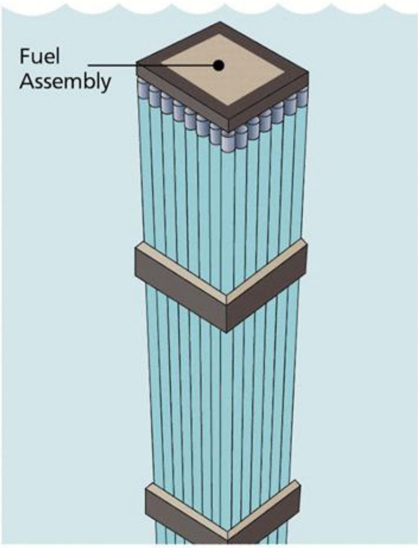
Additional content


Mining
Milling
Conversion

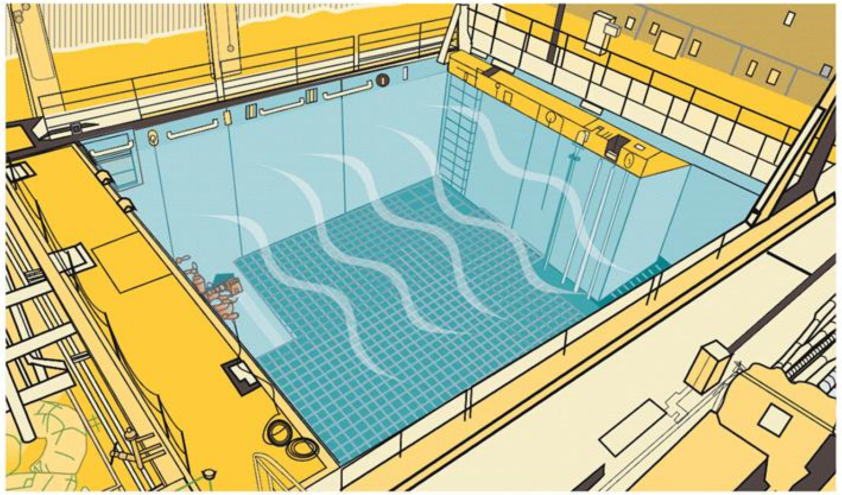
Spent Fuel Generation and Storage after Use

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 150 and 200 fuel assemblies. Boiling-water reactors (BWRs) contain between 370 and 800 fuel assemblies.

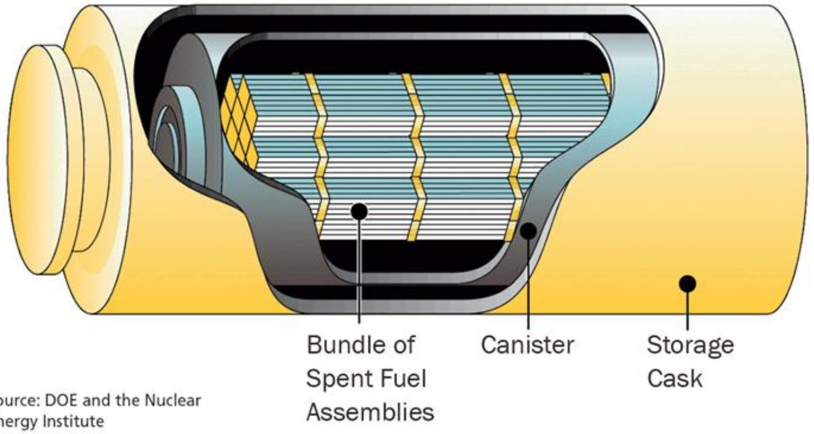




2 After 5–6 years, spent fuel assemblies—typically 14 feet (4.3 meters) long and containing nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs—are removed from the reactor and allowed to cool in storage pools for a few years. At this point, the 900-pound (409-kilogram) assemblies contain only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

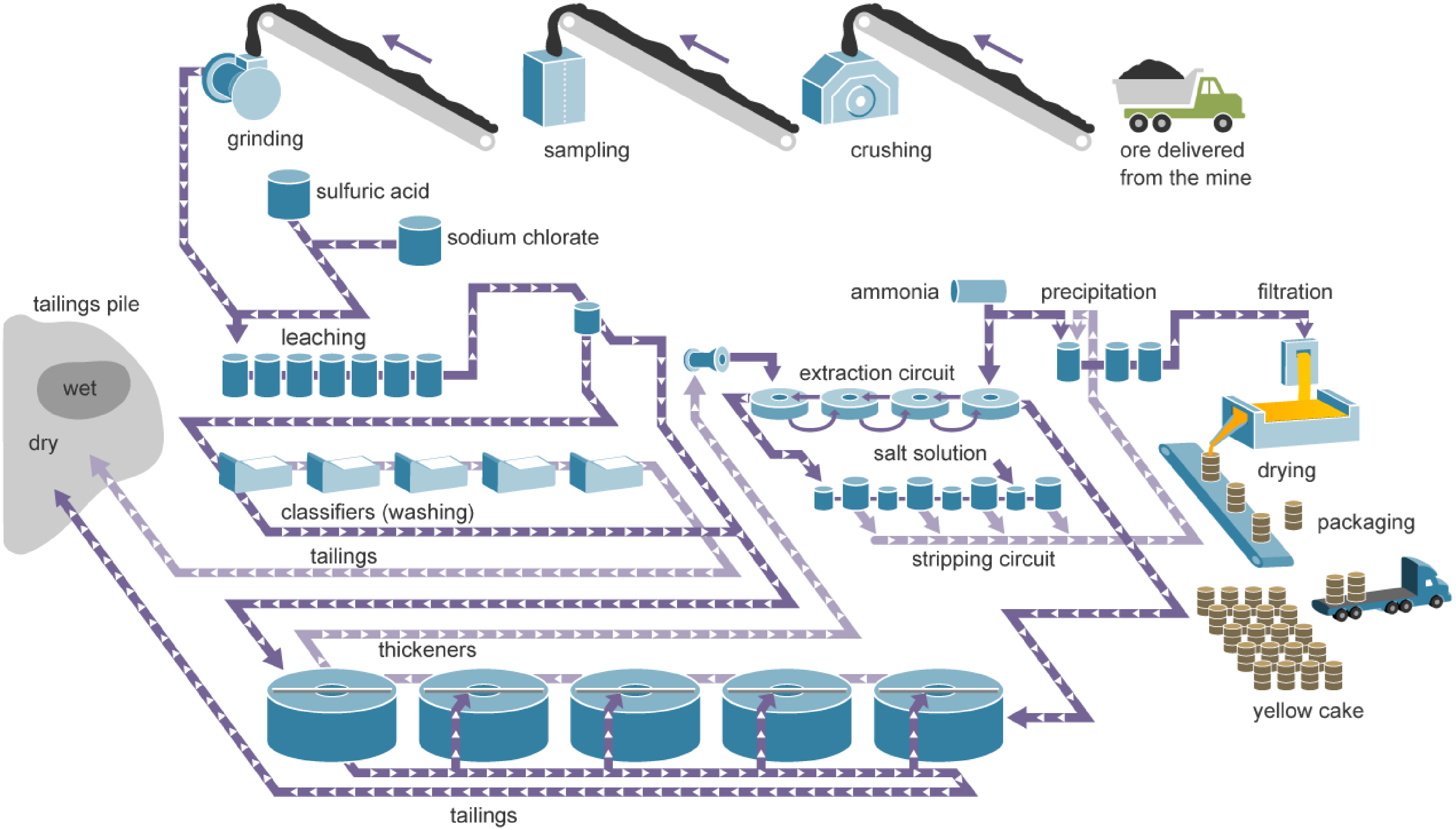


3 Commercial light-water nuclear reactors store spent radioactive fuel in a steel-lined, seismically designed concrete pool under about 40 feet (12.2 meters) of water that provides shielding from radiation. Water pumps supply continuously flowing water to cool the spent fuel. Extra water for the pool 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 can be transferred to dry casks onsite (as shown in Figure 42) or transported offsite to a high-level radioactive waste disposal site.



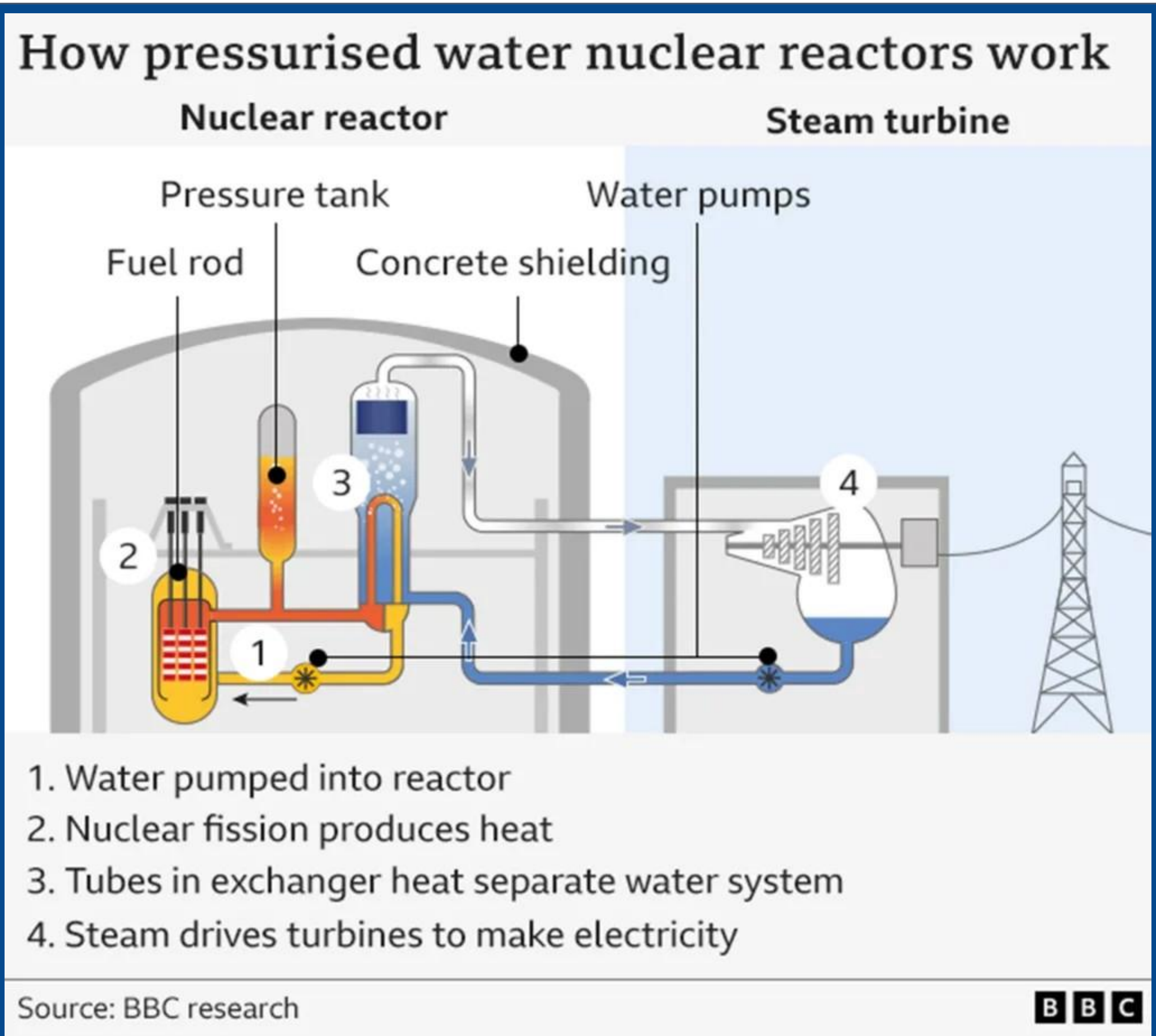
Source: DOE and the Nuclear Energy Institute

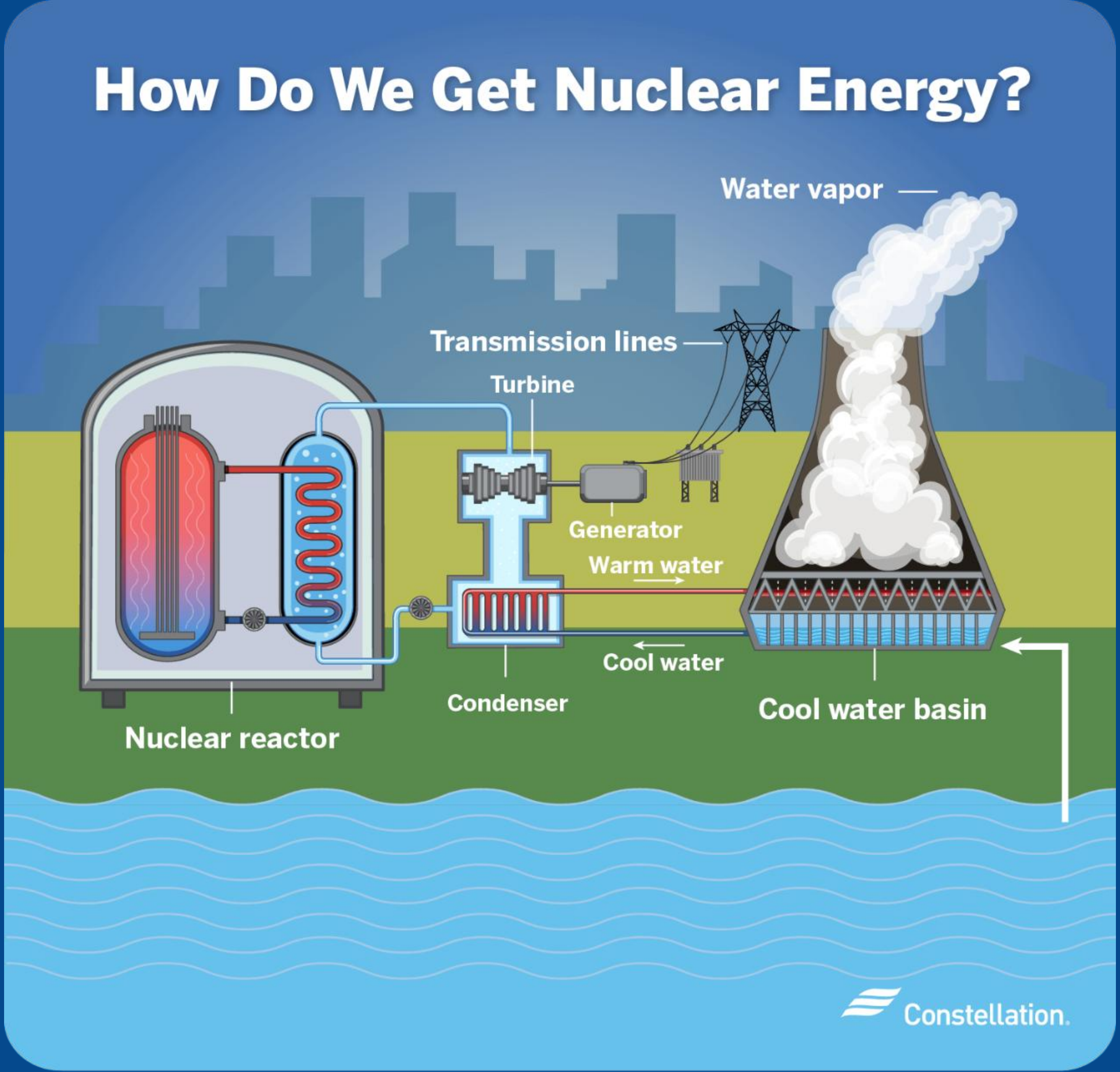
Typical conventional uranium mill



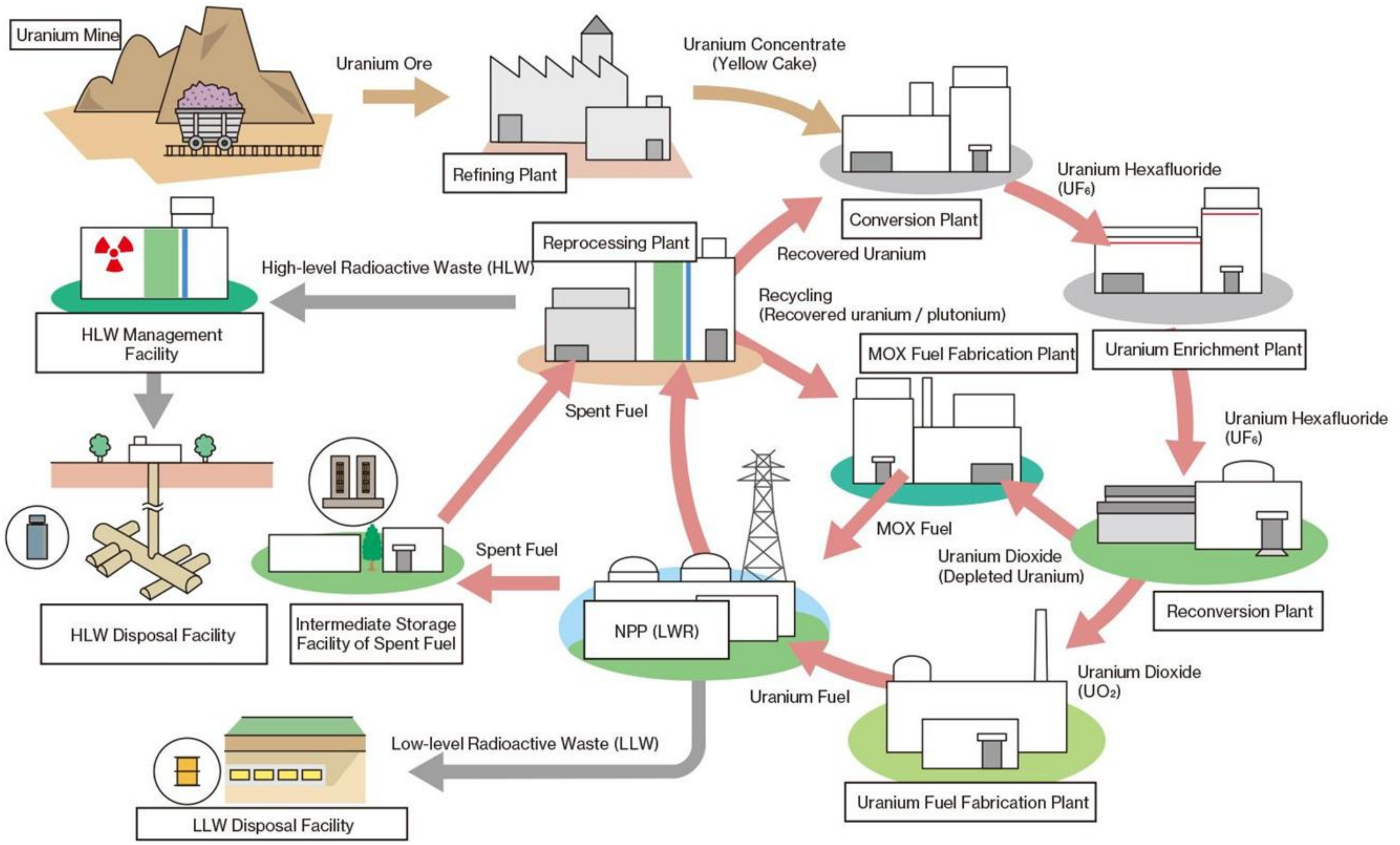
Source: U.S. Energy Information Administration

Technology Overview



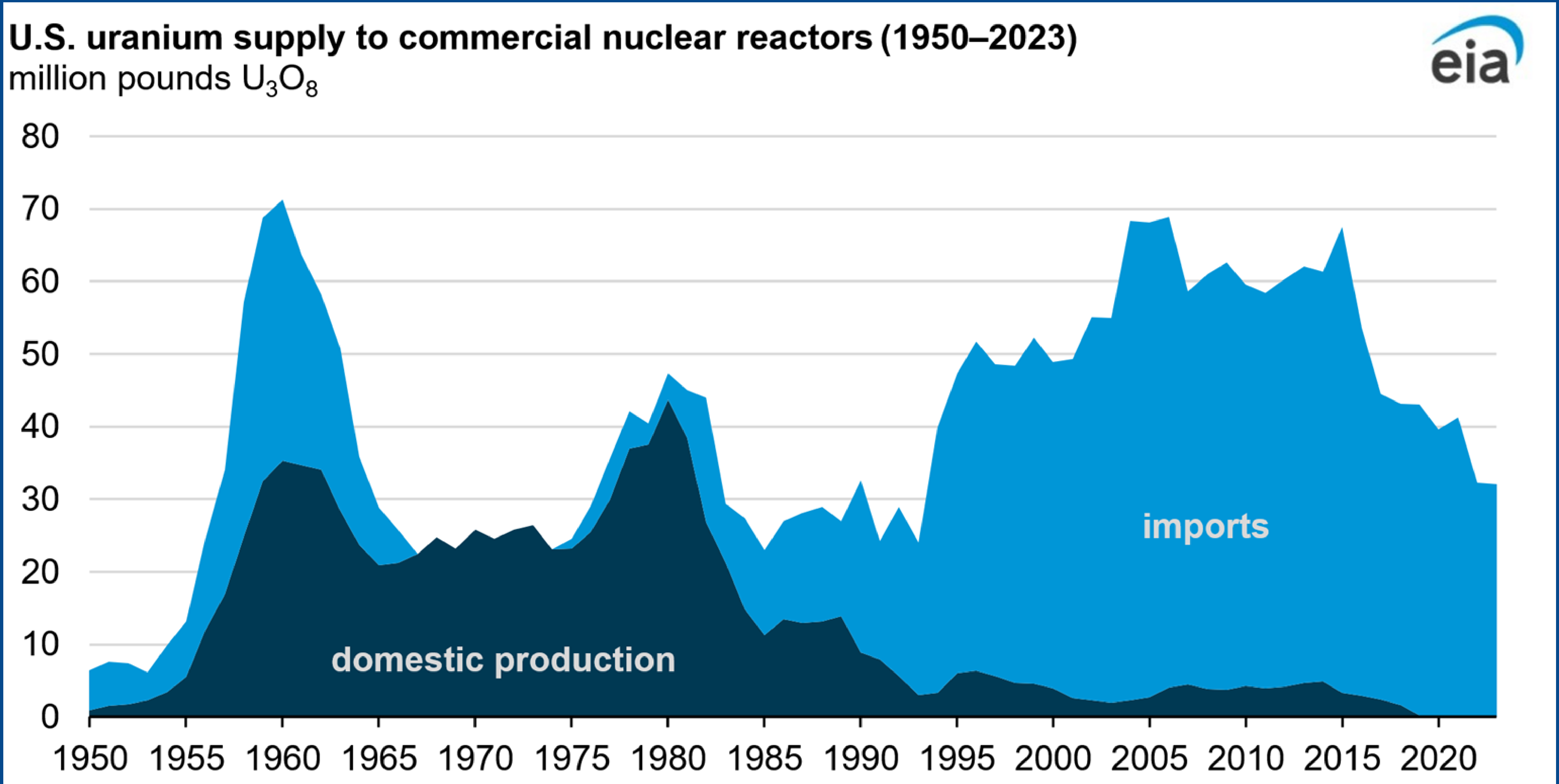

How Do We Get Nuclear Energy?
Water vapor
Transmission lines
Turbine
Generator
Warm water
Cool water
Condenser
Cool water basin
Nuclear reactor
Constellation.

Nuclear Fuel Cycle

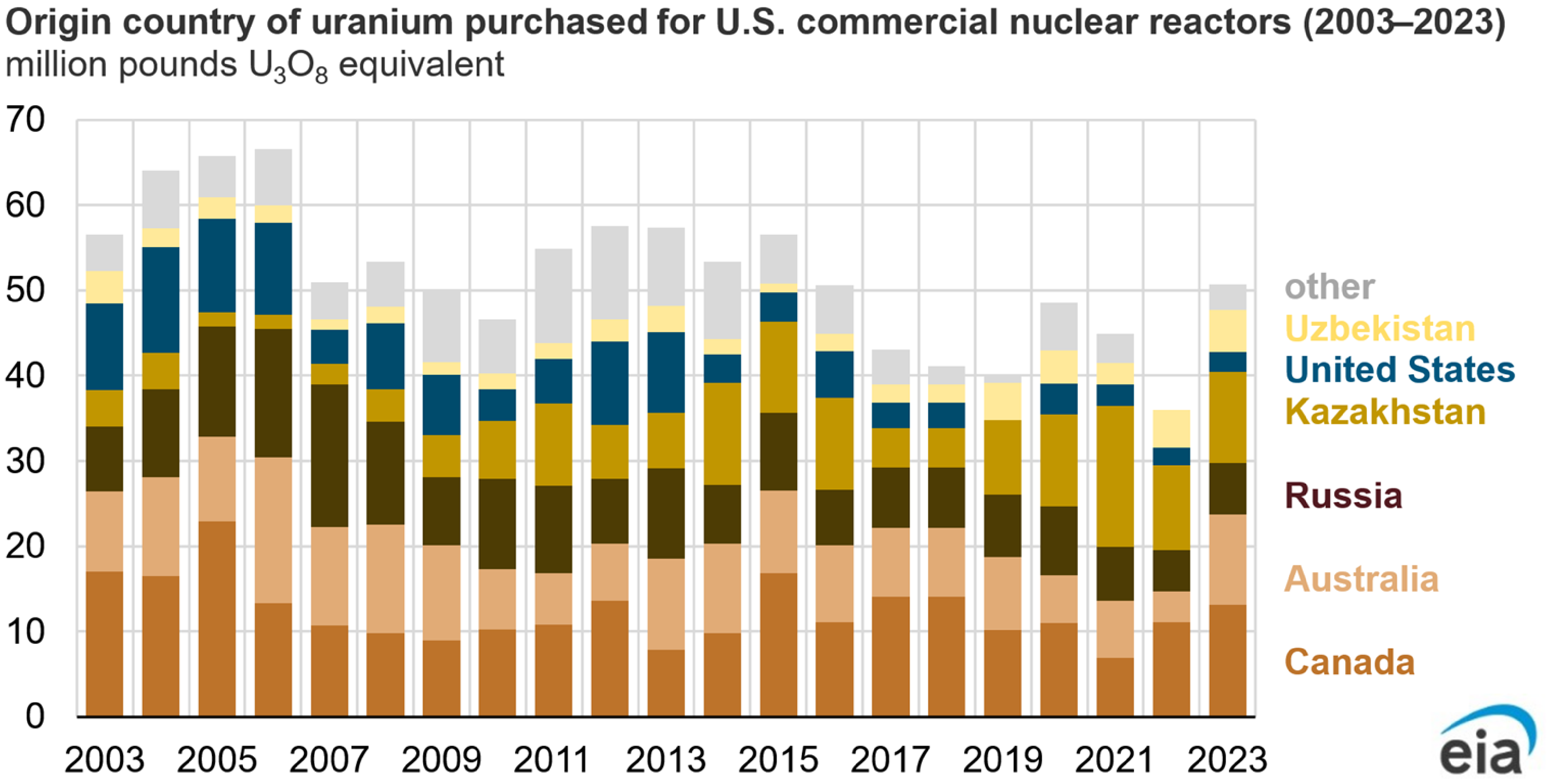


(Note) MOX Fuel: Uranium-Plutonium mixed oxide fuel

Technology Overview



Technology Overview



Technology Overview

Technology Overview

Nuclear Fuel Cycle

Front-end

- Exploration
- Mining (Uranium ore)
- Milling
- Conversion
- Enrichment
- Fuel Fabrication

mined uranium ore → refined uranium concentrate → uranium hexafluoride gas (UF6) → uranium gas enrichment (3-5% concentration of U-235 isotope) → fuel fabrication (UF6 gas processed to form UO2 powder and compressed into pellets, stacked into fuel rods)

Back-end

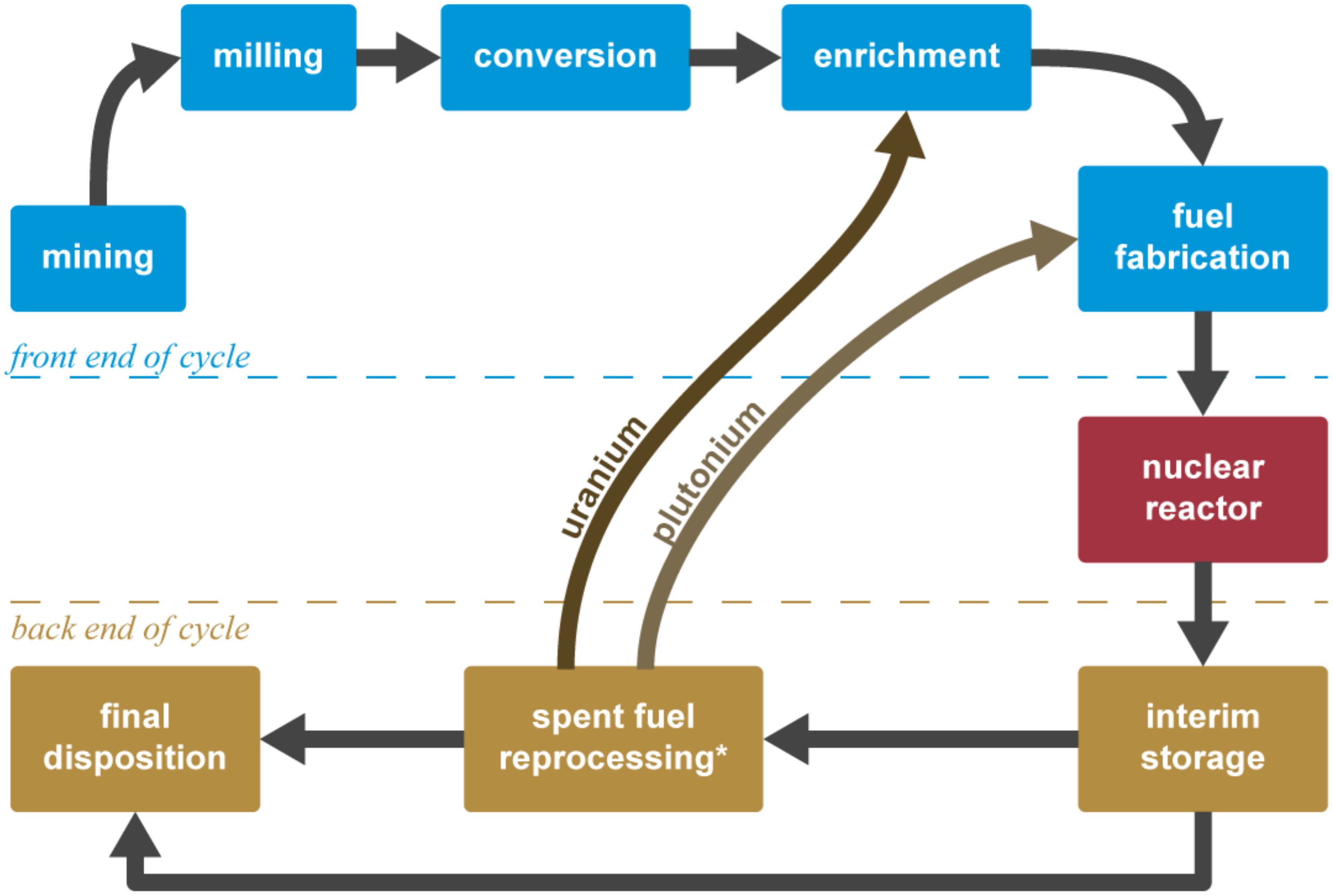
- Temporary on-site waste storage
- Long-term high-level waste storage*

radioactive used fuel assemblies are stored for several years in pools of water as they give off heat → cooled spent fuel is moved to dry cask storage on-site → spent fuel assemblies transferred to permanent underground repository*

Source: U.S. EIA

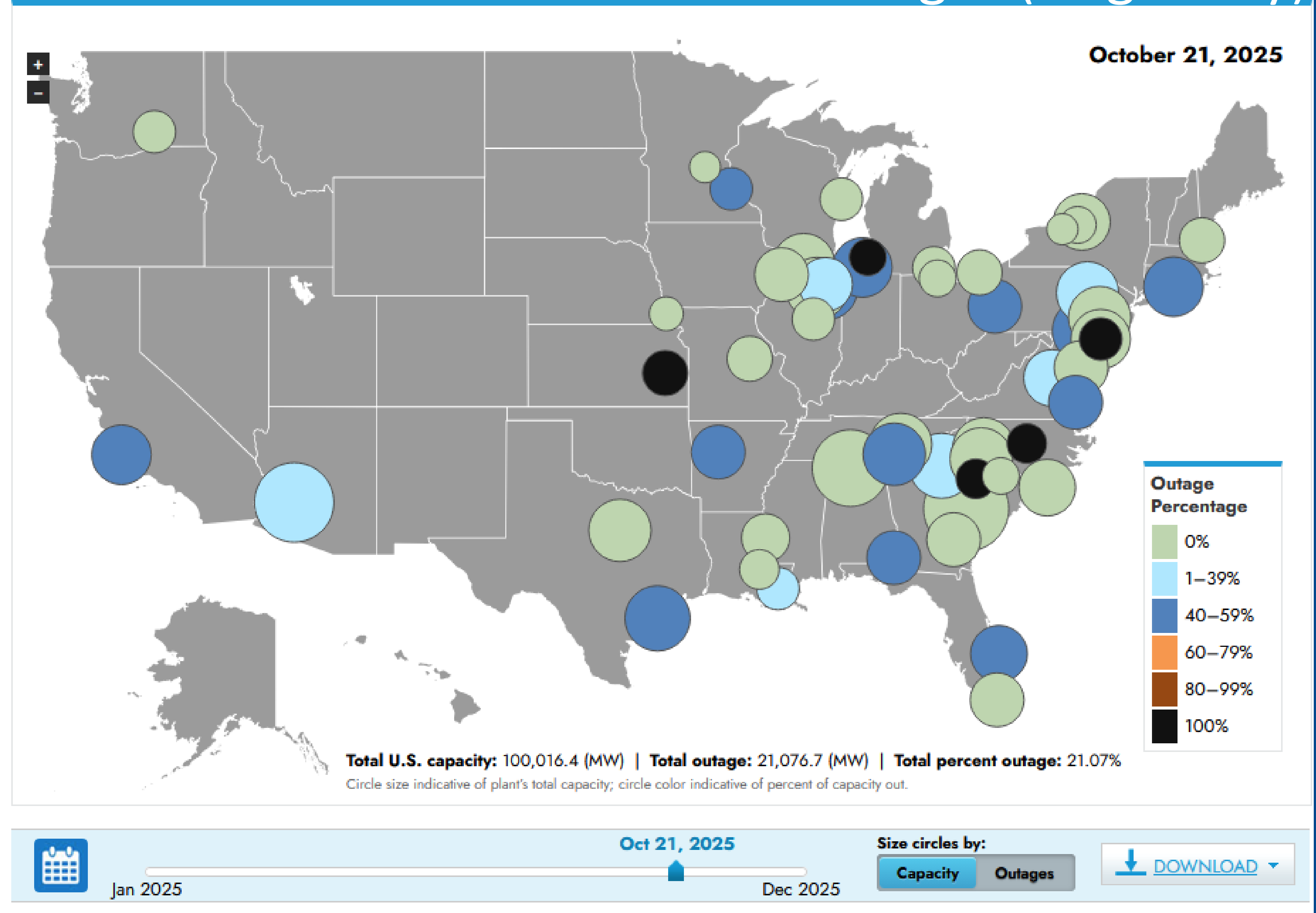
Source: Pennsylvania State University Radiation Science and Engineering Center (public domain)
Image source: U.S. EIA

Nuclear fuel cycle

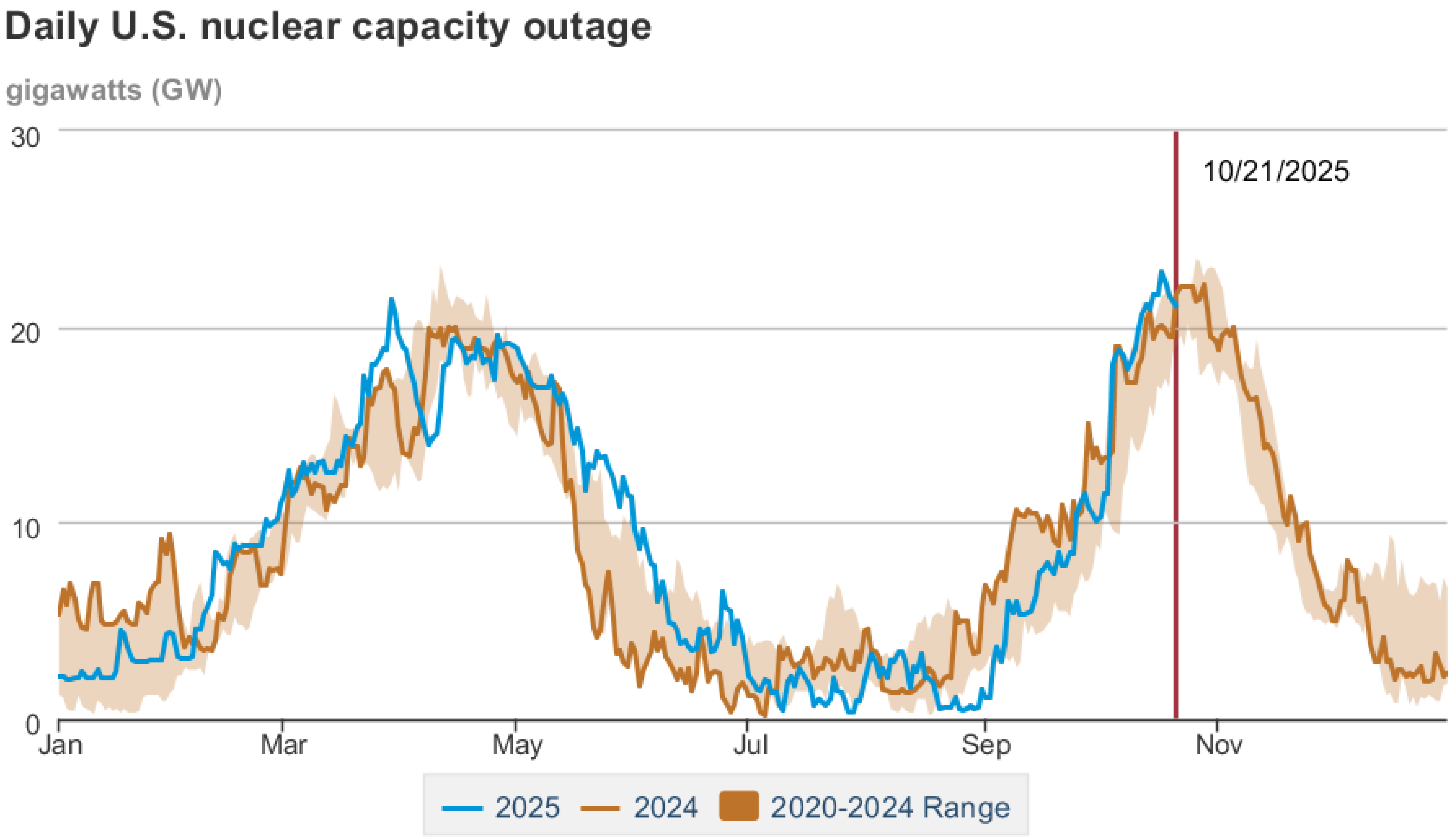


**Spent fuel reprocessing* is omitted from the cycle in most countries, including the United States.

Status of U.S. Nuclear Power Plant Outages (single-day)



Source: U.S. EIA
Accessed October 2025

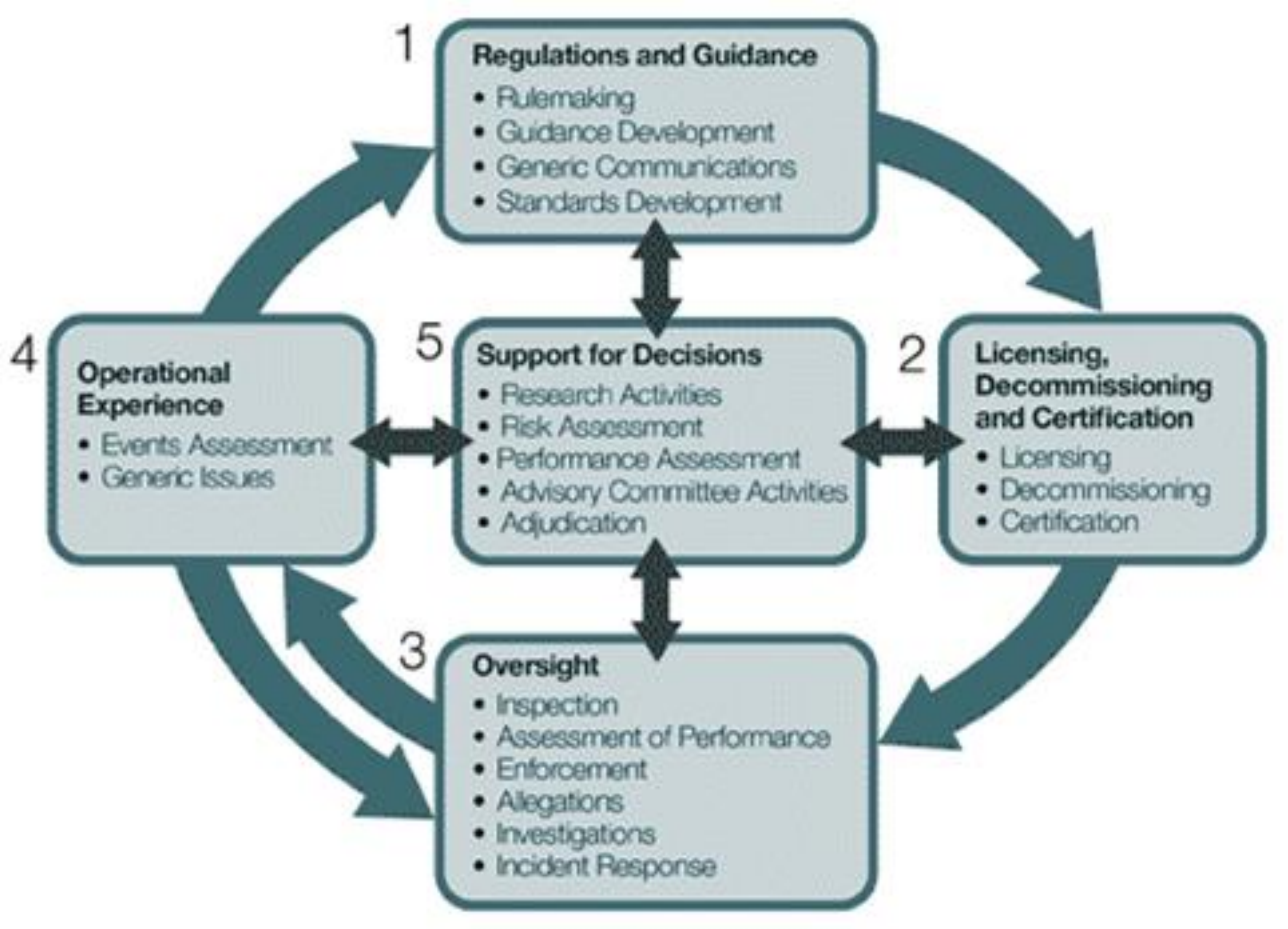


U.S. Energy Information Administration based on the Nuclear Regulatory Commission's Power Reactor Status R
Form EIA-860M Monthly Update to the Annual Electric Generator Report. **Note**: Outage data reflect only nuclear

Nuclear Waste Policy Act (1982)

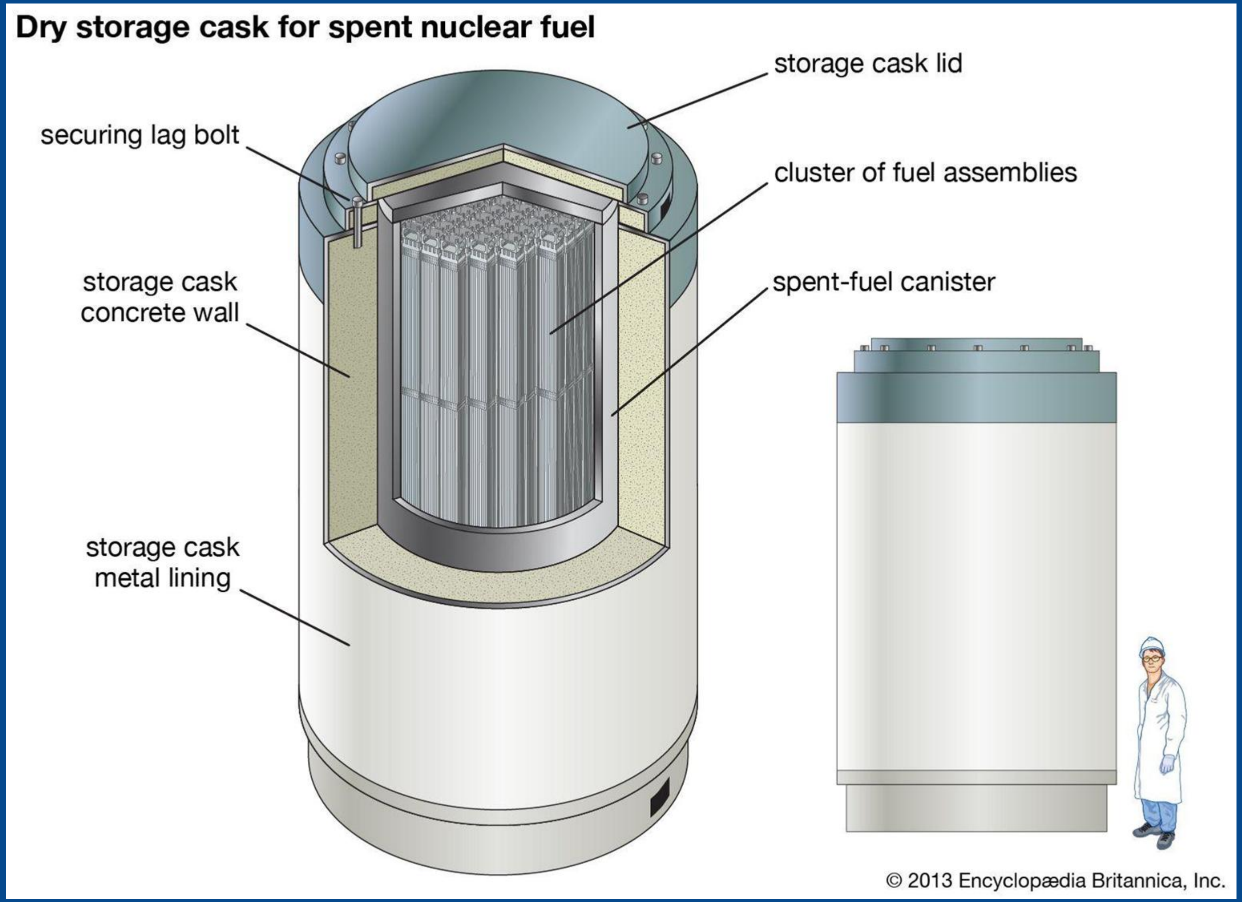
- Prohibits DOE from taking custody of spent nuclear fuel for interim storage until a long-term storage solution is licensed for construction

Nuclear Regulatory Commission (NRC)



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, investigating 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.*

As of June 2017


Dry storage cask for spent nuclear fuel
storage cask lid
securing lag bolt
cluster of fuel assemblies
storage cask
concrete wall
spent-fuel canister
storage cask
metal lining
© 2013 Encyclopædia Britannica, Inc.

Challenges in the nuclear fuel cycle

- Uranium mine cleanup from legacy mining
  - From 1944 to 1986, nearly 30 million tons of uranium ore were extracted from Navajo lands under leases with the Navajo Nation. This website describes how five federal agencies are working together to reduce the highest risks to Navajo people from uranium contamination resulting from the abandoned mines.
- Unsuccessful attempts to site a high-level waste (HLW), long-term repository for spent fuel
  - DOE pays penalties as reactors host spent fuel indefinitely

https://www.epa.gov/navajo-nation-uranium-cleanup

HALEU

High-Assay Low-Enriched Uranium

What is it?

Uranium enriched between

5% and 19.75%

in uranium-235 — the main fissile isotope that produces energy during a chain reaction.

< 20%	5% to 19.75%	≥ 20%
LEU	**HALEU**	**HEU**
Low-enriched uranium	High-assay low-enriched uranium	Highly enriched uranium
Existing Reactors: 3% to 5%	Accident Tolerant Fuel (5% - 10%) Advanced Reactor Fuel (10% - 19.75%)	Naval reactors: >90%

Low Enriched Uranium
>0.711% to <20%

KEY: U-238, U-235

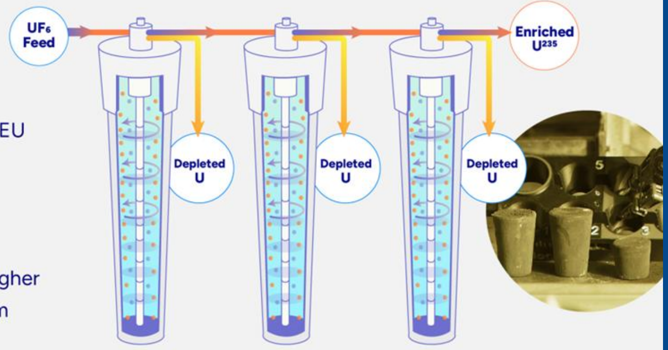
How is it made?

Chemical Processing

Recycle used goverment-owned HEU and downblend to HALEU

Enrichment

Gas centrifuges separate uranium isotopes by weight to produce a higher percentage of U-235 in the uranium



What are the benefits?

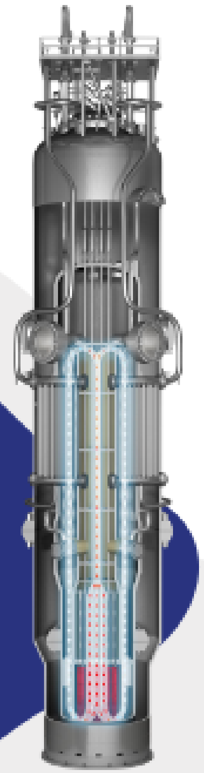
- Smaller designs
- Longer operating cycles
- Increased fuel efficiency
- Less waste

Per Module

77 MWe (gross) Electrical Power generating capability

Capacity factor >95 percent

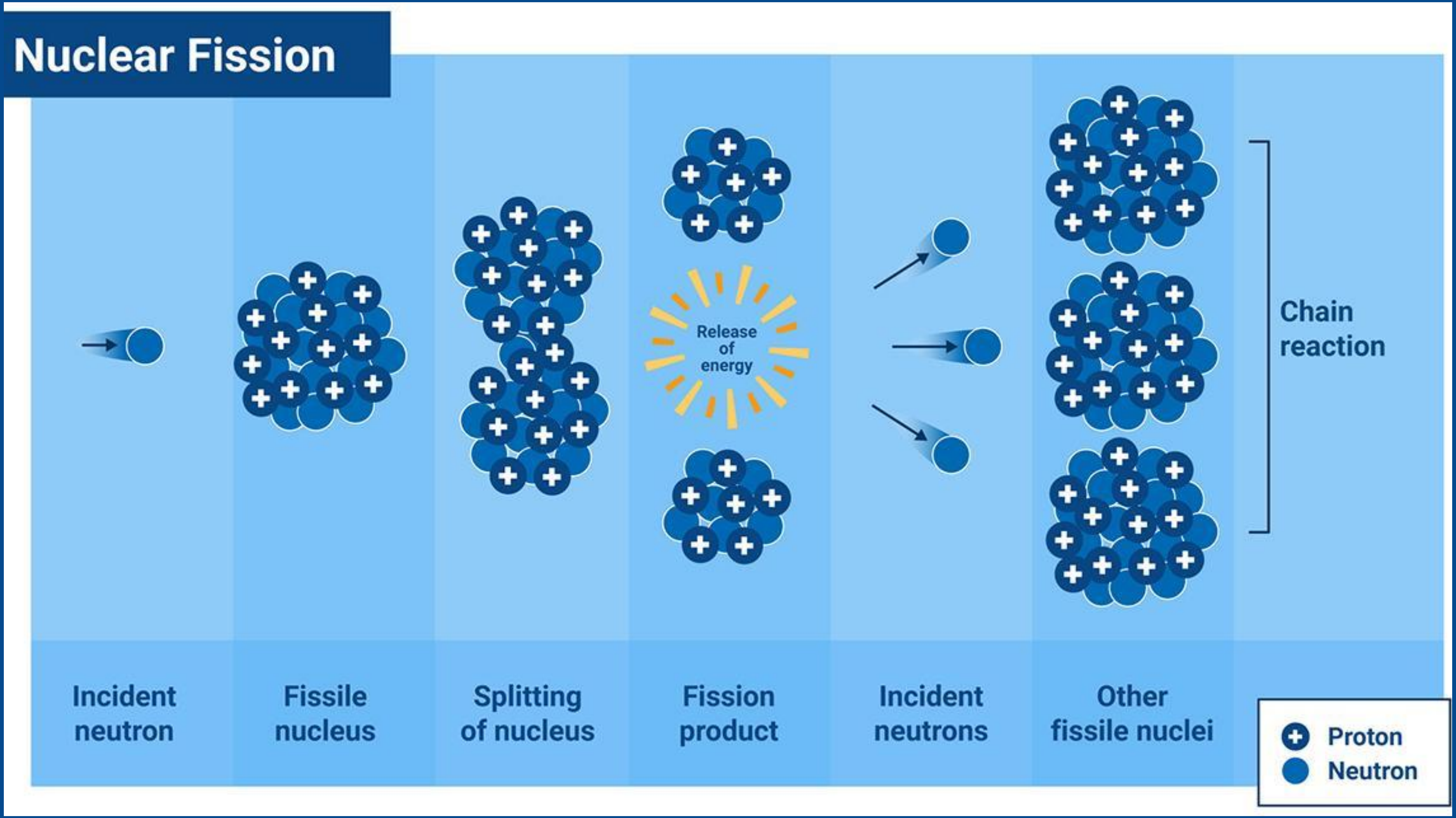
76' x 15' cylindrical containment vessel with reactor and steam generator



Technical Specifications

Plant Operation Objective	60 years
Thermal Power (per module)	250 MWt
Electrical Power (per module)	77 MWe (gross)
Thermal Efficiency	>30 percent
Steam Generators Number	2 independent tube bundles integrated into reactor vessel
Configuration	Once through helical
Operating Cycle Length	18-21 months
Outage Duration	10 days
Reactor Type	Integral Pressurized Water Reactor

"The NuScale Power Module design is based on proven pressurized water-cooled reactor technology and represents a 17-year and $1.6 billion investment."



Graphic: A. Vargas/IAEA