



NUCLEAR ENERGY

Just the Facts

FAST FACTS

Nuclear power generates



of our nation's
carbon-free electricity.

Nuclear plants operate



making them the ideal
zero-carbon **complement**
to wind and solar.



of the nation's
electricity is generated by
93 reactors in 28 states.



All **55 power plants** avoid more carbon emissions annually than the emissions produced by more than **100 million passenger vehicles.**



America's nuclear power industry directly employs nearly **100,000 people.** This number climbs to **475,000** including secondary jobs.



Nuclear saves consumers an average of **6 percent** on electricity bills and adds **\$60 billion** to the U.S. GDP.



A strong civil nuclear sector allows the U.S. to set international nuclear standards and form **100-year strategic relationships** around the world.



U.S. nuclear plants are more than **100 times safer** than regulatory safety goals.

1 Uranium Fuel Pellet



provides as much energy as



1 Ton of Coal



149 Gallons of Oil



17,000 Cubic Feet of Natural Gas

Powering America

4

Nuclear Energy in America	6
Clean Energy Leader	8
Powering the Economy	12

The Life Cycle of Nuclear

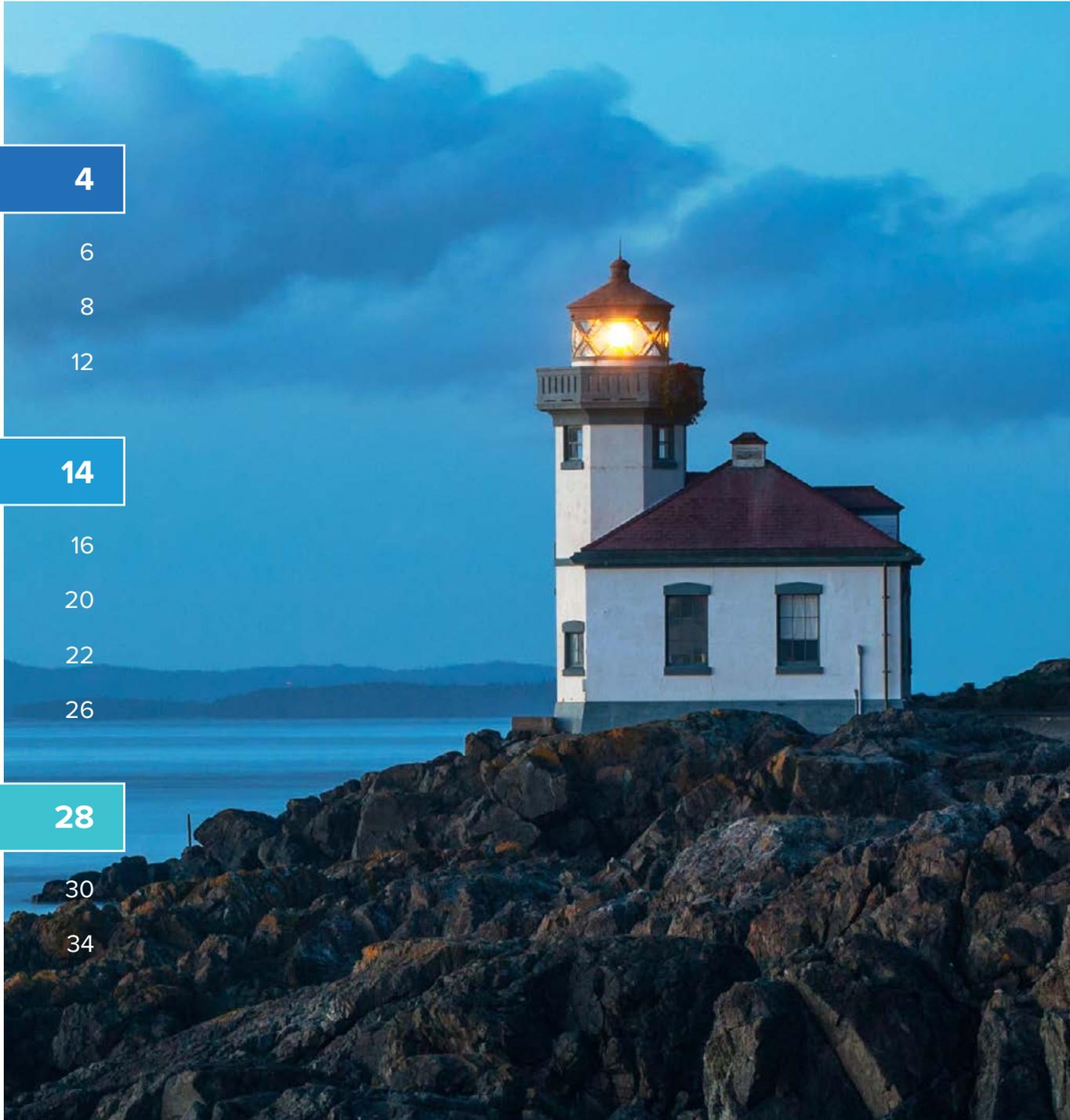
14

How Nuclear Fuel Is Made	16
How a Reactor Works	20
How Used Fuel Is Managed	22
Decommissioning a Nuclear Plant	26

Looking Forward

28

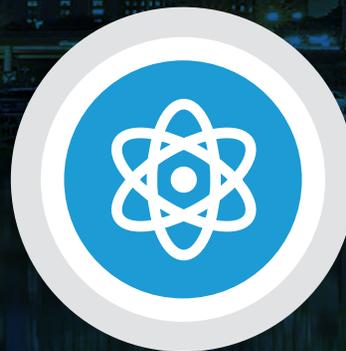
New Nuclear Technologies	30
Nuclear Energy Around the World	34



POWERING AMERICA



Nuclear energy generates **nearly 20 percent** of the nation's electricity.

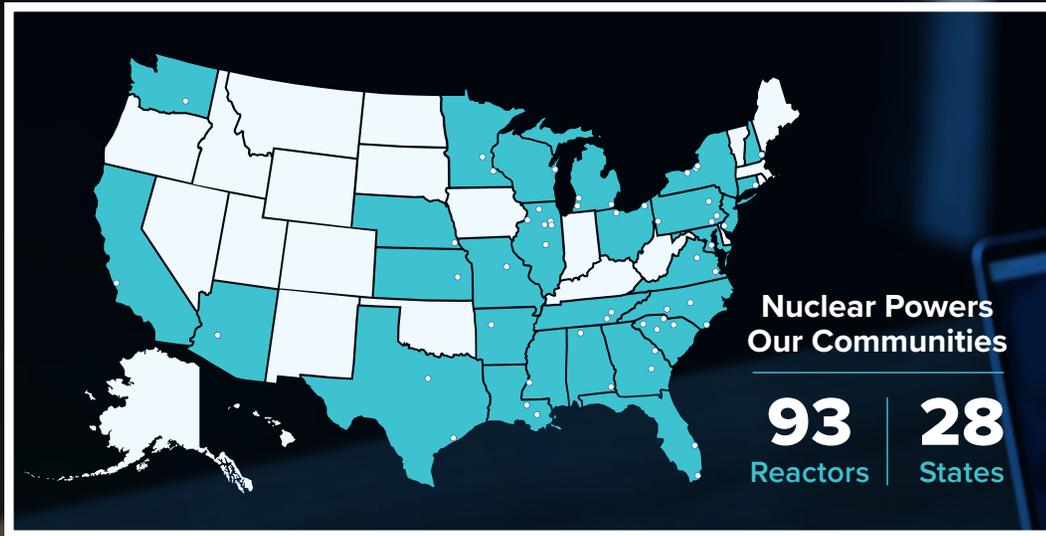


Nuclear powers America's cities and towns more reliably than any other energy source.



Nuclear is our largest source of clean energy, providing **more than 50 percent** of our carbon-free electricity.

NUCLEAR ENERGY IN AMERICA



Nuclear energy produces electricity for one in five homes and businesses across the United States, with 93 reactors in 28 states.

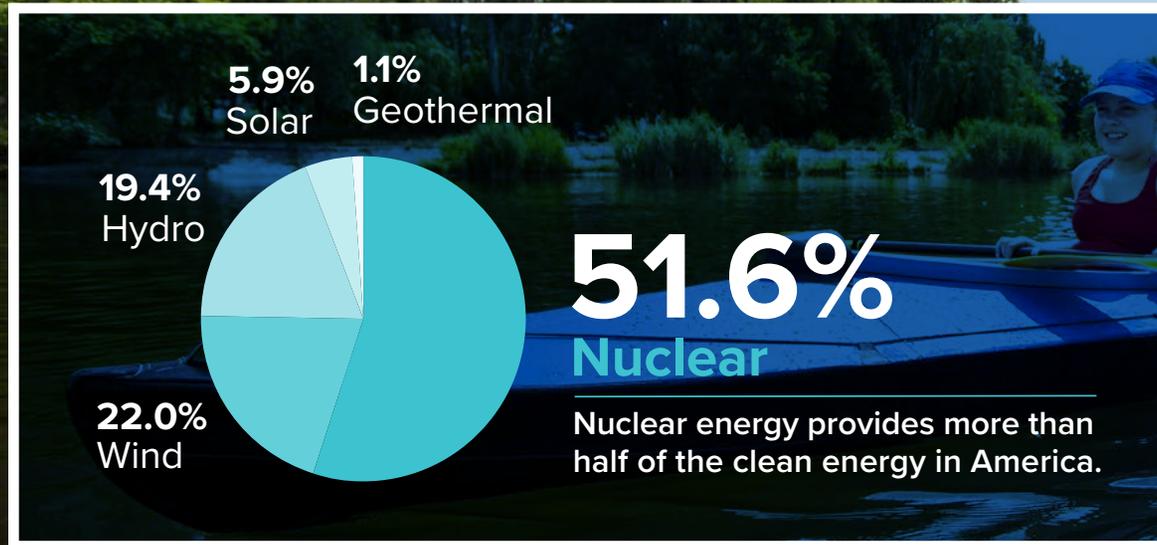
Electricity is essential to our everyday life—powering everything from iPhones to server farms and air conditioners, lighting homes and running factories. Electricity generation and distribution are among the greatest achievements of the past century. With affordable power available to all, electricity has transformed the way we live and continues to fuel America’s economy.

Now, we face a turning point. We need clean, always-on energy ready to meet the demands of a rapidly changing world. The choices

we make today about how we power our way of life will directly impact our climate, economy and national security.

Why choose nuclear? Our country’s largest source of clean electricity is nuclear energy, accounting for more than half of all carbon-free electricity generated. America’s reactors operate nonstop, stabilizing the nation’s energy grid and providing us with reliable and affordable power.

CLEAN ENERGY LEADER



Clean sources, including nuclear, provide more than 38 percent of America's electricity. More than half of that comes from nuclear energy.

The United States generates most of its electricity by burning fossil fuels, a process that produces contaminants such as sulfur dioxide, nitrogen oxides and carbon dioxide. Nuclear power plants produce no combustion byproducts, so they do not release any emissions. They help protect our air quality and have been an important tool in meeting our domestic clean air goals.

As our largest source of clean energy, nuclear power is critical to reducing carbon emissions. Wind, solar and geothermal are on the rise, but the smartest policies will ensure these technologies complement, not replace, nuclear's clean energy production. Protecting and growing our use of nuclear technologies are

important ways to reduce greenhouse gases and help us make meaningful progress in addressing climate change. **We cannot decarbonize the economy without nuclear energy in the mix.**

Americans need abundant energy and want clean energy. With nuclear, they can have both. Given the country's growing demand for new sources of electricity—an increase of as much as 34 percent by 2050, according to the U.S. Energy Information Administration's recent forecast—nuclear is a must for America's clean energy future. Nuclear is the only baseload, emissions-free energy source that is widely scalable.

**24/7
365**
Nuclear energy produces 24/7, emission-free energy.

Endangered species, such as sea turtles, find sanctuaries at nuclear plants.

Environmental advocates support nuclear energy.

Nuclear power plants avoid more than 471 million metric tons of carbon emissions each year.

Nuclear plants provide excellent habitats for wildlife and plants. Some nuclear energy companies have preserved environmentally rich wetlands, providing better nesting areas for waterfowl and other birds; new habitats for fish; and sanctuaries for other wildlife, flowers and grasses. Nuclear plants provide homes for many endangered and protected species, such as the American crocodile, manatee, shortnose sturgeon and sea turtle.

By using nuclear energy instead of fossil fuel-based generating power plants, the nuclear energy industry avoids more than 471 million metric tons of carbon emissions each year, which amounts to over \$24 billion in annual savings, according to a recent independent report by The Brattle Group.

A growing and diverse group is standing behind nuclear energy as a key piece of the climate change solution. Recently, a collection of companies, environmental groups and nongovernmental organizations, such as The Nature Conservancy, the Union of Concerned Scientists and the MacArthur Foundation, has come forward to acknowledge that nuclear energy plays an essential role in reducing emissions and helping to meet America’s climate change goals in both the short and long run.

POWERING THE ECONOMY



Operation of a nuclear reactor generates an average of 700 permanent jobs.



Nuclear energy facilities provide economic benefits to their local communities.



Nuclear carbon-free energy is a low-cost producer of always-on electricity.



Up to 800 jobs at a nuclear reactor pay better than average salaries in the local area.

Each plant also creates an equivalent number of additional jobs in the local area, providing goods and services necessary to support the nuclear workforce. Building a nuclear power plant employs up to 7,000 workers at peak construction and each additional reactor generates 500 to 800 more permanent jobs.

These figures include both primary and secondary effects. Primary effects reflect the facility's expenditures for goods, services and labor. Secondary effects include subsequent spending attributable to the presence of the company and its employees as facility expenditures filter through the local economy. The nuclear industry is responsible for nearly \$10 billion annually in additional federal tax revenues and \$2.2 billion in additional state tax revenues. Because of the boost it gives to the economy, these tax dollars benefit schools, roads, and other state and local infrastructure.

Average electricity total generation costs at nuclear plants are less than 3.1 cents per kilowatt-hour. This includes the costs of operating and maintaining the facility, purchasing nuclear fuel and managing used fuel. Electricity generated from nuclear energy also has tremendous price stability because only about 20 percent of production costs are for fuel. Fuel accounts for up to 80 to 90 percent of the cost of electricity produced by fossil fuel-fired generation, making coal and natural gas prices highly susceptible to fluctuations.

Each year, the commercial nuclear energy industry contributes approximately \$60 billion annually to gross domestic product (GDP).

THE LIFE CYCLE OF NUCLEAR

**1 URANIUM
FUEL PELLET**

The Size of a Pencil Eraser



**PROVIDES
AS MUCH
ENERGY
AS**



**1 TON
of
Coal**



**149
GALLONS
of
Oil**



**17,000
CUBIC FEET
of
Natural Gas**



HOW NUCLEAR FUEL IS MADE



Uranium must undergo four processing steps to convert it from an ore to solid ceramic fuel pellets.



Milling and Mining

Uranium miners use several techniques: surface, underground and in-situ recovery.

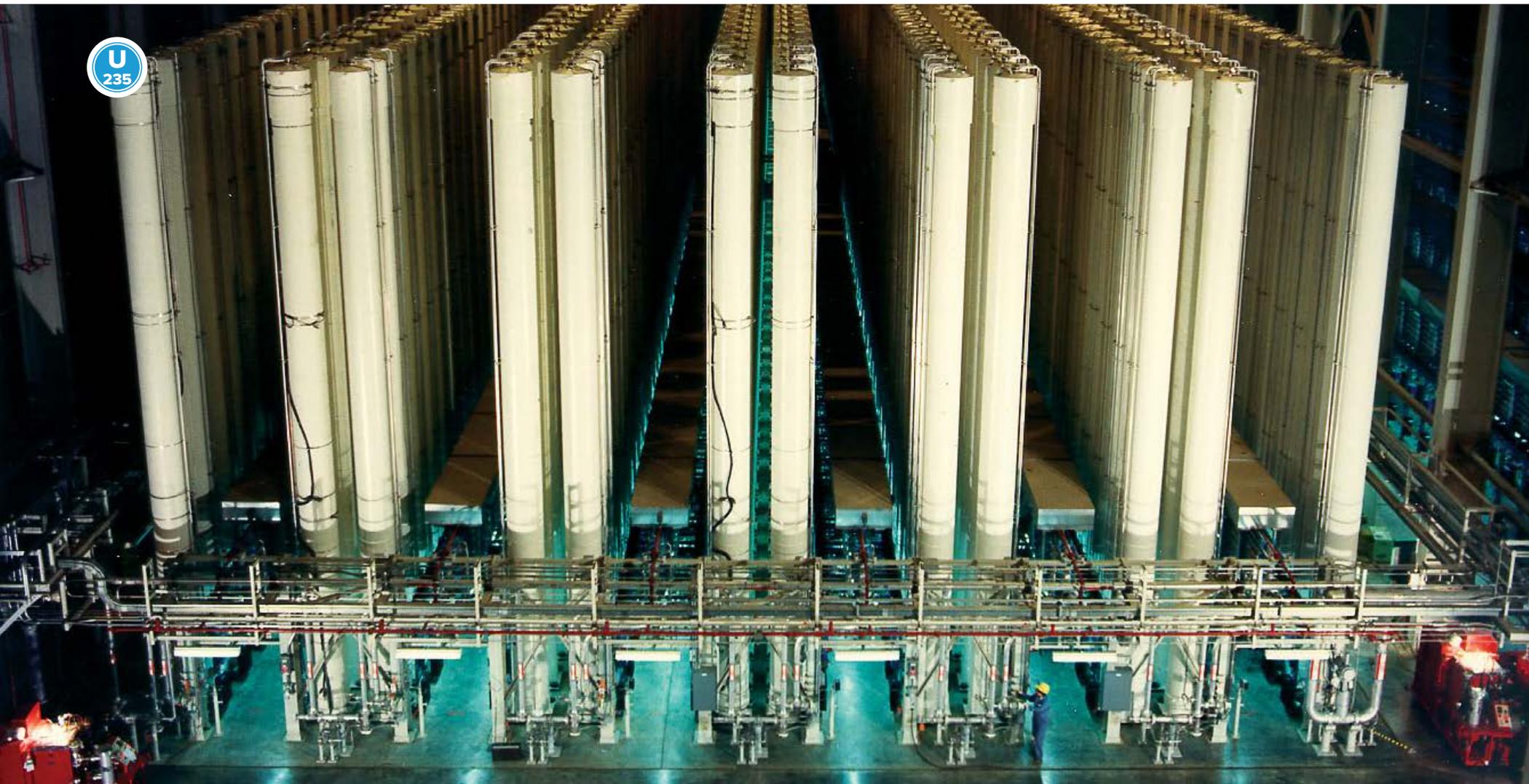
In-situ recovery uses water with oxygen and baking soda to recover minerals from the underground ore. Uranium also can be a byproduct of other mineral processing operations. After mining, the material is milled and processed to create uranium oxide, or “yellowcake.” Almost all uranium mining in the United States uses the in-situ process.



Conversion

Yellowcake requires further processing before it’s used as a fuel.

In the next step, the uranium oxide goes to a conversion facility, which removes impurities and chemically converts the material to uranium hexafluoride. The compound is heated to become a gas and is loaded into cylinders, where it cools and condenses into a solid. One of the world’s five commercial conversion facilities is in Metropolis, Illinois.



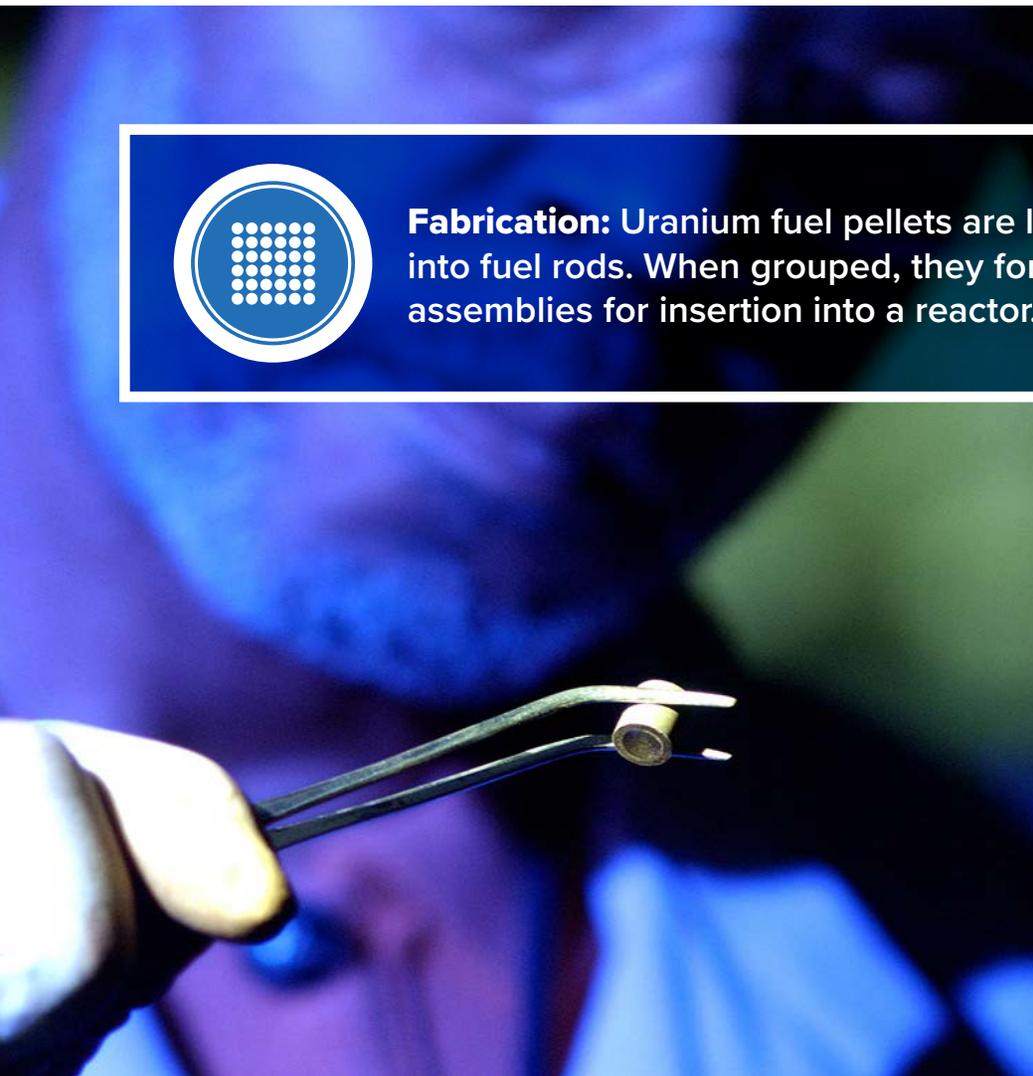
Enrichment

Utilities can buy uranium and have it enriched, or they can buy uranium that is already enriched.

Uranium is primarily composed of two different forms, or isotopes, of uranium; one (U-238) is heavier than the other (U-235). The lighter U-235 is fissile and typically makes up less than 1 percent of uranium by weight, while U-238 accounts for more than 99 percent. To make fuel for the nation's operating commercial reactors, the U-235 content must be increased to between 3 to 5 percent by weight through a process called enrichment.



Fabrication: Uranium fuel pellets are loaded into fuel rods. When grouped, they form fuel assemblies for insertion into a reactor.



Fabrication

Fuel assemblies are designed to meet the specific requirements of each reactor.

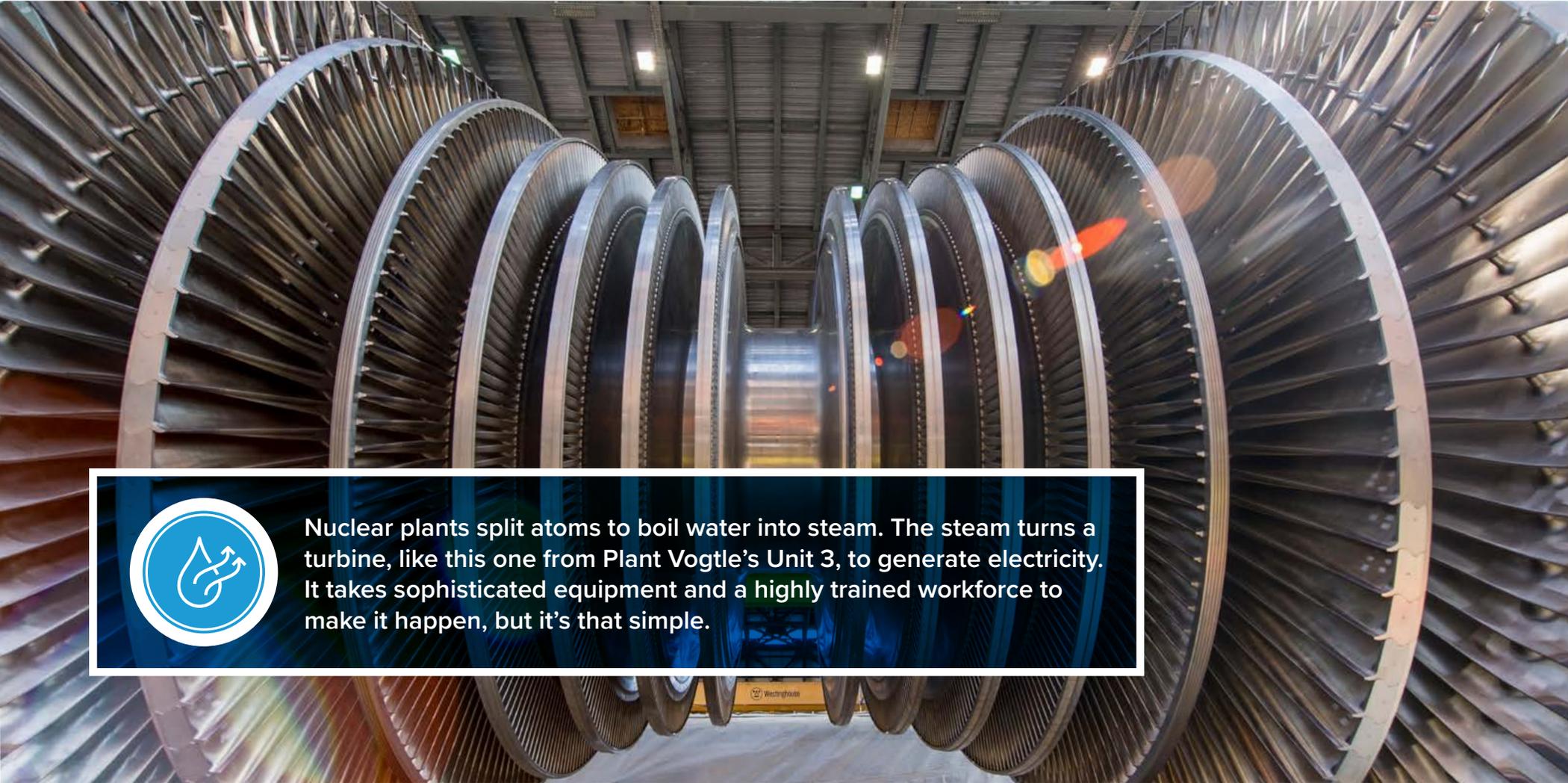
After enrichment, a fuel fabricator converts uranium hexafluoride into uranium dioxide powder and presses it into fuel pellets. The fabricator loads the ceramic pellets into long tubes made of a noncorrosive material, usually a zirconium alloy. Once grouped together in a bundle, these fuel rods form a fuel assembly. Multiple assemblies, ranging from 12 to 14 feet in height, power a reactor for 54 to 72 months, after which the chain reaction's efficiency begins to decrease. Operators replace about one-quarter to one-third of the fuel assemblies with new fuel every 18 to 24 months.

Accident Tolerant Fuels (ATF) have the potential to transform the safety and operation of nuclear plants.

The U.S. nuclear industry has been aggressively developing different types of reactor fuels that are more robust and result in improved performance during normal and off-normal conditions. The goal is to deploy these game-changing fuels with increased burnup and enrichment in the mid-2020s. These technologies create opportunities to modernize the industry and enhance safety. However, these benefits will not be attained without consciously changing the way fuel technology is licensed by our industry regulator, the U.S. Nuclear Regulatory Commission. The first ATF designs have already been loaded and completed initial cycles in U.S. reactors. Utilities, vendors, national labs, universities, and others are working collaboratively to accelerate the deployment.



HOW A REACTOR WORKS



Nuclear plants split atoms to boil water into steam. The steam turns a turbine, like this one from Plant Vogtle's Unit 3, to generate electricity. It takes sophisticated equipment and a highly trained workforce to make it happen, but it's that simple.

Uranium fuel: solid ceramic pellets

The uranium fuel at currently operating nuclear reactors arrives as small ceramic pellets inserted and sealed into long, vertical metal alloy tubes or rods. Inside the reactor vessel, or the core, nuclear fission produces heat to create steam that powers electricity-producing generators.

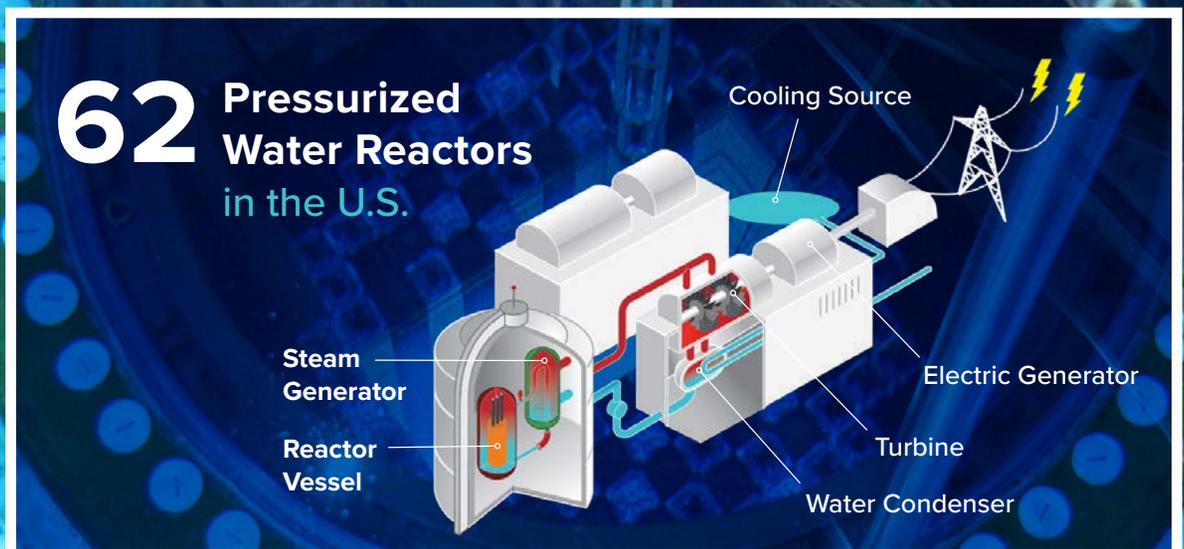
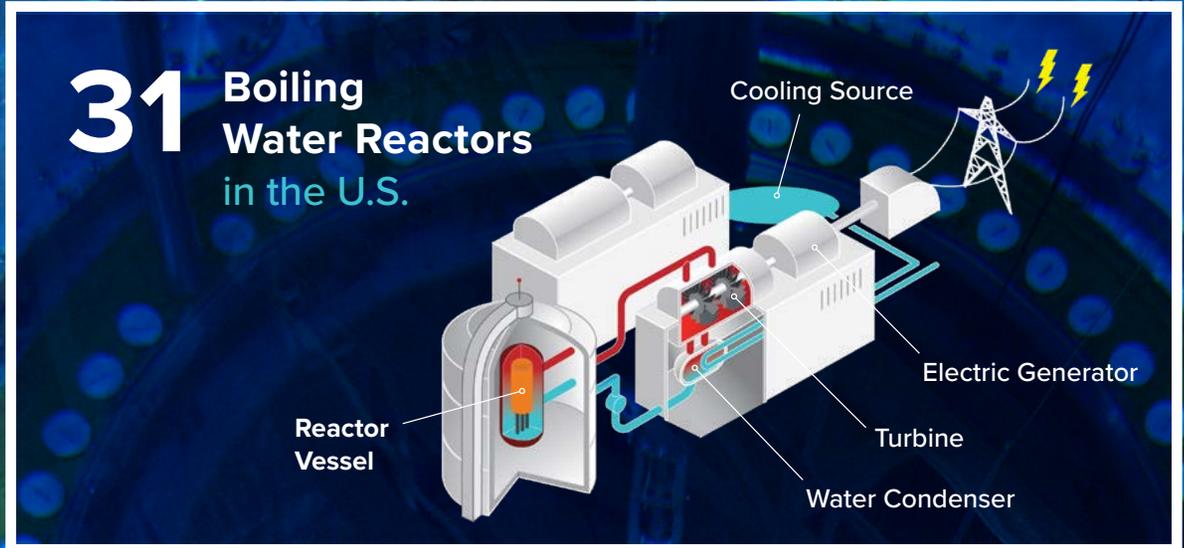
Types of nuclear reactors

We have two types of reactors currently operating in the United States: boiling water reactors and pressurized water reactors. Of the nation's 93 reactors, 62 are pressurized water reactors, while 31 are boiling water reactors.

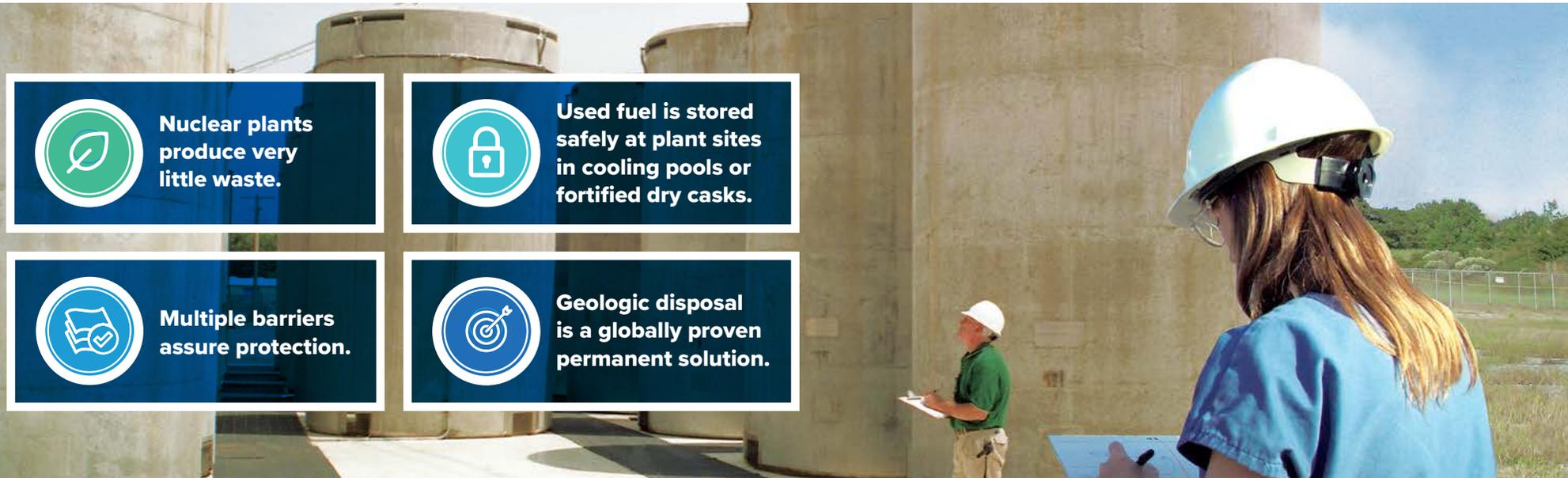
Ordinary water provides cooling for both types. Water is essential to the process that converts fission energy to electrical energy.

Boiling water reactors heat the water surrounding the nuclear fuel directly into steam in the reactor vessel. Pipes carry steam directly to the turbine, which drives the electric generator to produce electricity.

Pressurized water reactors heat the water surrounding the nuclear fuel in the reactor vessel but keep the water under pressure to prevent it from boiling. Pumps move the hot water from the reactor vessel to a steam generator. There, the water pumped from the reactor heats a second, separate supply of water, which boils to make steam. The steam then spins the turbine, which drives the generator that produces electricity.



HOW USED FUEL IS MANAGED



Nuclear plants produce very little waste.



Used fuel is stored safely at plant sites in cooling pools or fortified dry casks.



Multiple barriers assure protection.



Geologic disposal is a globally proven permanent solution.

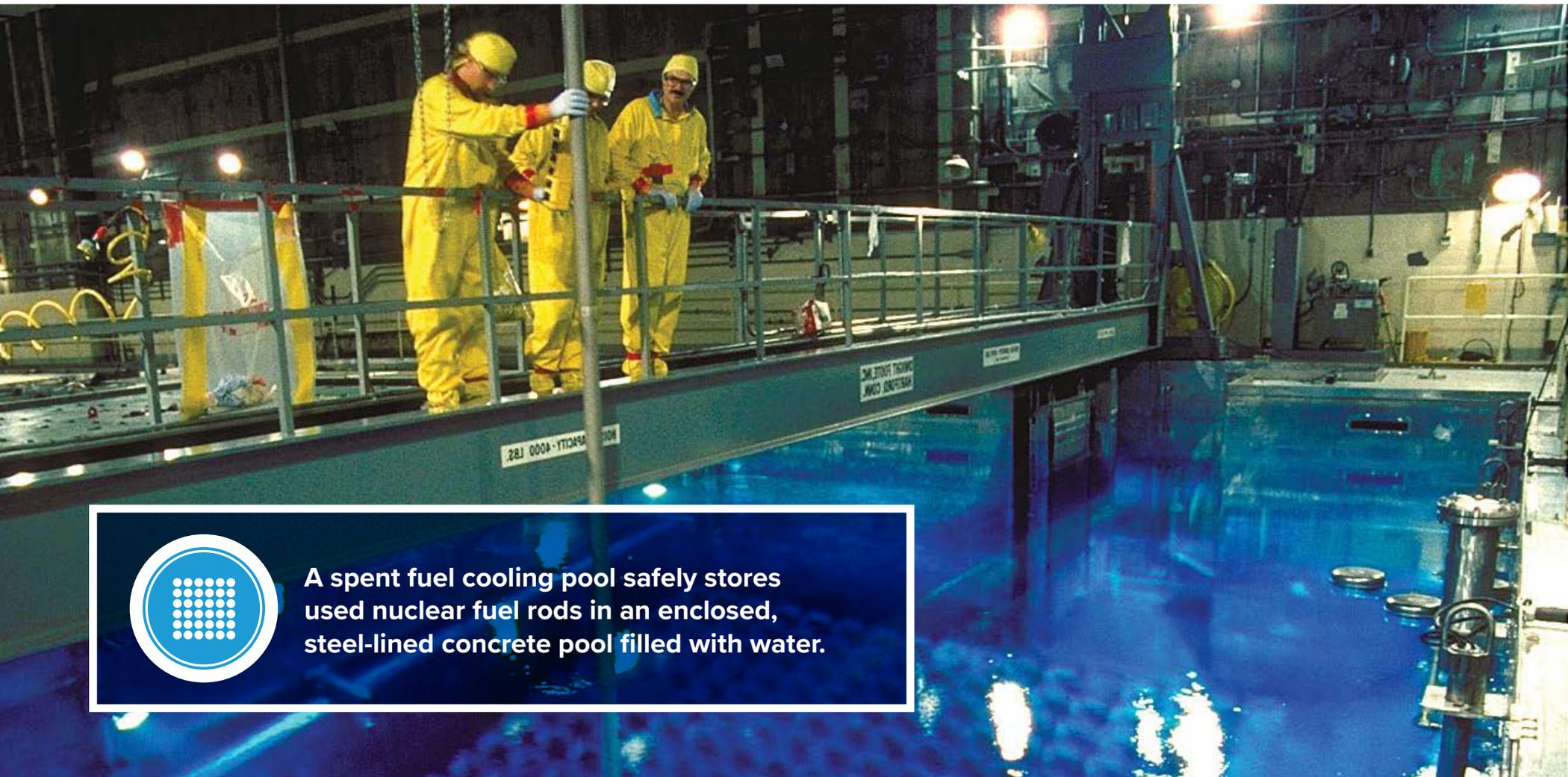
Nuclear plants produce waste—or more accurately, used nuclear fuel—while generating electricity. But it’s not glowing green goo like you see in the movies or “The Simpsons.” In fact, used nuclear fuel is much different from what you might think. Nuclear fuel is solid when it goes in a reactor and solid when it comes out. It is arranged in fuel assemblies: sets of sealed metal tubes that hold ceramic uranium pellets. No green goo anywhere.

All of the used fuel ever produced by the commercial nuclear industry since the late 1950s would cover a football field to a height of less than 10 yards. That might seem like a lot, but coal plants generate that same amount of waste every hour.

A typical nuclear plant reactor produces enough electricity for more than 760,000 homes, but only about 20 metric tons of used uranium fuel each year. In terms of volume, that is roughly equivalent to the cargo area of a small truck.

The nuclear energy industry takes full responsibility for all of its byproducts and factors that into its production costs, while still remaining one of the lowest-cost producers of 24/7, baseload electricity. The highest level of public safety and environmental protection is provided by an integrated program that includes temporary storage of used nuclear fuel, development of consolidated storage facilities and a permanent disposal facility.

Used nuclear fuel rods are stored safely and securely at reactor and storage sites around the country, either in enclosed, steel-lined and steel-reinforced concrete pools filled with water or in steel-reinforced concrete containers, called dry casks. In these containers the fuel is kept safe in an inert environment behind multiple layers of protection. These protective features are engineered and secured to the same high standards as the plants themselves.



A spent fuel cooling pool safely stores used nuclear fuel rods in an enclosed, steel-lined concrete pool filled with water.

The NRC has concluded that used nuclear fuel can be stored at plant sites or consolidated interim storage facilities for an indefinite period. However, on-site storage of used nuclear fuel was never intended to be permanent.

There is scientific consensus worldwide that disposal in a specialized facility deep underground is the safest approach. “After four decades of study, geological disposal remains the only scientifically and technically credible long-term solution available to meet the need

for safety without reliance on active management,” according to the National Academy of Sciences.

Several nations, including Finland, Sweden, France and Switzerland, are currently developing geologic repositories for used nuclear fuel. As nuclear energy becomes an increasingly important tool for meeting the United States’ decarbonization goals, we expect to see renewed efforts to develop a U.S. repository.

DECOMMISSIONING A NUCLEAR PLANT

After the closure of a nuclear power plant, the plant owner is accountable for reducing the site’s residual radioactivity to safe levels. The site must be decommissioned within 60 years of the plant closure. Eleven reactors have been successfully and safely decommissioned, proving that the industry is well-equipped to accomplish these major projects and that existing safety and environmental standards are robust.

Once the decommissioning process is complete, the NRC terminates the owner’s license and releases the site property for other uses. However, when it comes to transitioning reactors out of operation and through the decommissioning process, the regulatory process needs to be more efficient. These inefficiencies not only hinder plant owners

from focusing on the task at hand, they also increase uncertainty for plant employees, add unnecessarily to costs and can postpone a community’s redevelopment plans for the site for years.

Companies that specialize in decommissioning nuclear plants have significant experience managing the process with impeccable safety records. These third-party companies can take over responsibility for shutdown nuclear plants, with approval from the NRC, and significantly accelerate the decommissioning process. In fact, recent trends show that decommissioning can be completed in as little as eight years. Examples of this accelerated decommissioning approach are playing out at recently retired reactors in Vernon, Vermont; Plymouth, Massachusetts; and Forked River, New Jersey.

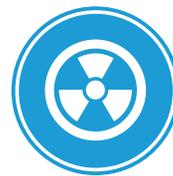
The Decommissioning Process



Removal of used nuclear fuel from the reactor



Placing it into the used fuel pool and dry storage containers (on- or off-site)



Dismantling systems or components containing radioactive products (reactor vessel)



Dismantling and removing contaminated materials from the facility



Disposing contaminated materials on-site or shipping them to a waste-processing, storage or disposal facility

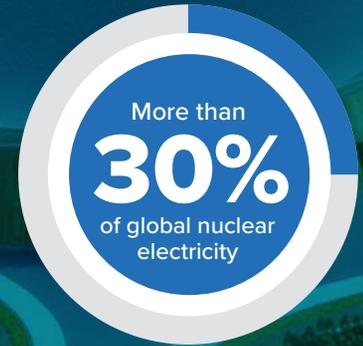
LOOKING FORWARD



The United States will need **34 percent more electricity by 2050**, according to the U.S. Energy Information Administration.



Next-generation reactors will protect the climate, boost the economy with quality jobs, and ensure global leadership and national security.



The United States' nuclear reactor fleet generates more than **30 percent of global nuclear electricity.**

NEW NUCLEAR TECHNOLOGIES



We need new, innovative technologies to reduce emissions and achieve a carbon-free future. According to the United Nations Intergovernmental Panel on Climate Change, unless we drastically reduce carbon emissions by 2030, we won't be able to avoid the worst effects of climate change. Adding to this challenge, the United States will need 34 percent more electricity by 2050, according to the U.S. Energy Information Administration.

As companies, leaders and policymakers are making commitments to be carbon-free or carbon-neutral, the need for clean energy and the rising demand for electricity makes new nuclear reactors—and the zero-emission energy they provide—vital to our energy mix.

Together with large, traditional reactors, advanced reactors are expanding the nuclear energy portfolio that is tailored to meet our national goals on energy security and mitigation of climate change.

Small modular reactors (SMRs) are advanced reactors that produce 300 megawatts or less of electricity. They utilize components that can

be factory-built—minimizing costs, improving quality and reducing construction schedules—thereby enabling rapid construction to meet growing demand for carbon-free electricity. Future advanced reactors will integrate well with other carbon-free sources like wind and solar.

Micro-reactors—just a few megawatts of nuclear generation—are capable of operating independently from the grid to supply power when and where it is needed most. Certain micro-reactor designs have the potential to be relocated as needed, with attributes that hold special promise to the nation's largest energy user—the United States military.

Nonwater cooled reactors are being developed to use liquid metal, high-temperature gas or molten salt coolant. These reactors will have a high temperature output for potential use in industrial applications. For example, they can be used for hydrogen production which will be instrumental in reducing carbon emissions in other sectors of the economy.



 **22 new reactors began operating since the beginning of 2018, including Westinghouse AP1000.**

New reactors will provide built-in, inherent safety features. Some designs will work under normal atmospheric pressure, require smaller emergency planning zones, and can even recover and recycle elements in used fuel that still have energy-producing potential.

There has been significant progress towards deploying new and advanced nuclear reactors. In Georgia, two state-of-the-art Westinghouse AP1000 reactors are under construction, which will provide more than 2,200 megawatts of carbon-free energy to the state upon completion. The staff of the U.S. Nuclear Regulatory Commission has approved the design of NuScale Power’s SMR and has accepted Oklo Inc.’s combined license application for review.

Congress authorized and appropriated funds for an Advanced Reactor Demonstration Program (ARDP) in fiscal year 2020. That same year, the U.S. Department of Energy made commitments to support two public-private partnerships through this program; X-energy and TerraPower will receive \$3.2 billion in funding to build their advanced reactors and fuel fabrication facilities by 2030.

The DOE program also supports multiple public-private partnerships to develop other advanced reactor designs that could be demonstrated in the early 2030s from companies like Kairos Power, Westinghouse Electric Co., BWXT Advanced Technologies, Holtec International, Southern Company Services and more.

Benefits of Next-Generation Advanced Reactors:

-  **Factory-built**
-  **Transportable**
-  **Self-regulating**



Upon completion, two new reactors at Vogtle will provide enough carbon-free electricity to power 500,000 Georgia homes and businesses.



Outside of the ARDP, DOE also reached an agreement to provide \$1.4 billion through a cost-share to assist Utah Associated Municipal Power Systems and NuScale in building an SMR by 2029.

The momentum is not limited to these partnerships, though. Private companies, like Oklo, are planning demonstrations in the mid-2020s without direct federal funding.

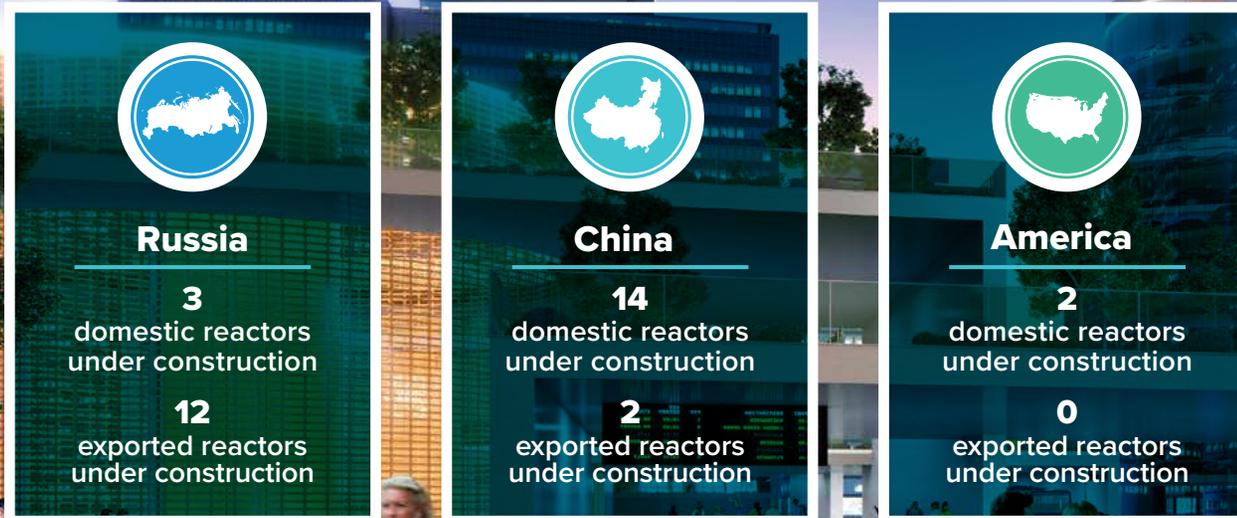
Additional policy actions will be required to spur construction of more new nuclear plants in the U.S.:

- Continued federal support of the private-public partnerships being used to develop advanced reactors, including SMRs and micro-reactors and the federal loan guarantee program.
- Policy incentives, such as the tax credits used to accelerate deployment of wind and solar power.
- Expansion and use of federal authorities for power purchase agreements, site use licenses and other mechanisms for federal support.

As we look towards the future, the industry is focused on recruiting a diverse, high-quality workforce. This includes intensified efforts to expand opportunities for women and ethnic minorities and to attract a new generation of employees for specific professions, such as nuclear engineering and health physics.



NUCLEAR ENERGY AROUND THE WORLD



More than half of all nuclear reactors under construction today are Russian or Chinese designs.

Today, the U.S. operates the largest fleet of nuclear reactors and produces more electricity from nuclear energy than any other country.

The United States' nuclear reactor fleet makes up more than 20 percent of the total global fleet. It produces more than two times the energy of the nuclear fleets of both France and China and more than four times the energy of Russia.

More reactors around the globe are of U.S. design than that of any other country. This has allowed the U.S. to significantly influence global nuclear safety, security and nonproliferation norms.

Unless there are significant policy changes, U.S. leadership will erode and China and Russia will dominate the global nuclear market.

More than half of all nuclear plants under construction today are Russian or Chinese designs. China and Russia are rapidly adding new nuclear plants to their domestic nuclear fleets. In addition, Russia and China are signing cooperation agreements with numerous nations around the globe, which will facilitate their long-term partnership for the supply of nuclear reactors. For example, Rosatom (Russia's state-owned nuclear enterprise) reports a presence in 50 countries with over \$130 billion in orders. Given the century-long relationship that nuclear energy brings, this is not only an economic challenge to U.S. leadership, it is a geopolitical challenge.



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