Understanding the Nuclear Fuel Cycle

An introduction to how nuclear fuel is made, used, and managed in the United States

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Why This Matters Now

Growing Demand

Nuclear energy is receiving renewed attention across the United States as electricity demand grows and interest increases in expanding domestic energy production, advanced manufacturing, and the nuclear fuel cycle.

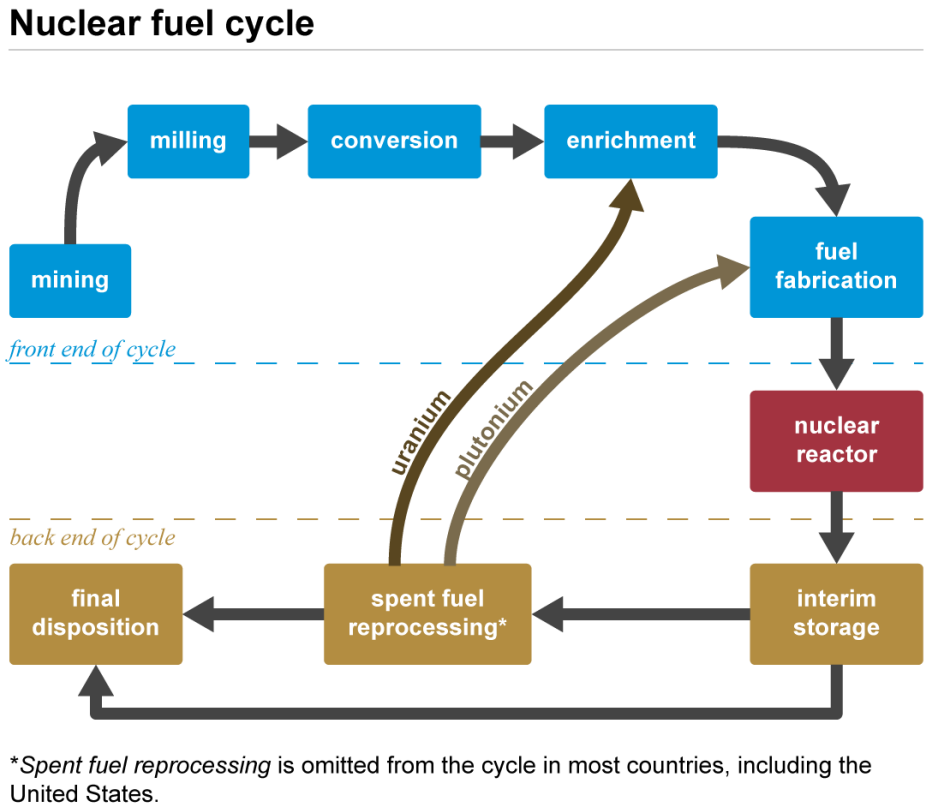
A Federal Step Forward

The U.S. Department of Energy is exploring the development of Nuclear Lifecycle Innovation Campuses to strengthen the nation's nuclear capabilities. Oklahoma is one of five states selected as finalists to partner with DOE in this effort.

Why This Briefing

Before discussing what a Nuclear Lifecycle Innovation Campus could mean for Oklahoma, it helps to establish a common vocabulary and understand how nuclear fuel is developed, used, recycled, and managed throughout its lifecycle.

The Nuclear Fuel Cycle

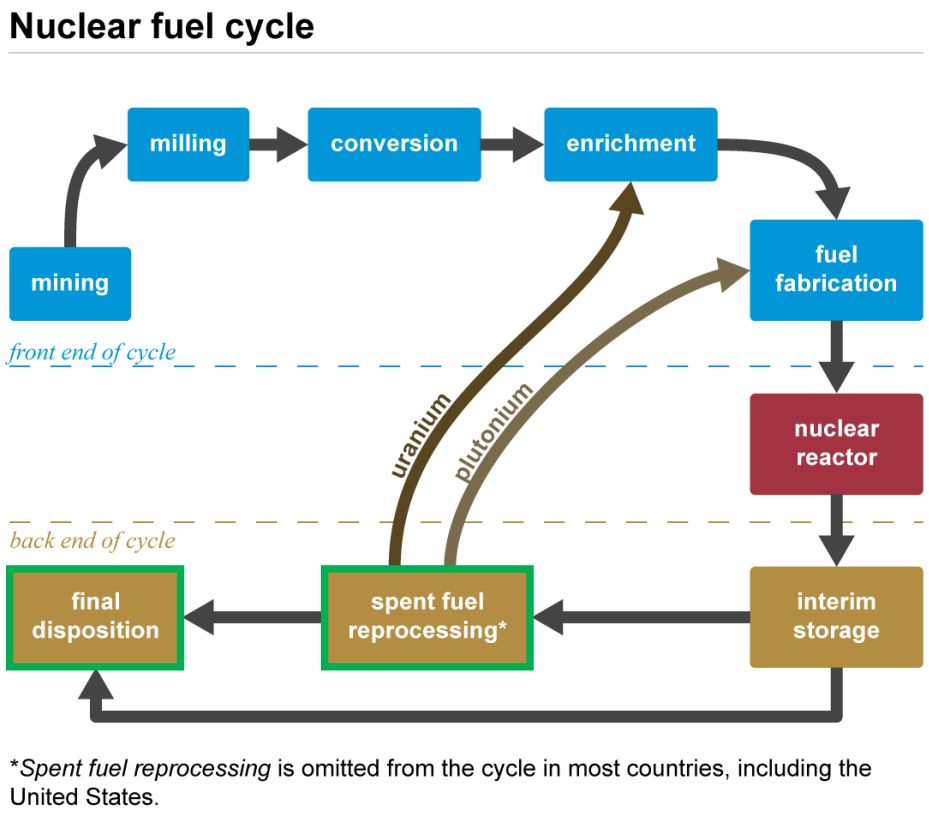


The nuclear fuel cycle describes the sequence of activities required to produce nuclear fuel, generate electricity, and safely manage used nuclear materials.

Three Parts of the Fuel Cycle:

- **Front end:** produce the fuel
- **Reactor:** use the fuel to generate electricity
- **Back end:** manage the fuel once it is used

The Nuclear Fuel Cycle



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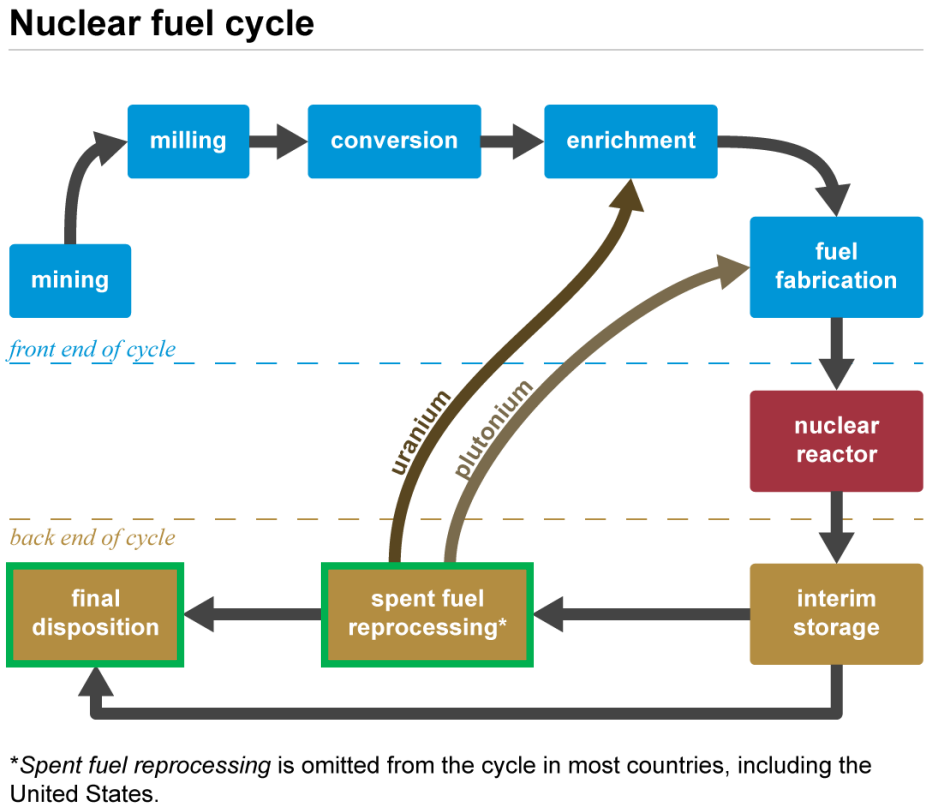

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Big picture: The United States has extensive expertise across the nuclear fuel cycle but today relies heavily on foreign suppliers for several front-end activities. Federal policy is now focused on strengthening domestic capabilities.

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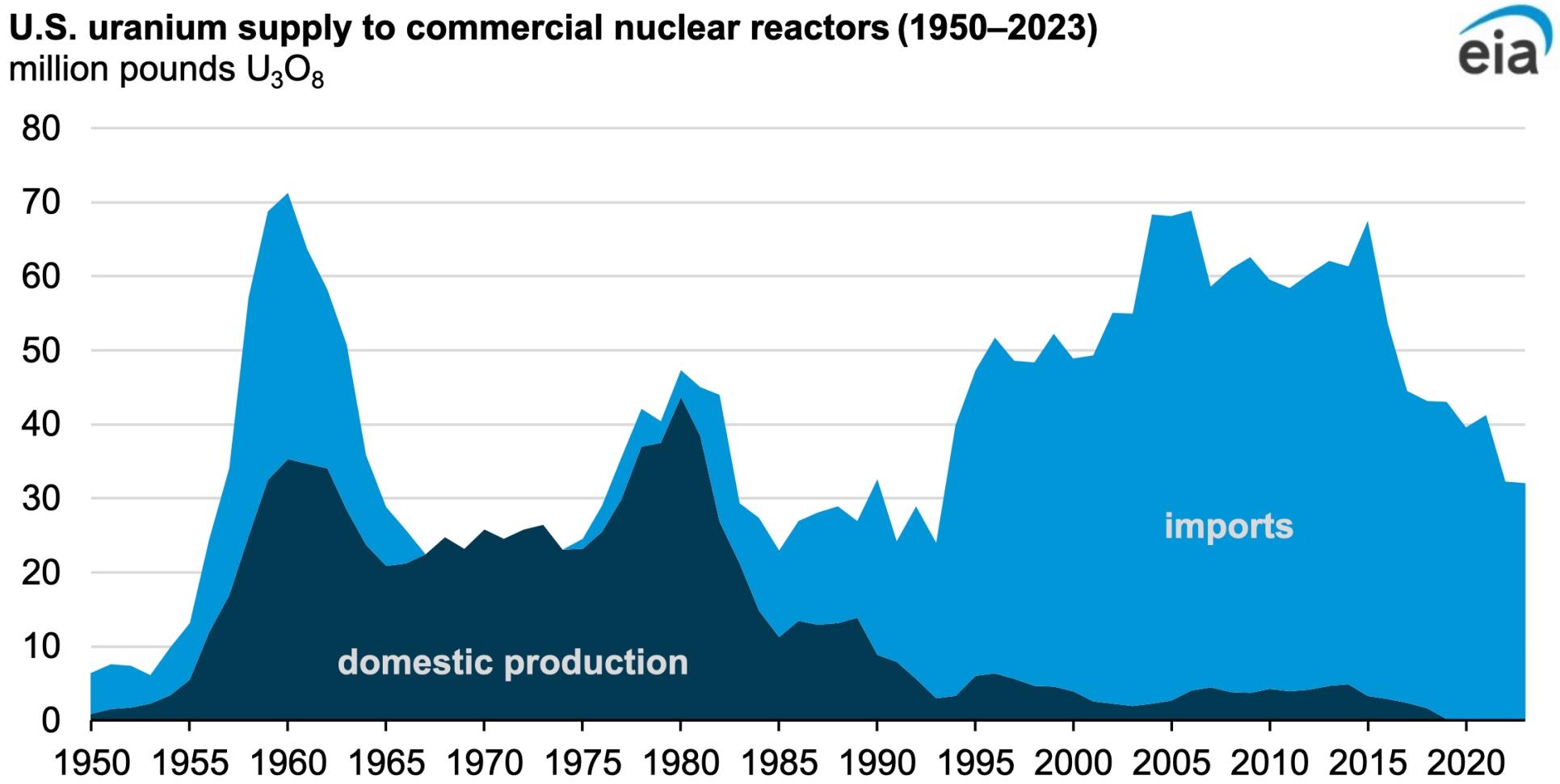
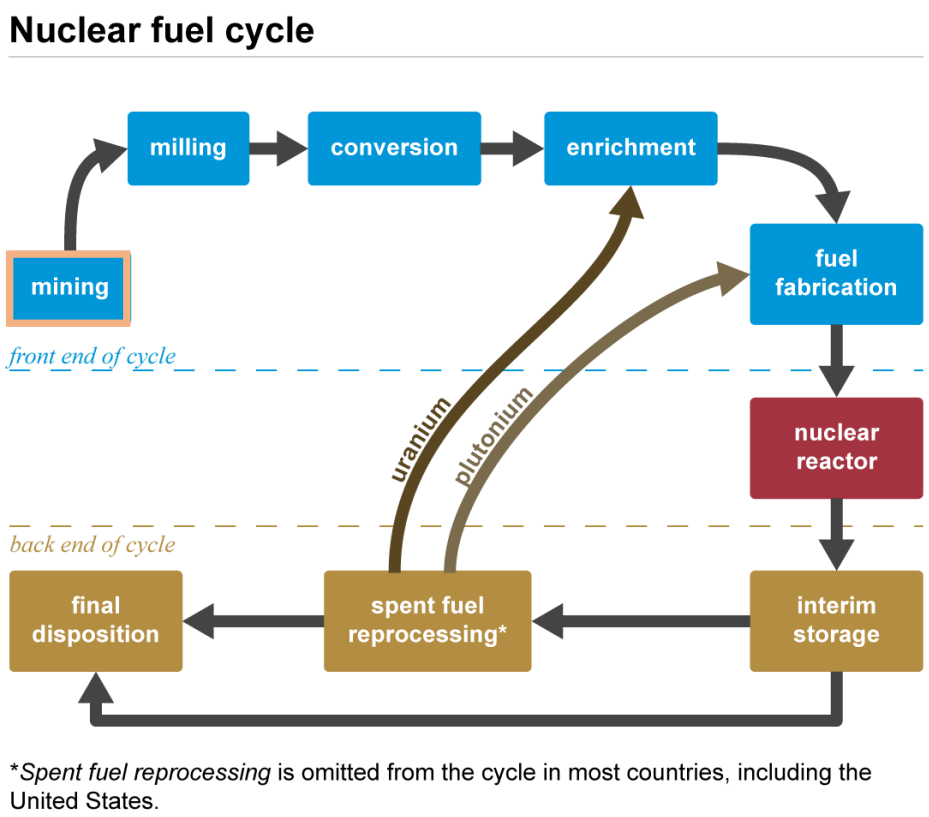


Data source: U.S. Energy Information Administration, *Monthly Energy Review*, *Domestic Uranium Production Report*, and *Uranium Marketing Annual Report*

The Front End: Making Nuclear Fuel



**Mining:* Uranium is recovered from naturally occurring deposits in the earth.

Most uranium used by U.S. nuclear power plants is imported, though domestic uranium production (7%) is increasing. Major suppliers include Canada (32%), Kazakhstan (28%), and Australia (15%).

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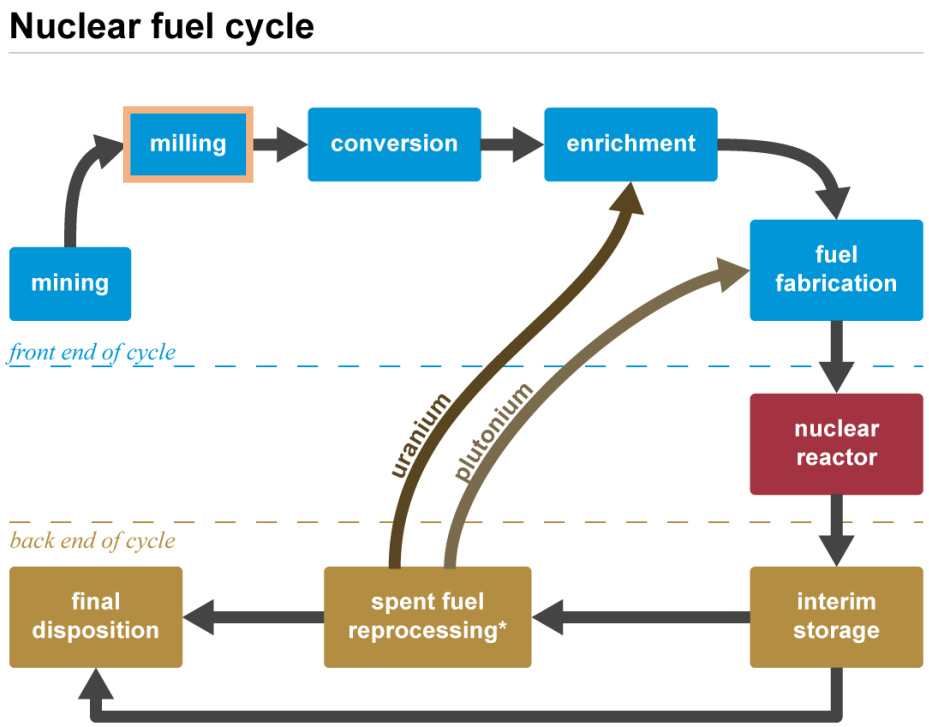
The Front End: Making Nuclear Fuel



**Milling:* Uranium is separated from mined ore or uranium-bearing solutions and concentrated into a powder called yellowcake.

Most milling for uranium used by U.S. nuclear power plants occurs outside the United States, typically near the mine where the uranium is produced.

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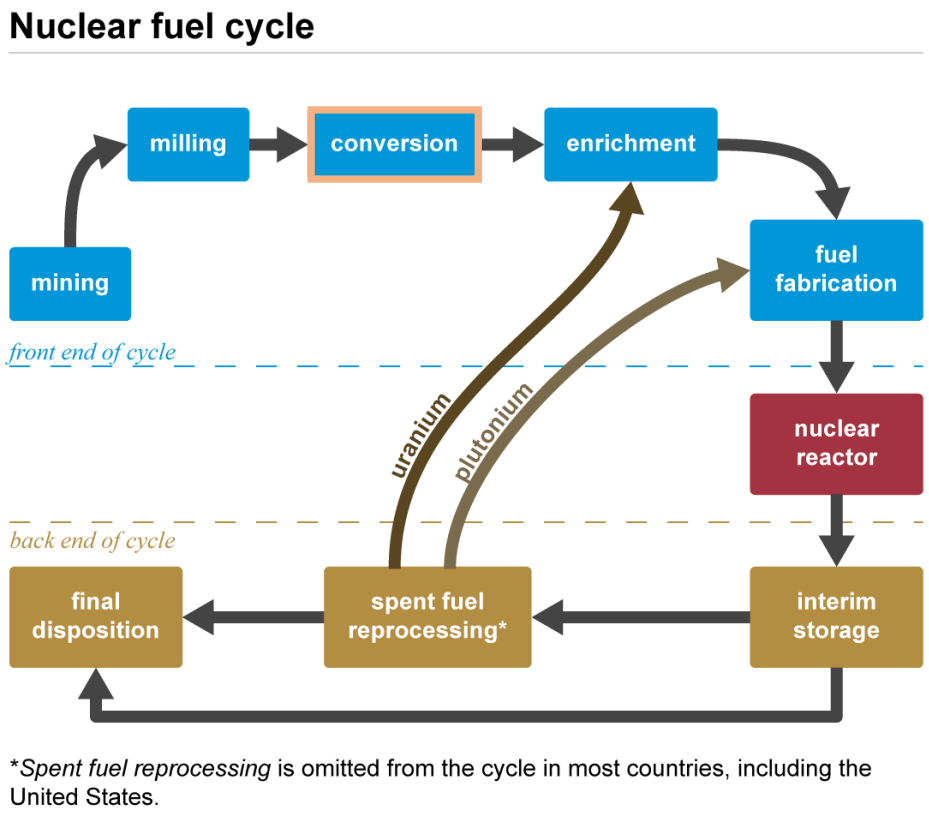
The Front End: Making Nuclear Fuel



**Conversion:* Yellowcake is purified and converted into uranium hexafluoride (UF_6), a chemical form that can be heated into a gas for enrichment.

Much of the uranium conversion for U.S. commercial reactor fuel occurs outside the United States, though domestic conversion capacity is expanding.

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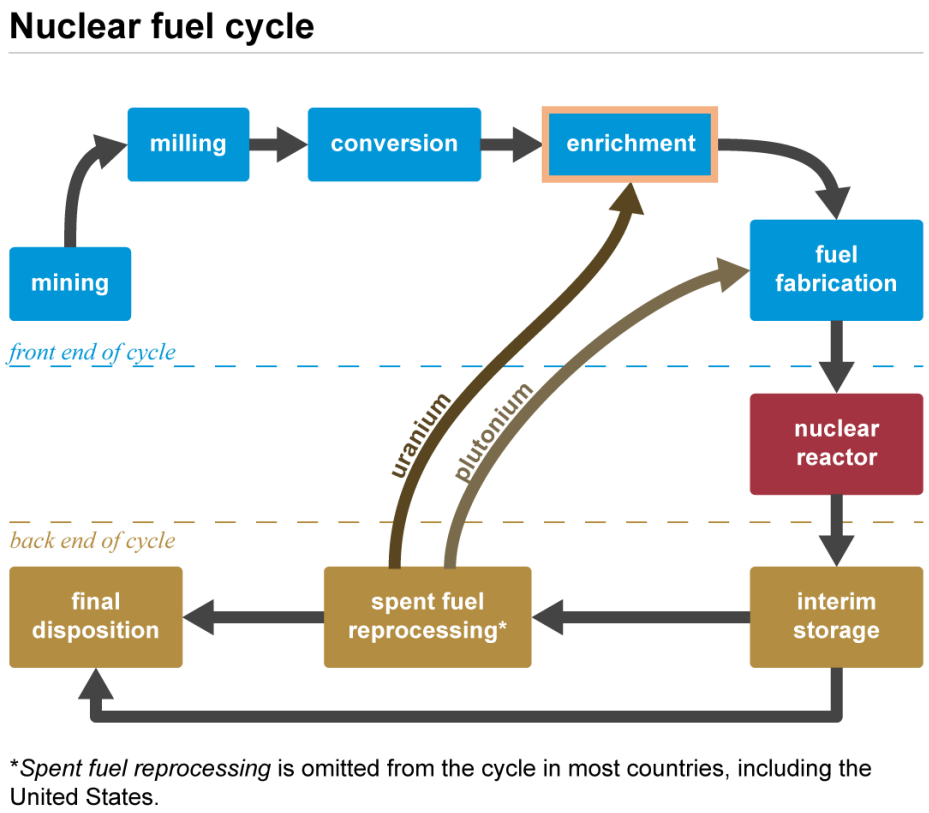

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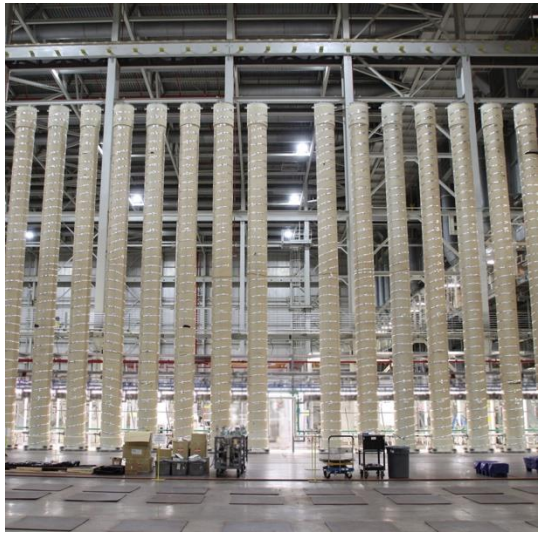
Enrichment: Uranium hexafluoride (UF_6) gas passes through centrifuges that increase the concentration of uranium-235 from about 0.7% to about 3-5% for most commercial reactors.



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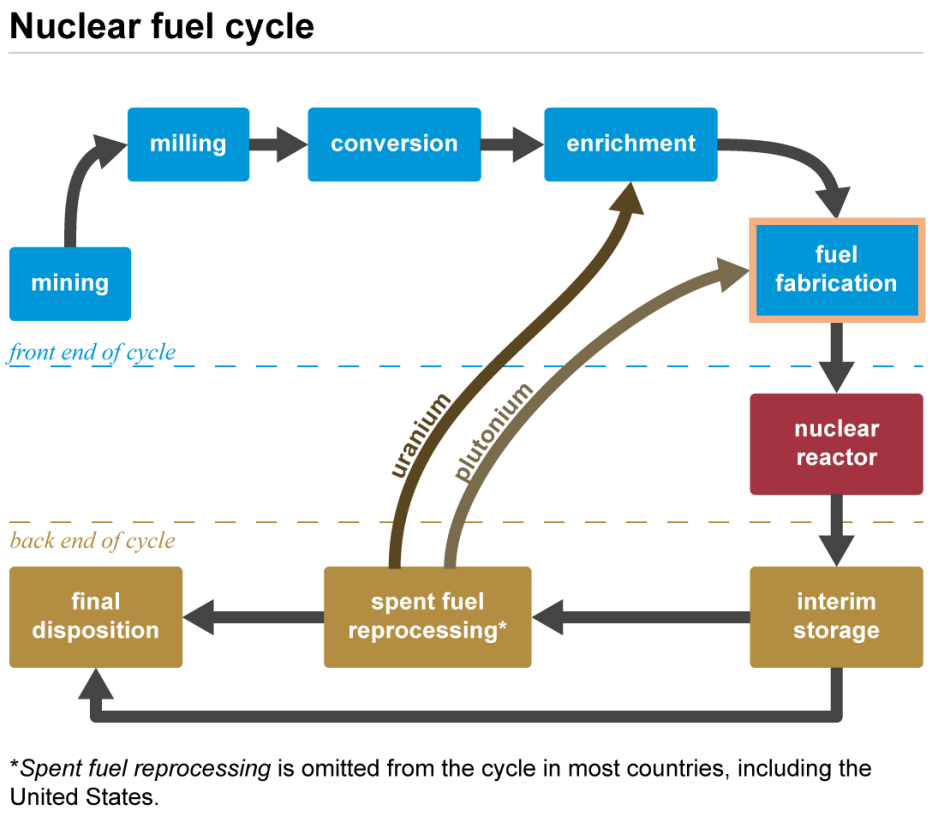
The Front End: Making Nuclear Fuel

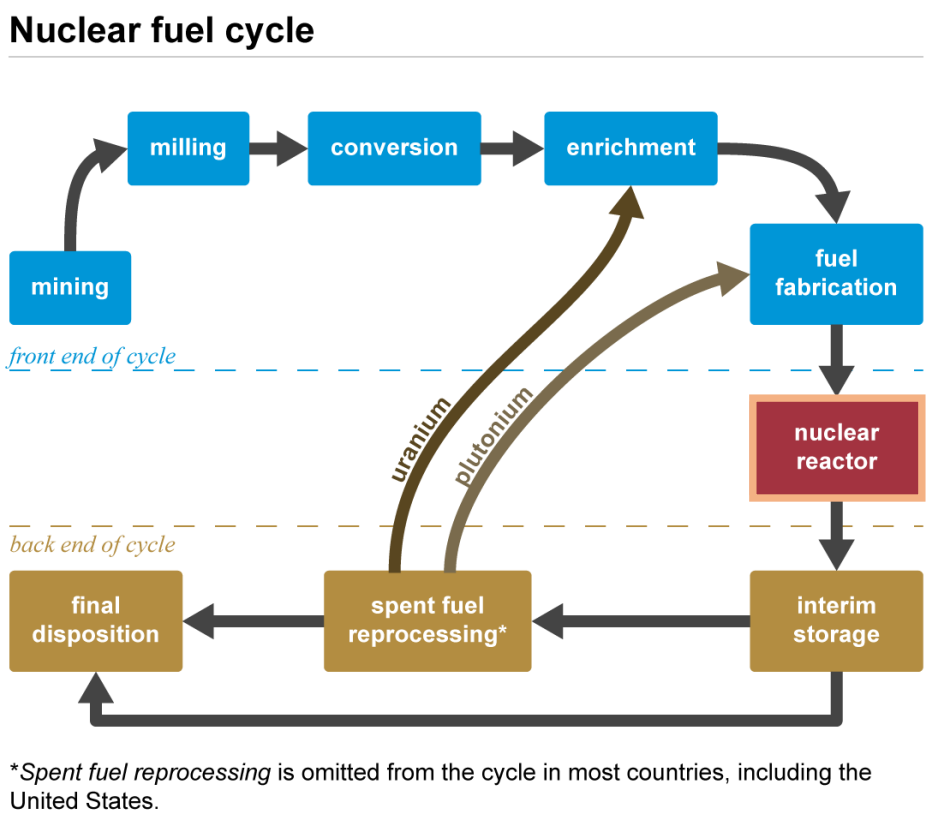


**Fuel fabrication:* Spent fuel reprocessing is omitted from the cycle in most countries, including the United States.

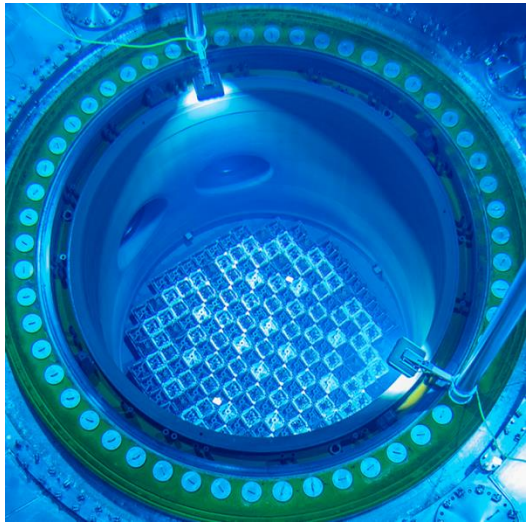
Fuel fabrication: Enriched uranium is converted into uranium dioxide, pressed into ceramic pellets, sealed in fuel rods, and assembled into fuel assemblies.

Most fuel fabrication for U.S. commercial reactor fuel already takes place in the United States, with additional capacity being developed to support advanced reactors.

The Reactor: Generating Electricity

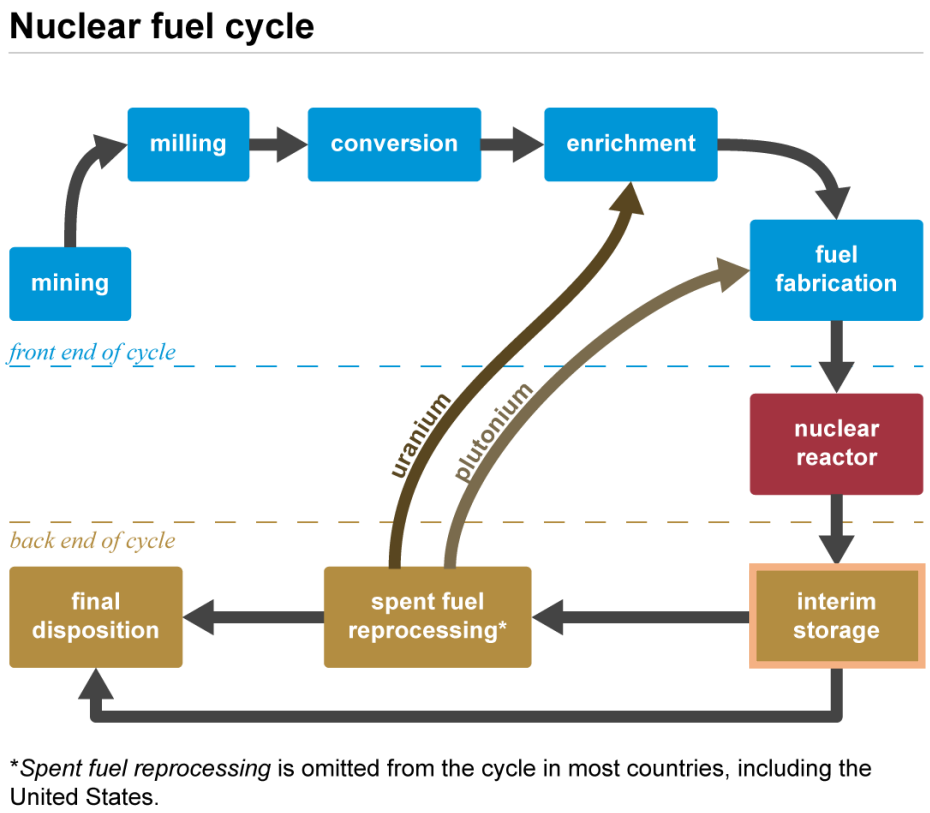


Nuclear Fission: Fuel assemblies are loaded into the reactor core, where uranium atoms split in a controlled chain reaction. The heat released produces steam, which spins a turbine to generate electricity.

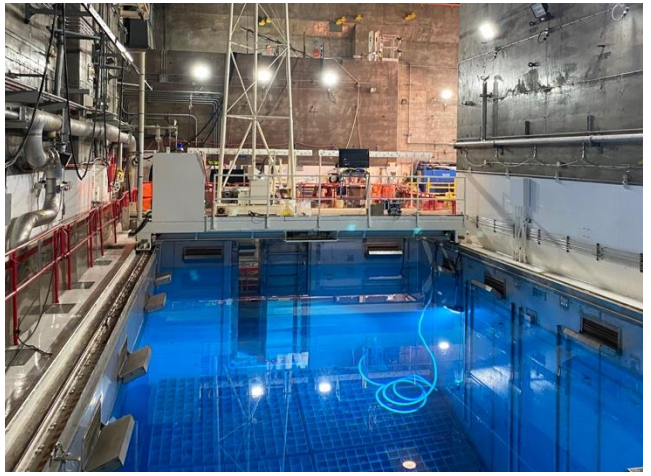


Nuclear power plants generate about 19% of U.S. electricity. Several new reactors are now under construction or planned, including TerraPower's Natrium reactor in WY and TVA's proposed SMR project at the Clinch River site in TN.

The Back End: Managing Used Nuclear Fuel



Used Fuel Storage: After 5-10 years in a reactor, used fuel assemblies are removed and placed in deep pools of water, where they cool and are safely shielded. After several years, they are transferred to dry storage casks designed for safe long-term storage.



The US does not currently have a centralized interim storage or a final disposition facility for commercial used nuclear fuel. As a result, nearly all used fuel is stored safely at the nuclear power plants where it was generated.

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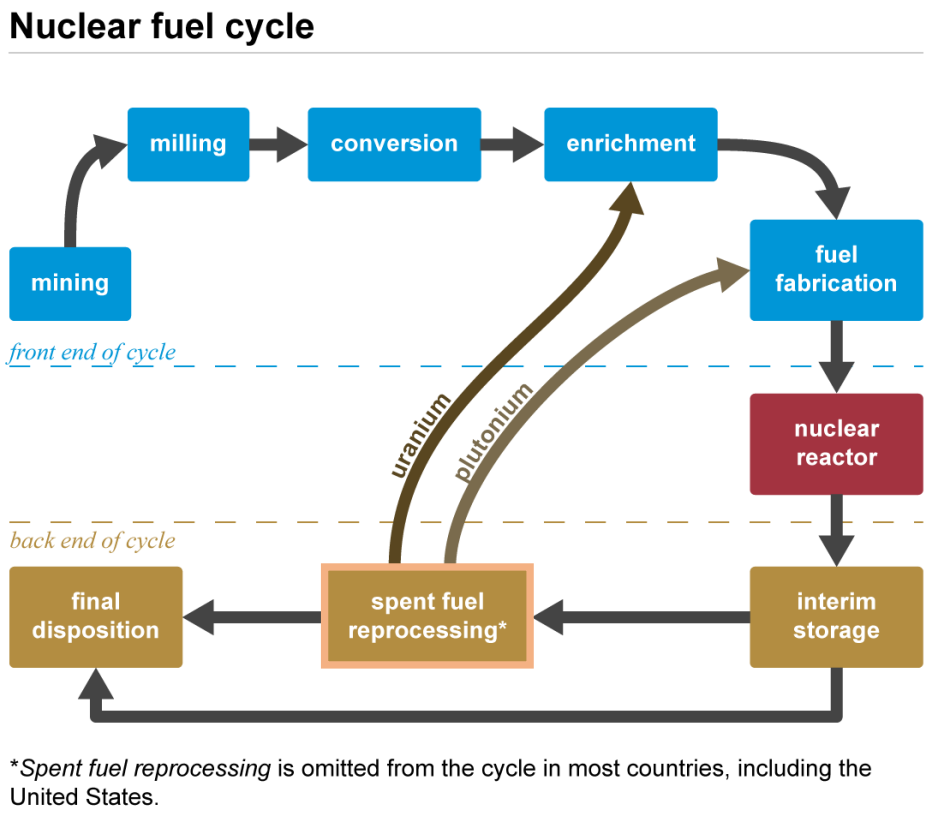
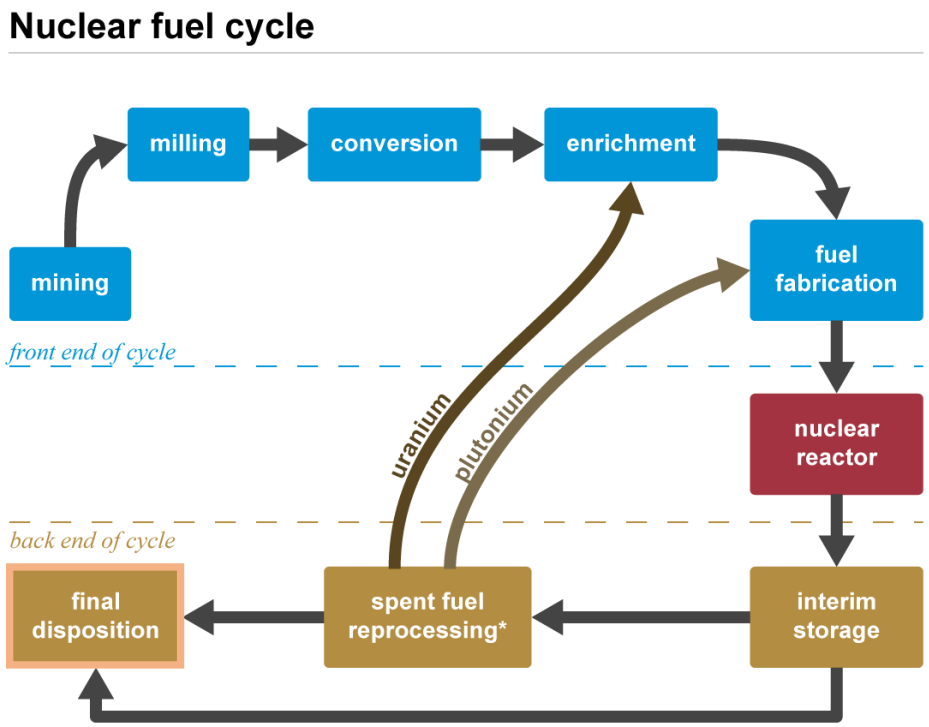


**Used Fuel Reprocessing:* Spent fuel reprocessing* is omitted from the cycle in most countries, including the United States.

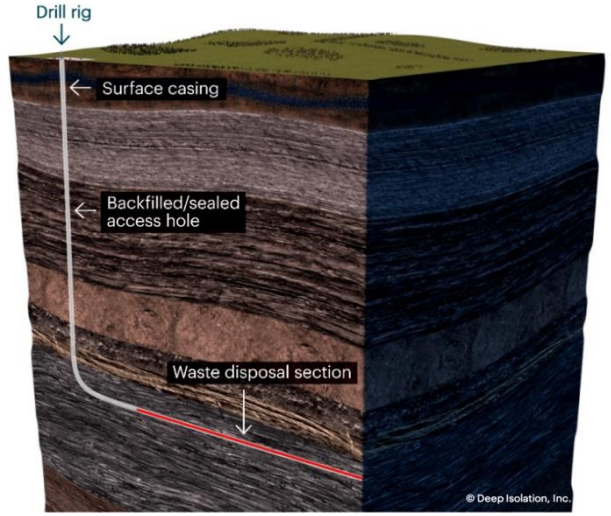
Used Fuel Reprocessing: Used nuclear fuel can be chemically processed to recover uranium and plutonium that can be recycled into new reactor fuel. This reduces the amount of material requiring long-term disposal.

The United States does not currently reprocess commercial used nuclear fuel. However, renewed federal and private-sector interest in advanced fuel recycling is driving the development of new recycling technologies.

The Back End: Managing Used Nuclear Fuel



**Final Disposition:* Materials that cannot be recycled are prepared for permanent disposition in deep geologic disposal systems designed to isolate radioactive materials from people and the environment.



The United States does not currently have a permanent disposal system for commercial used nuclear fuel. Internationally, several countries are developing deep geologic disposal systems, and Finland has become the first to implement one.

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More Than Electricity

The nuclear fuel cycle supports more than electricity generation.

- New fuel: Specialized reactors produce **medical isotopes** that help diagnose and treat diseases such as cancer.
- Used fuel: Advanced fuel recycling can recover additional high-value isotopes and reusable materials.
- Key takeaway: The nuclear fuel cycle is designed to maximize the value of nuclear materials throughout their entire lifecycle.

Resources

World Nuclear Association
U.S. Nuclear Fuel Cycle
world-nuclear.org

U.S. Energy Information Administration
Nuclear Explained
eia.gov/energyexplained

U.S. Nuclear Regulatory Commission
Nuclear Materials and Fuel Cycle
nrc.gov/materials

Where the U.S. Nuclear Fuel Cycle Operates Today