OFFICE OF NUCLEAR ENERGY:

Strategic Vision

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

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Nuclear is one of the most resilient, environmentally sustainable, and reliable energy sources on the grid today. Globally, nuclear energy produces about 10 percent of the world's electricity and nearly 30 percent of its emissions-free electricity. Here in the United States, those numbers are even higher: Nuclear provides approximately 20 percent of our electricity, more than 55 percent of our clean energy, and supports about half a million American jobs.

Despite these benefits, the U.S. nuclear industry faces significant challenges. Market conditions are forcing reactors into early retirement and weakening our national supply chain. Countries like Russia and China are quickly becoming leading exporters of the nuclear technologies that the United States first developed, and our global influence over how other countries support and use nuclear power is slowly diminishing.

As the use of nuclear energy continues to expand internationally, it is crucial that the United States reassert itself as a leader in this incredible technology. Existing U.S. nuclear plants prevent almost 500 million metric tons of carbon dioxide emissions each year—the equivalent of taking 100 million cars off the roads. New advanced reactor designs show enormous potential to help decarbonize energy-intensive manufacturing processes and will make nuclear more flexible and accessible than ever. Taking the reins of this emerging market will lead to more American jobs, a stronger economy, lower emissions, and a healthier environment.

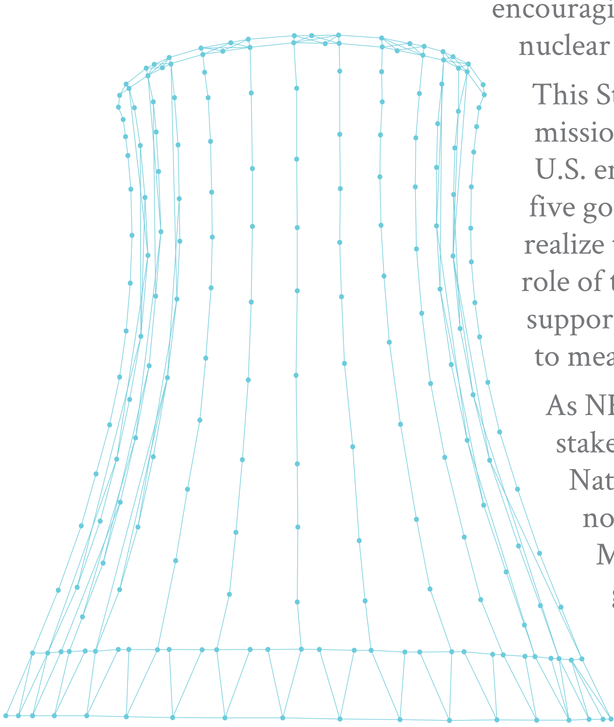
Now is the time to develop, demonstrate, and build these new technologies. The Department of Energy (DOE) Office of Nuclear Energy (NE) is working hard to deliver on the enormous promise of nuclear technology. This Strategic Vision is the blueprint that guides our office in achieving its mission to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. Where appropriate, it also directs NE in meeting the recommendations of the United States Nuclear Fuel Working Group's *Restoring America's Competitive Nuclear Advantage.* As we work to achieve our goals, NE is developing a more sustainable and resilient energy supply that will strengthen our economy and make our nation more secure.

INTRODUCTION

The United States pioneered the development of nuclear power to produce electricity in the late 1940s. Since then, U.S. leadership in nuclear energy technology has given us the benefit of clean, reliable electricity for nearly seven decades. Our fleet of nuclear power plants supplies approximately 20 percent of the electricity generated in the United States, while avoiding millions of tons of carbon dioxide emissions each year. It is by far the largest source of clean, carbon-free energy and the most reliable, operating at a capacity factor of more than 93 percent.

However, many U.S. reactors face economic challenges or are nearing the end of their planned operating lives. New construction of traditional reactors is costly and time consuming, and we need to demonstrate advanced reactor designs rapidly to provide clean energy and expand market opportunities before we lose access to key infrastructure and supply chain capabilities in the United States.

NE serves a vital role in addressing these challenges. As an applied energy research and development (R&D) organization, we enable innovation, support unique research infrastructure, and solve crosscutting challenges facing the nuclear energy sector. NE invests in R&D that the private sector or other non-government stakeholders are unable to perform due to the cost, scale, or timeframe required. NE funds and creates opportunities for world-class researchers in industry, academia, and the national laboratories to collaborate and solve pressing scientific and engineering challenges. By leveraging private-public partnerships and our national laboratory system, we are making nuclear energy more cost effective, accelerating advanced reactor deployment, making nuclear fuel cycles more sustainable, encouraging a resilient supply chain, and promoting a strong nuclear workforce.



This Strategic Vision serves as a blueprint for NE to achieve its mission of advancing nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. NE has identified five goals to address challenges in the nuclear energy sector, help realize the potential of advanced technology, and leverage the unique role of the government in spurring innovation. Each goal includes supporting objectives to ensure progress and performance indicators to measure success.

As NE pursues these goals, we will coordinate with relevant stakeholders and government agencies, including working with the National Nuclear Security Administration to ensure impacts to nonproliferation and national security missions are considered. Meeting our goals will require the coordinated work of government, industry, academia, and the national laboratories.

VISION

A thriving U.S. nuclear energy sector delivering clean energy and economic opportunities.

MISSION

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

GOALS	OBJECTIVES	PERFORMANCE INDICATORS
1. Enable continued operation of existing U.S. nuclear reactors.	1. Develop technologies that reduce operating costs. 2. Expand to markets beyond electricity. 3. Provide scientific basis for continued operation of existing plants.	1. By 2022, demonstrate a scalable hydrogen generation pilot plant. 2. By 2025, begin replacing existing fuel in U.S. commercial reactors with accident tolerant fuel. 3. By 2026, complete engineering and licensing activities needed to demonstrate successful deployment of a digital reactor safety system in an operating plant. 4. By 2030, achieve widespread implementation of accident tolerant fuel.
2. Enable deployment of advanced nuclear reactors.	1. Reduce risk and time needed to deploy advanced nuclear technology. 2. Develop reactors that expand market opportunities for nuclear energy. 3. Support a diversity of designs that improve resource utilization.	1. By 2024, demonstrate and test a fueled microreactor core fabricated by advanced manufacturing techniques. 2. By 2025, enable demonstration of a commercial U.S. microreactor. 3. By 2027, demonstrate operation of a nuclear-renewable hybrid energy system. 4. By 2028, demonstrate two U.S. advanced reactor designs through cost-shared partnerships with industry. 5. By 2029, enable operation of the first commercial U.S. small modular reactor. 6. By 2035, demonstrate at least two additional advanced reactor designs through partnerships with industry.
3. Develop advanced nuclear fuel cycles.	1. Address gaps in the domestic nuclear fuel supply chain. 2. Address gaps in the domestic nuclear fuel cycle for advanced reactors. 3. Evaluate options to establish an integrated waste management system.	1. By 2021, begin procurement process for establishing a uranium reserve. 2. By 2022, demonstrate domestic HALEU enrichment. 3. By 2023, make available up to five metric tons of HALEU from non-defense DOE material. 4. By 2030, evaluate fuel cycles for advanced reactors.
4. Maintain U.S. leadership in nuclear energy technology.	1. Facilitate global opportunities for U.S. nuclear sector. 2. Maintain world-class research and development capabilities. 3. Develop highly trained scientists to support the future nuclear workforce.	1. By 2021, award up to 50 university R&D projects and $5 million in student scholarships and fellowships. 2. By 2021, support restart of sole source TRIGA fuel used in university reactors. 3. By 2021, establish formal cooperation with five countries seeking to develop their nuclear energy programs. 4. By 2021, create a comprehensive approach to assist countries developing their nuclear energy programs. 5. By 2022, increase U.S. leadership and participation in multilateral organizations promoting the peaceful uses of nuclear energy. 6. By 2026, build the Versatile Test Reactor. 7. By 2026, complete the Sample Preparation Laboratory. 8. By 2030, work with NASA to demonstrate fission power systems for surface power and propulsion.
5. Enable a high-performing organization.	1. Support and invest in the Office of Nuclear Energy workforce. 2. Effectively manage programs, projects, R&D investments, and contracts. 3. Communicate regularly with stakeholders.	1. By 2021, develop a multi-year program plan for each program office in NE. 2. By 2021, meet 95 percent of high-level milestones on time and within budget. 3. By 2021, fill key personnel gaps through new hires, in accordance with the NE hiring plan. 4. By 2022, update the NE Strategic Vision to reflect any changes to goals, objectives, and performance indicators. 5. By 2022, increase the number of active NETWG Tribal members from 11 to 13.

Goal 1: Enable continued operation of existing U.S. nuclear reactors.

The United States benefits from the largest fleet of nuclear reactors in the world, with 94 reactors operating in 28 states. These reactors generate more than 800 billion kilowatt hours of electricity each year and provide more than half of our nation's clean energy.

Maintaining access to the carbon-free electricity supplied by our current fleet of nuclear reactors is essential to reduce carbon emissions in the energy sector. To support this goal, NE is supporting research to maintain and extend the operating lives of the nation's existing reactors, improve performance and efficiency, develop advanced fuel technologies, and expand to markets beyond electricity. These improvements could lead to significant reductions in operating costs, improve the economic competitiveness of existing plants, and contribute to their extended operation.

Goal 1 Performance Indicators

1. By 2022, demonstrate a scalable hydrogen generation pilot plant.
2. By 2025, begin replacing existing fuel in U.S. commercial reactors with accident tolerant fuel.
3. By 2026, complete engineering and licensing activities needed to demonstrate successful deployment of a digital reactor safety system in an operating plant.
4. By 2030, achieve widespread implementation of accident tolerant fuel.

Tools like INL's Human System Simulation Laboratory help make improvements to plant operations that can reduce costs.

Objective 1: Develop technologies that reduce operating costs.

Over the past decade, a number of nuclear power plants have retired prior to their license expirations due to challenging market conditions. As nuclear plants retire, their generating capacity has been replaced primarily by higher carbon-emitting energy sources. This represents a threat to our supply of emissions-free electricity, as well as the infrastructure, capabilities, and supply chain needed to retain U.S. leadership in the nuclear field and enable the deployment of advanced nuclear technologies.

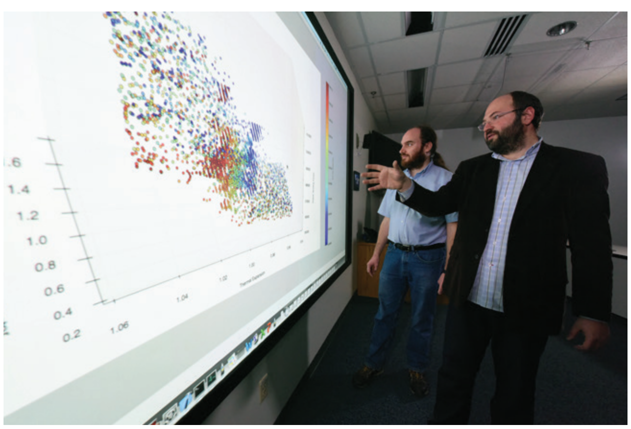
Operators' decisions to continue operating ultimately rely on economic factors. Therefore, NE is working to reduce the technical and regulatory risk to modernize plant systems, apply risk-informed systems analysis, and develop new accident tolerant fuels—all to enhance performance and reduce operating costs.

Nuclear power plants can reduce operating costs through comprehensive plant modernization. Most sectors of the industrial economy renew and modernize their infrastructure on a regular basis, adjusting to new market conditions and applying digital technologies. The existing nuclear fleet, by contrast, operates largely based on a state of technology that is over 40 years old. NE is conducting research to develop and deploy advanced digital technologies that promote new and more efficient ways of operating. As part of this research, NE works to address the technical and regulatory barriers to increased use of digital technologies. Ultimately, this will enable widespread cost reduction and operational improvements in the existing fleet. NE will complete the engineering and licensing activities needed to demonstrate successful deployment of a digital reactor safety system in an operating nuclear power plant by 2026.

In addition to plant modernization, nuclear plants can reduce costs by optimizing safety margins. Historically, nuclear reactors have implemented multiple, redundant safety systems to ensure that in rare emergency scenarios, public health and safety are protected. Overly conservative operating requirements can increase costs with no measurable benefits. Risk-informed systems analysis provides a method to identify areas where costs and efficiencies can be recovered without decreasing technical reliability or operational safety. Using the extensive computational expertise of the national laboratories, NE will provide the data and the technical basis to enable reactor operators to modify plant designs, improve operations, and enhance existing safety features, leading to substantially reduced costs.

NE is also developing new accident tolerant fuels that could increase efficiency, improve performance, and reduce operating costs. These fuels leverage new materials that improve fission product retention, and are structurally more resistant to radiation, corrosion, and high temperatures, which reduces the potential for hydrogen buildup. Accident tolerant fuels are expected to last longer, potentially extending the time between refueling from 1.5 to 2 years. This could reduce the amount of fuel needed by approximately 30 percent, resulting in less waste and used nuclear fuel.[1] It could also reduce fuel costs over the life of the reactor.

Accident tolerant fuels could increase efficiency, improve performance, and reduce operating costs.



Tools like RAVEN perform risk-informed systems analysis to identify opportunities to reduce costs while maintaining technical reliability and safety.

NE will continue to work with industry partners to develop accident tolerant fuels. Framatome, General Electric, and Westinghouse are each working with NE and U.S. national laboratories to commercialize their new fuels by 2025. NE is providing irradiation and safety testing and advanced modeling and simulation to help these companies qualify their fuels with the Nuclear Regulatory Commission (NRC). Industry will begin replacing existing fuel with accident tolerant fuel by 2025 and aims to achieve widespread implementation in U.S. commercial reactors by 2030.

1 The term 'used nuclear fuel' is synonymous with the term 'spent nuclear fuel' as used in the Nuclear Waste Policy Act and the Standard Contracts.

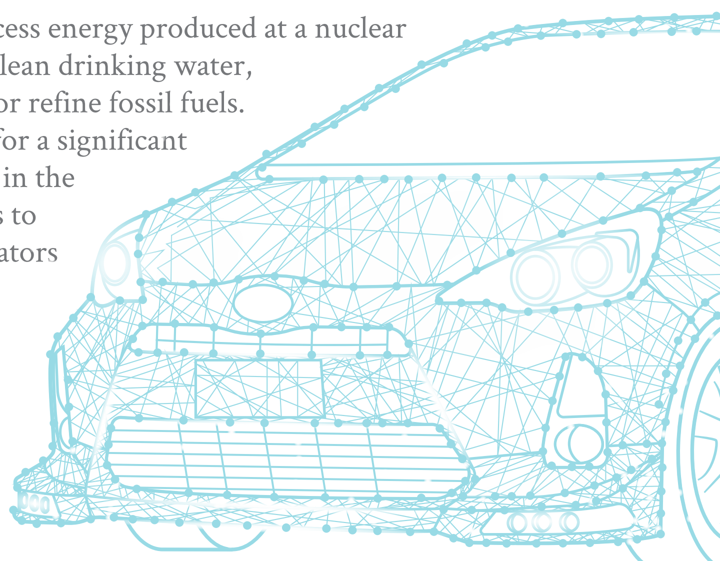
INL is performing research on integrated energy systems that can produce hydrogen using electricity and heat.

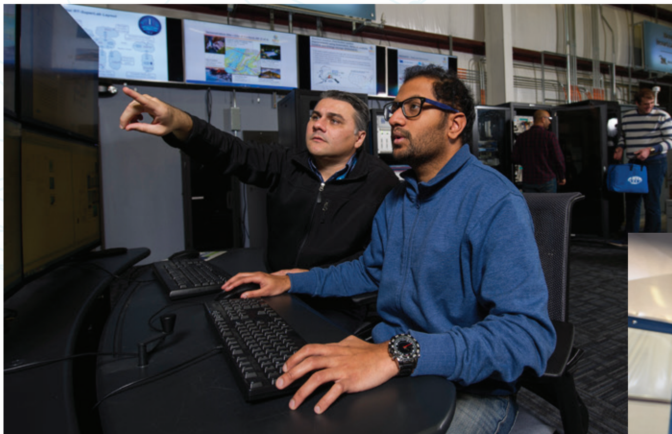
Objective 2: Expand to markets beyond electricity.

Lack of market value and historically low natural gas prices make it difficult for the nuclear sector to compete in certain markets. In addition, traditional nuclear plants are designed to create massive amounts of energy and operate most efficiently by operating constantly. This means that when other intermittent sources of electricity flood the grid, nuclear plants produce energy that is not needed for electricity generation.

This represents a huge opportunity for the nuclear sector. Excess energy produced at a nuclear plant can be routed to power desalination plants to generate clean drinking water, produce hydrogen for transportation or industrial processes, or refine fossil fuels. These types of energy-intensive industrial processes account for a significant portion of the environmental footprint and carbon emissions in the United States. Expanding operations at existing nuclear plants to support these processes could increase revenue for plant operators while significantly reducing industrial carbon emissions.

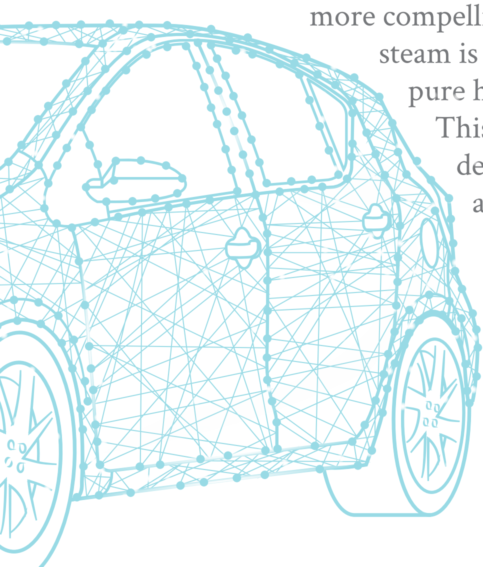
Hydrogen production in particular represents a key market opportunity. Today, we primarily use hydrogen for oil refiningand ammonia production, but there is a growing demand for it in steel manufacturing and in transportation to power vehicles, upgrade biofuels, and even produce synthetic fuels that may use carbon dioxide as a feedstock.





The Dynamic Energy Transport and Integration Laboratory (DETAIL) will integrate a grid simulator, left, with a thermal energy distribution system that will feed heat to a steam electrolysis station, right.

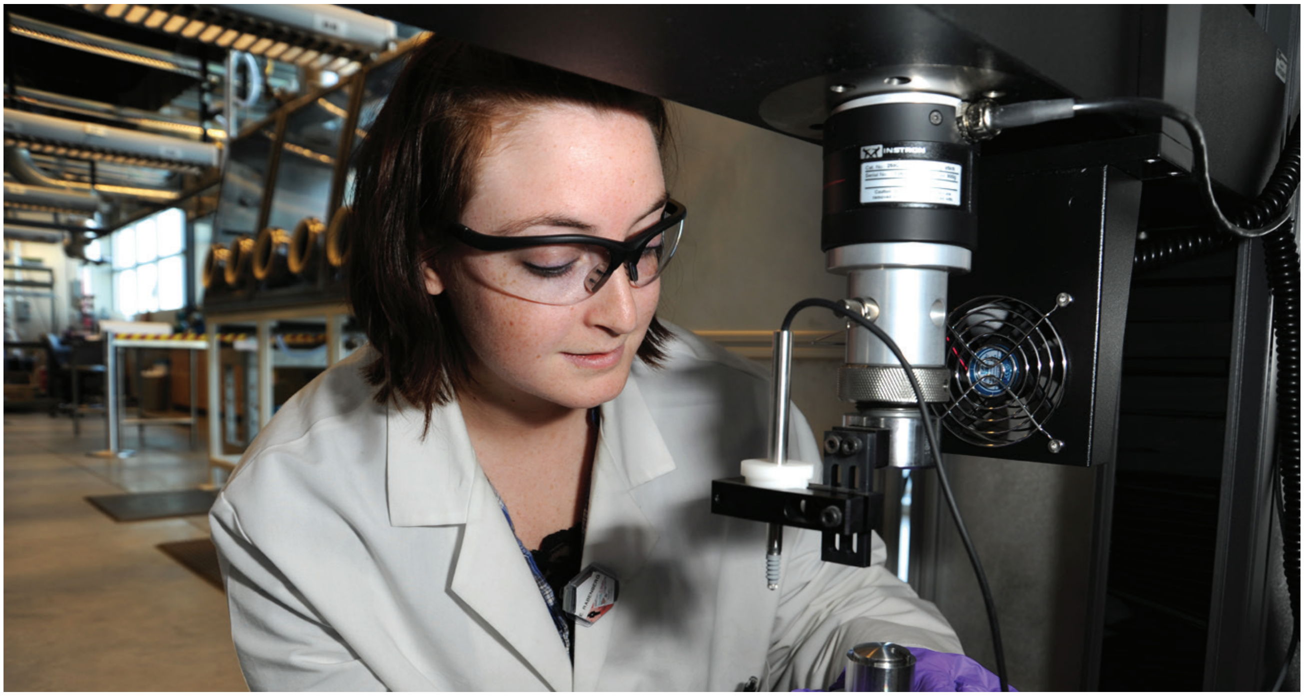
Nuclear power plants can produce hydrogen through a variety of methods that would greatly reduce air emissions while taking advantage of the constant thermal energy and electricity provided. Existing nuclear plants could produce high quality steam at lower costs than natural gas boilers. This approach could be used in many industrial processes, including steam-methane reforming. The case for nuclear becomes even more compelling when this high-quality steam is electrolyzed and split into pure hydrogen and oxygen. This approach completely decarbonizes the process and opens the door to other environmentally friendly advancements in electric vehicles, biofuel upgrades, and synthetic fuel production.



This process would allow utilities to produce and sell hydrogen regionally as a commodity in addition to providing clean and reliable electricity to the grid. This entirely new revenue stream could help build the economic case to keep the nation's reactors operating—possibly providing higher market value for hydrogen commodities in states and countries that are looking to reduce emissions.

NE will support demonstration of a scalable hydrogen generation pilot plant connected to an existing nuclear plant by 2022. The pilot will be fully integrated into routine operations of the plant and the data collected will inform a business case for implementing hydrogen production capabilities at other nuclear plants.

NE is performing research into how materials perform as they age to ensure existing plants can continue to operate.



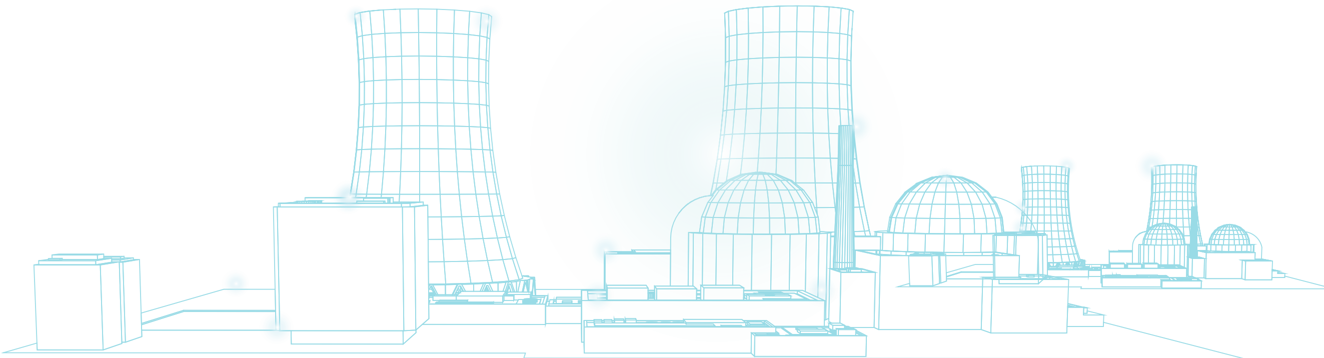
Objective 3: Provide scientific basis for continued operation of existing plants.

The NRC issues initial licenses for commercial nuclear power reactors to operate for 40 years. After that, plants can apply to operate for an additional 20 years at a time. Most of our existing reactors have already renewed their licenses once, and half of the nation's nuclear plants will need to obtain a second license renewal by 2040 to continue operating.

If existing nuclear power plants do not operate beyond 60 years, the amount of electricity supplied by nuclear power in the United States will rapidly decline, jeopardizing our supply of carbon-free electricity. Therefore, it is imperative that we enable the continued operation of the existing fleet of reactors. NE will continue to work with owner-operators of existing plants to address key issues needed to support the technical basis for continued long-term operation of our nation's nuclear power assets.

The systems, structures, and components used in a nuclear reactor are subject to extreme operating environments. Many of the materials used must withstand high temperatures, stress, vibration, and an intense neutron field. We have a well-established understanding of how these materials perform over 60 years of operation in a nuclear plant. However, to continue operating beyond 60 years, plant operators must demonstrate that the materials can continue to withstand the operating environment safely and effectively. Research performed by NE and the Electric Power Research Institute has shown that with proactive monitoring and maintenance of materials, there are no technical limits to operating beyond 60 years.

Eight reactors are already using this research to apply to the NRC for a license renewal to be able to operate up to 80 years. Four of these applications have already been approved by the NRC. To date,



20 reactors, representing more than a fifth of the nation's fleet, are planning to operate up to 80 years. More are expected to apply for license renewals as they approach the end of their current operating license. Over the next decade, NE will continue to work with industry partners to provide the technical basis for continued operation, enabling license extensions for additional reactors.

DOE and its national laboratories maintain world-renowned theoretical, computational, and experimental expertise that can contribute to the scientific basis, data, and testing required to prove the safety and performance of the existing fleet beyond 60 years. These capabilities, along with the strategic importance of the existing fleet, makes government support key to enabling its continued operation. Deeper understanding of how materials perform over the long term will also benefit advanced reactor technologies that are still under development.

Researchers at INL's TREAT reactor test the performance of fuels and structural materials, helping bring new technologies to market.

Goal 2: Enable deployment of advanced nuclear reactors.

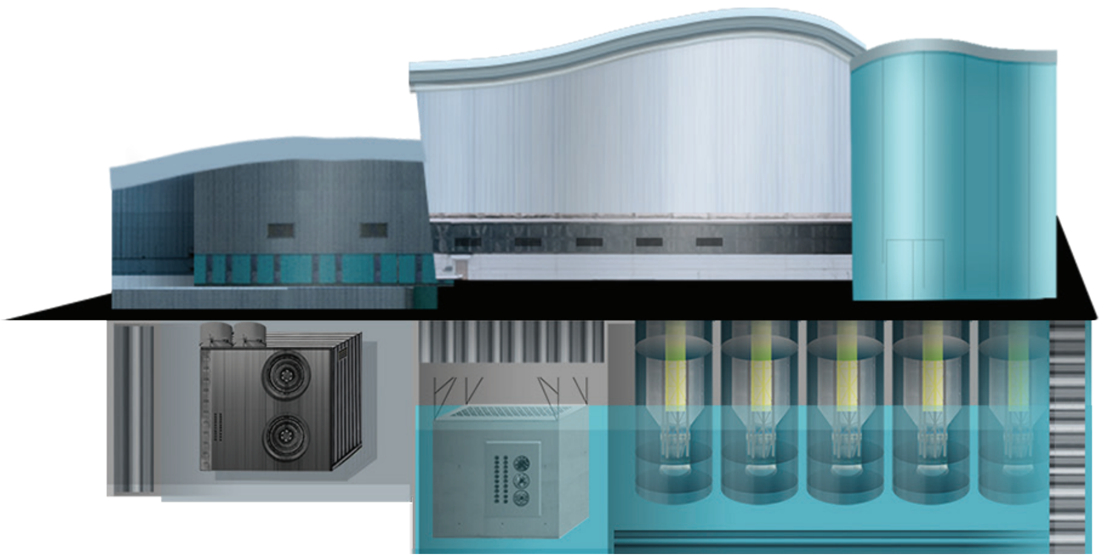
Image credit: Third Way/Gensler/advancednuclearenergy.org

Advanced nuclear energy systems hold enormous potential to lower emissions, create new jobs, and build an even stronger economy. More than 50 U.S. developers are pursuing advanced technologies that will make nuclear energy more efficient and affordable to construct, operate, and maintain. With help from DOE and the national laboratories, a new generation of reactors could be demonstrated by the mid-2020s.

Goal 2 Performance Indicators

1. By 2024, demonstrate and test a fueled microreactor core fabricated by advanced manufacturing techniques.
2. By 2025, enable demonstration of a commercial U.S. microreactor.
3. By 2027, demonstrate operation of a nuclear-renewable hybrid energy system.
4. By 2028, demonstrate two U.S. advanced reactor designs through cost-shared partnerships with industry.
5. By 2029, enable operation of the first commercial U.S. small modular reactor.
6. By 2035, demonstrate at least two additional advanced reactor designs through partnerships with industry.

Advanced reactors will be more flexible and versatile. For example, small modular reactors can add modules to meet growing energy needs.



Objective 1: Reduce risk and time needed to deploy advanced nuclear technology.

The United States needs to move with a sense of urgency to deploy advanced nuclear energy technologies to meet our energy, environmental, and national security needs. If we do not deploy these designs quickly, our supply of carbon-free electricity will be at risk and we will lose ground to countries like China and Russia that are moving rapidly to bring advanced technologies to market.

The U.S. government has a unique role to play in reducing risk for developers and reducing the time required to develop new technology. Nuclear technology development requires unique facilities and capabilities that the private sector cannot maintain alone. Our national laboratories possess decades of experience in nuclear technology development, exceptional research capabilities, and some of the top scientists in the field.

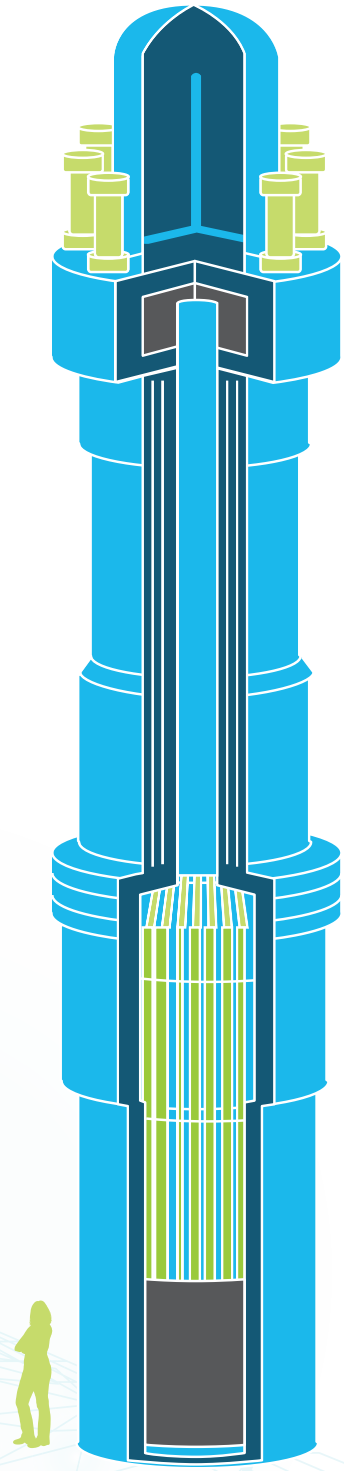
Recognizing the need to provide the U.S. industry better access to the unique resources of DOE, NE launched the Gateway for Accelerated Innovation in Nuclear (GAIN) in 2015. GAIN connects industry with the national laboratories to accelerate the development and commercialization of advanced nuclear technologies. GAIN bridges the gap between innovators in the private sector and the world-class research capabilities of our national laboratories. It offers a single point of access to the nuclear facilities and expertise at the laboratories and ensures this work has a real impact on the future of nuclear energy technology.

Building on the success of GAIN, NE recently established the National Reactor Innovation Center (NRIC) to help developers test and demonstrate their advanced reactor technologies at DOE-owned sites. NRIC will reduce the time it takes for developers to move new reactor technologies from proof-of-concept through proof-of-operations. Demonstrating these advanced nuclear technologies through NRIC will ultimately reduce costs and improve performance of these technologies as they progress to full commercialization.

Through NRIC, NE will also work with the NRC to accelerate the licensing process for advanced reactors. NE will open its sites to NRC regulators to observe the development of advanced reactors. This will further broaden the NRC's understanding of the designs and inform its approach to licensing new technologies. In addition to information sharing, NE will also provide the NRC access to state-of-the-art computing capabilities and modeling codes that can be used to predict reactor operations, including fuel and material performance. These advanced modeling capabilities will reduce the time it takes to validate and certify new designs, enabling a faster commercialization process.

As a way to develop private-public partnerships with industry, NE established the U.S. Industry Funding Opportunity Announcements (iFOA) for Advanced Nuclear Technology Development in 2017. This provides a direct vehicle to support innovative, domestic technologies with high potential to improve the overall economic outlook for nuclear power in the United States. NE's investment will accelerate development of these designs and technologies so that the most mature new designs can be deployed as early as mid-2020s.

In support of the United States Nuclear Fuel Working Group policy recommendations and as directed by Congress, NE also initiated the Advanced Reactor Demonstration Program. Through research and development activities, bolstered by private-public partnerships, NE will support the demonstration of at least two U.S. advanced nuclear reactor designs by 2028 and an additional two reactors by 2035.



NE is accelerating the development of advanced nuclear technology, including small modular reactors.

As communities work to meet energy demand without increasing carbon emissions, advanced nuclear technology can play an important role.

Image credit: Third Way/Gensler/advancednuclearenergy.org

Objective 2: Develop reactors that expand market opportunities for nuclear energy.

As communities work to meet energy demand without increasing carbon emissions, advanced nuclear technology can play an important role. New reactor designs are more flexible and versatile, designed to meet the needs of the communities who use them. They come in a range of sizes, from a few megawatts (MW) to more than 1,000 MW. They can adjust their electricity output to match demand and can pair with renewables to provide around-the-clock, emissions-free electricity. Furthermore, they expand the benefits of nuclear power beyond electricity generation. They can provide process heat to create hydrogen to help decarbonize the industrial and transportation sectors or provide clean drinking water from desalination plants.

By supporting the development of advanced reactor types that provide different benefits to consumers and communities, NE will expand market opportunities for the application of nuclear energy. By investing in new applications of nuclear technology, NE will bolster the nation's supply of clean energy and reduce overall carbon emissions.

NE is supporting the development of reactors that are much smaller than traditional nuclear reactors. Small modular reactors (SMRs) are smaller, manufactured reactors that are expected to be less expensive to build and operate. Because SMRs have a simpler, compact design, utilities have more options to deploy nuclear power. This includes developing reactors in locations unable to support larger nuclear power plants. SMRs can power smaller electricity markets and grids, isolated areas, and sites with limited water. They can also be scaled up to meet energy demands by adding modules. SMRs are also right-sized to replace aging and retiring fossil energy plants. Utilities and developers could take advantage of existing infrastructure, such as water intakes and electrical distribution equipment, as they identify locations to deploy SMRs. NE is supporting demonstration of the nation's first SMR, which is expected to be operational by 2029.

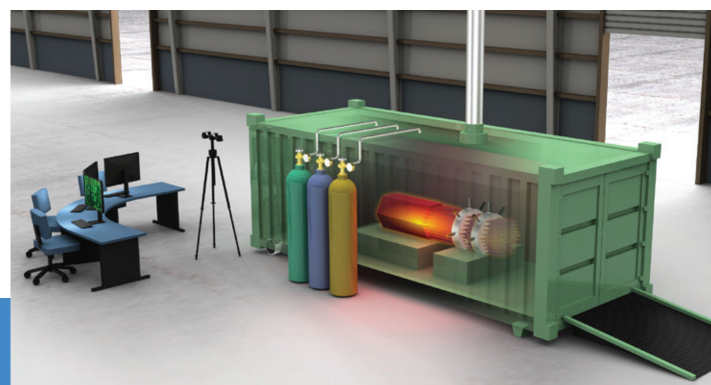
Microreactors will be even smaller than SMRs. Vendors will be able to ship the entire reactor by truck, shipping vessel, airplane, or rail car. This means that microreactors could be dispatched to sites and set up in days. They could be used to restore power to areas hit by natural disasters or to power military bases and remote locations where traditional infrastructure does not exist. Many very remote communities currently rely on shipments of diesel to run generators. Microreactors will provide an important option for these communities to access clean, continuous, cost-effective electricity for up to 10 years at a time without refueling. Microreactors could also be used to power independent microgrids, providing secure power for hospitals, emergency services, or continuous manufacturing processes. NE will enable demonstration of a commercial U.S. microreactor by 2025.

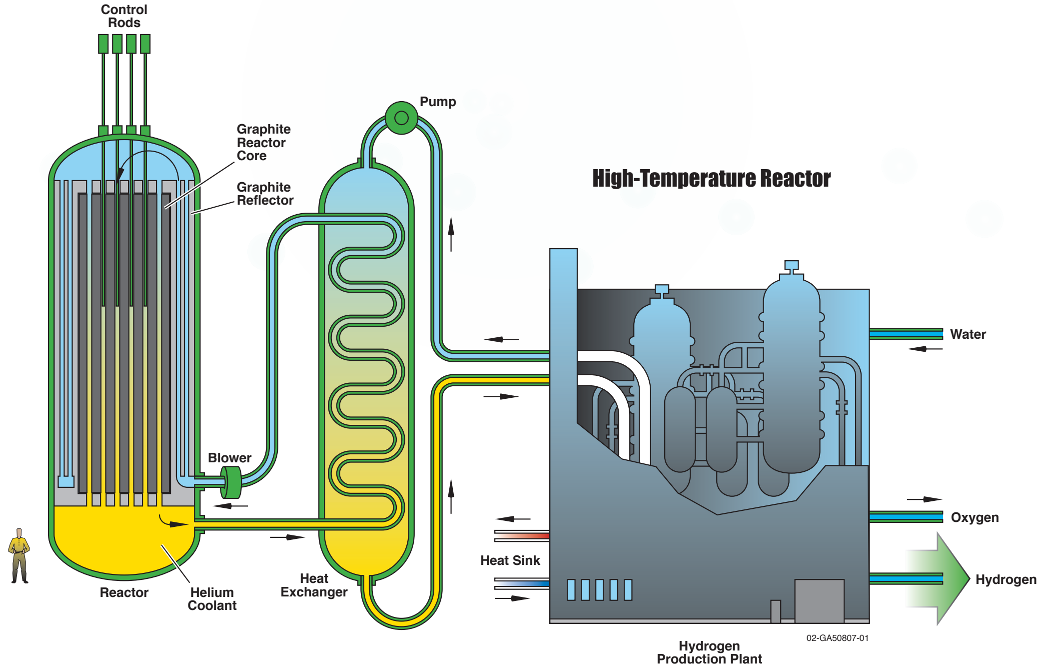
NE is developing processes for advanced manufacturing of microreactor components. Additive manufacturing—more commonly known as 3D printing—allows complex designs to be rapidly prototyped, tested, and produced. This could significantly reduce the time and cost of bringing new components to market. NE will support demonstration and testing of a fueled microreactor core fabricated by advanced manufacturing techniques by 2024.

Small modular reactors and microreactors will expand opportunities to deploy nuclear technology. Because of their smaller sizes, passive safety features, and smaller emergency planning zones, they can simply go where large-scale reactors cannot. They provide choices to customers that need a constant and reliable source of clean power without the real estate requirements and capital costs of a large construction project.

NE is also supporting development of advanced reactors that can be used in energy-intensive processes that currently rely on fossil fuels,

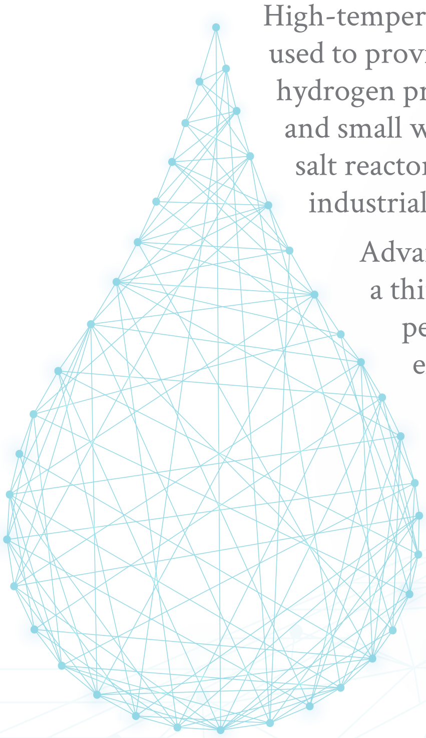
Microreactors are small and transportable. They can power remote communities, support independent microgrids, and restore power to areas hit by natural disasters.





High-temperature reactors open up markets for industrial uses other than electricity generation, including the production of hydrogen.

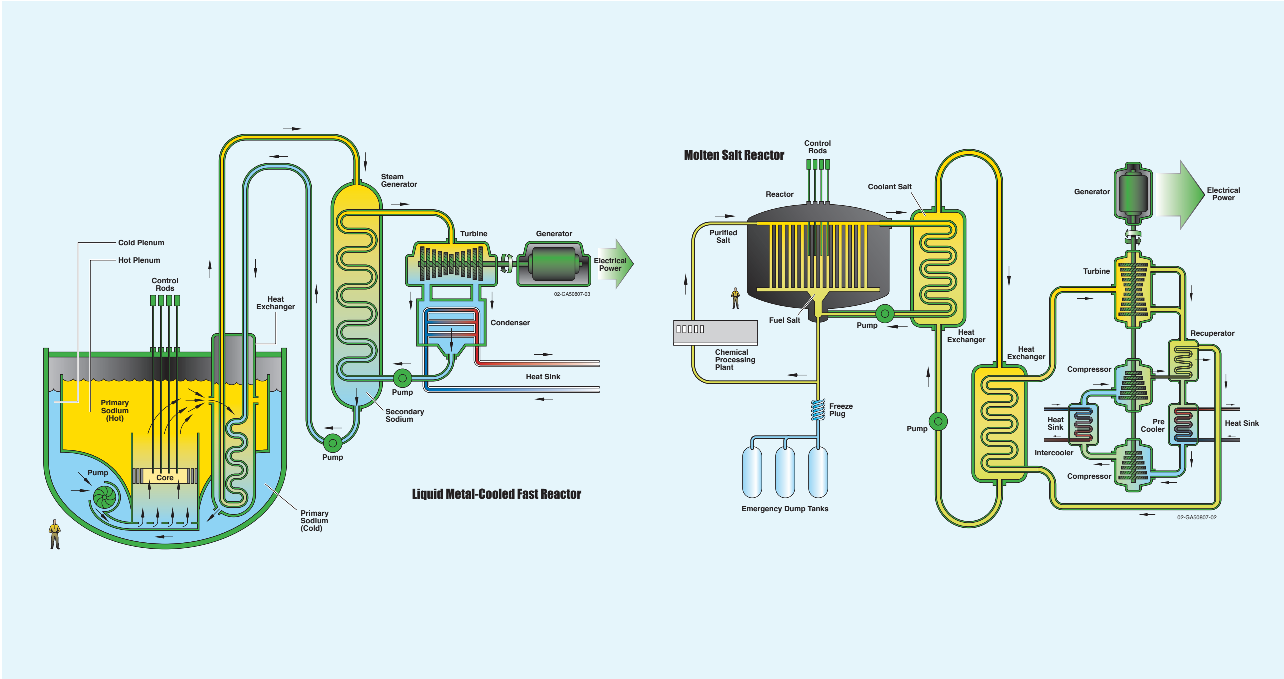
including hydrogen production, desalination, district heating, petroleum refining, and fertilizer production. As discussed under Goal 1, this opens up an important market opportunity for nuclear developers and the opportunity to significantly reduce carbon emissions in industrial processes.



High-temperature reactors operate at very high temperatures (750°C and above) that can be used to provide electricity and support non-electric applications such as water desalination, hydrogen production, and chemical processing. These reactors can be scaled to be modular and small with 75 MW electric output, or as large as current light-water reactors. Molten salt reactors, discussed further below, can also be used for non-electric industrial applications.

Advanced reactors could also be particularly useful in water desalination. Almost a third of the world lacks access to clean drinking water, with more than 2 billion people living in countries affected by water scarcity. These numbers are only expected to rise. Current desalination plants around the world produce 10 trillion gallons of drinking water each year. More are coming online to meet future water needs, which are expected to grow by up to 30 percent in the next 3 decades. While existing desalination plants are energy intensive and rely heavily on fossil fuels, nuclear energy could play a major role in providing clean energy that would get us closer to worldwide water security. A new fleet of reactors could expedite this process. SMRs will offer greater flexibility in size and operation to generate electrical energy and thermal energy at seawater desalination plants.

Liquid metal-cooled fast reactors and molten salt reactors offer significant advantages, including greater efficiency and less waste.



Objective 3: Support a diversity of designs that improve resource utilization.

The United States is developing a wide range of advanced reactors that maximize resource utilization, minimize waste, and take advantage of a diversity of materials.

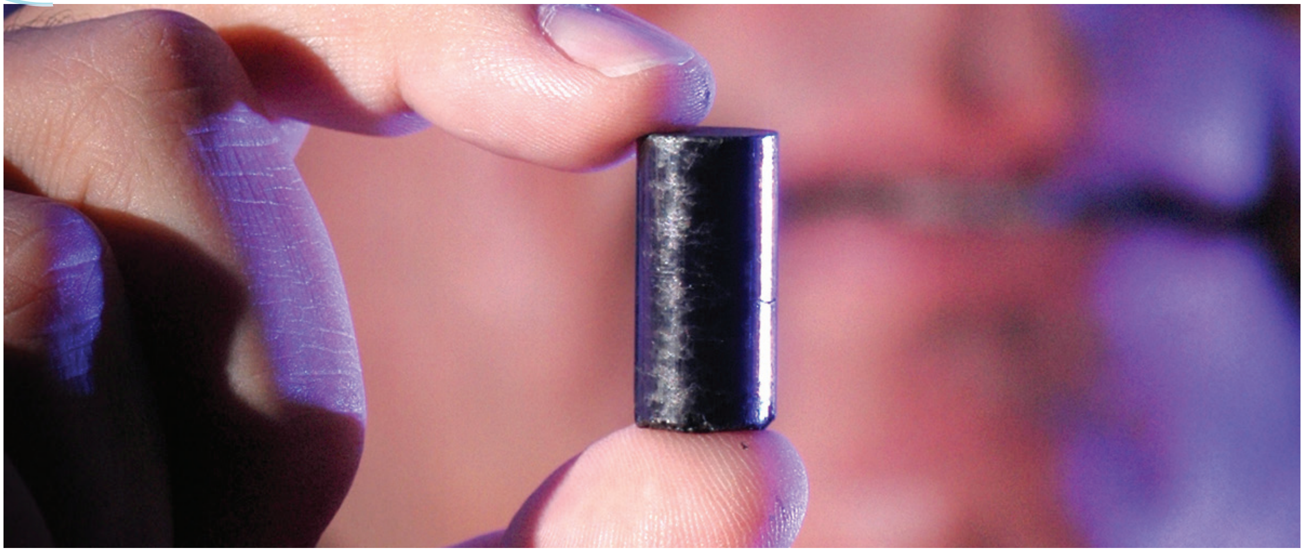
Liquid metal-cooled fast reactors use liquid metal—such as sodium or lead—as a coolant. This enables operation at higher temperatures and lower pressure than current reactors, improving efficiency. Because they use a fast neutron spectrum (neutrons can be used to cause fission without having to be slowed down), these reactors could also operate with used fuel from current reactors to produce energy.

High-temperature reactors, discussed above, also improve efficiency by operating at a high temperature. Online refueling allows for even higher capacity factors.

Molten salt reactors use molten fluoride or chloride salts as coolant or fuel. Due to their higher operating temperatures and online fuel reprocessing, they could use resources more effectively and produce less radioactive waste. They have the potential to improve the economics of nuclear energy production by using a low-pressure coolant system and adding fresh fuel without lengthy refueling outages. Some molten salt reactor concepts could consume used fuel from other reactors, reducing the amount of material for disposal.

NE is also performing research on advanced integrated energy systems. These systems couple nuclear, renewable, and fossil energy sources to produce electricity and non-electric energy products such as heat. These integrated systems make smarter use of resources and allow for flexible energy production, making them more responsive to market dynamics and more profitable. We aim to demonstrate operation of a thermally integrated, nuclear-renewable hybrid energy system by 2027 and enable broad commercial adoption for new builds by 2035.

Goal 3: Develop advanced nuclear fuel cycles.



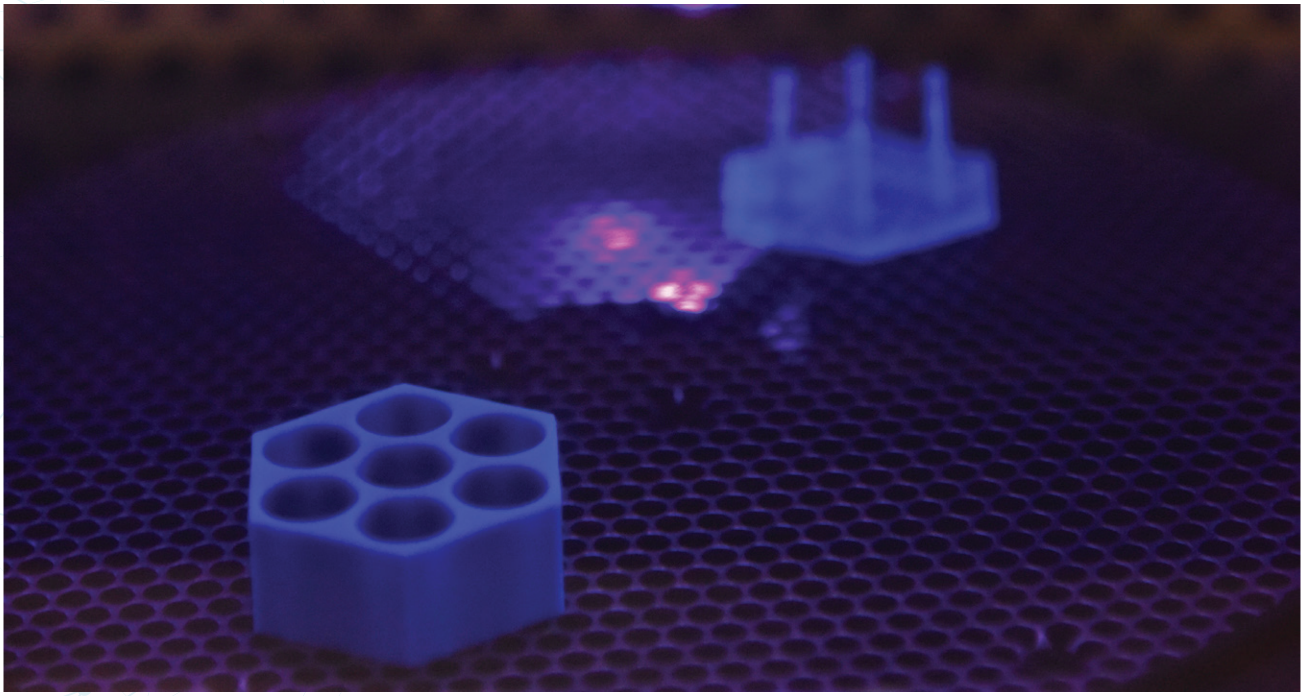
As we develop technology to help sustain the existing fleet and deploy advanced nuclear reactors, we need to pursue advanced fuel cycles to fully take advantage of modern nuclear technology. NE is developing sustainable fuel systems that reduce used nuclear fuel and waste, improve performance, use resources efficiently, and further enhance safety. Advanced nuclear technology paired with sustainable fuel cycle choices will expand opportunities for reactor deployment domestically and abroad.

Goal 3 Performance Indicators

1. By 2021, begin procurement process for establishing a uranium reserve.
2. By 2022, demonstrate domestic HALEU enrichment.
3. By 2023, make available up to five metric tons of HALEU from non-defense DOE material.
4. By 2030, evaluate fuel cycles for advanced reactors.

The HALEU program enables deployment of advanced reactors to help secure America's clean energy future.

HALEU fuels will be used in many new advanced reactor designs, some using entirely new fabrication techniques.



Objective 1: Address gaps in the domestic nuclear fuel supply chain.

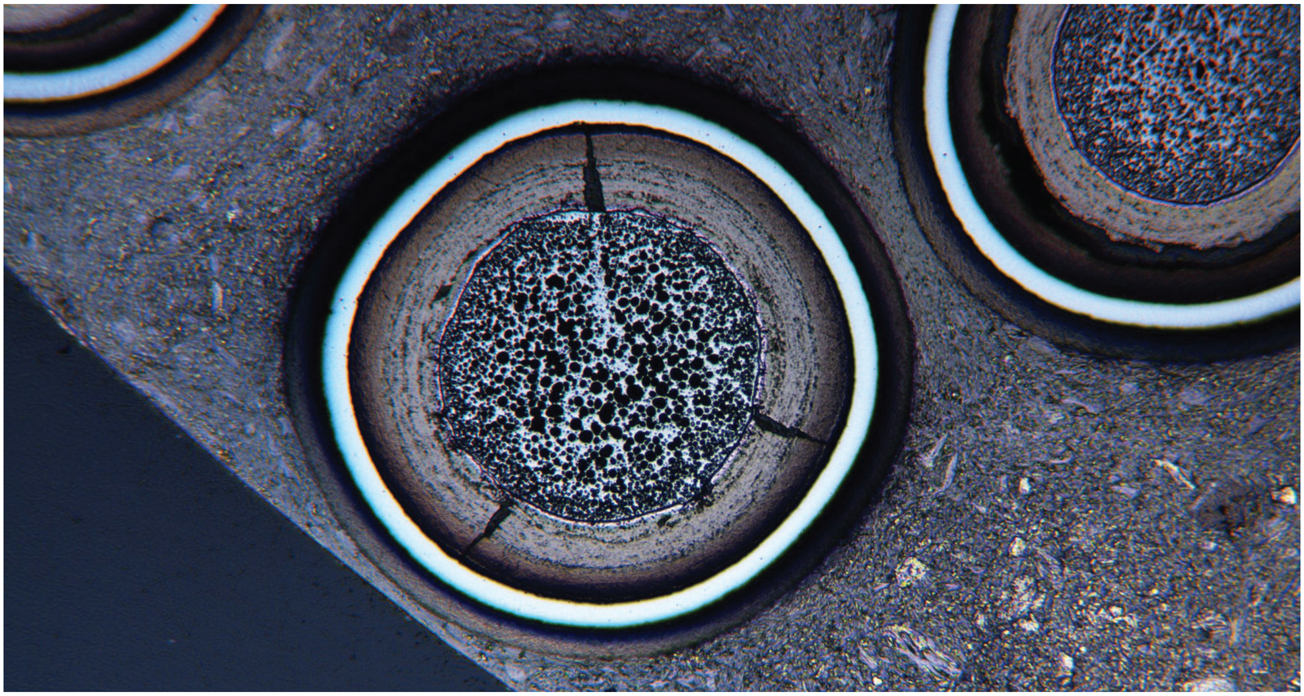
Many advanced reactor concepts require a higher-enriched fuel to achieve smaller plant size, better fuel utilization, and more efficient plant operations. This fuel is called high-assay, low-enriched uranium (HALEU) and the U.S. nuclear industry currently estimates it may need up to 600 metric tons of it by 2030.

NE is investigating multiple options to support the availability of HALEU. In the near term, HALEU will be provided from down-blending limited quantities of DOE-managed, non-defense, high-enriched uranium feedstocks and by processing used reactor fuel from the Experimental Breeder Reactor-II (EBR-II). We aim to make up to five metric tons of HALEU from non-defense DOE material available by 2023.

In the long term, commercial quantities of HALEU will require a commercial-scale enrichment operation. To develop this capability in time to meet the needs of advanced reactor developers, NE is implementing a program to demonstrate HALEU enrichment using U.S.-origin technology by 2022. Once demonstrated, we expect industry will scale up operations to meet market demand. A commercial enrichment capability will fill an important gap in the supply chain for advanced reactor systems.

The U.S. supply chain for uranium is facing a number of challenges. U.S. uranium production has decreased significantly in recent years and U.S. uranium conversion has been idle since 2017 due to unfavorable market conditions. NE is planning to establish a uranium reserve to provide support to these capabilities and create a backup supply of uranium in the event of a significant market disruption. NE plans to initiate a procurement process for establishing the uranium reserve by 2021.

Individual TRISO fuel particles at 100um scale



Objective 2: Address gaps in the domestic nuclear fuel cycle for advanced reactors.

Many of the advanced reactor technologies being developed and demonstrated under Goal 2 use fuel cycles that are significantly different from what is used for existing light water reactors. Some of these advanced systems use solid fuels, including a range of materials beyond uranium dioxide. These include various tristructural isotropic (TRISO) fuel forms, nitrides, and metallic alloys. Other advanced systems use liquid fuel, including various molten salt options. Some of the reactor designs have lifetime or long-life cores. Others operate with burnups well beyond those of the current fleet. Additionally, advanced reactor concepts focus on sustainability and resource utilization and address fuel feedstocks. Each of these options will require specific supportive fuel cycles. As these diverse reactor concepts are being further developed and demonstrated, NE will continue to evaluate their associated fuel cycles.

Dry storage casks at the Idaho Nuclear Technology and Engineering Center at INL.

Objective 3: Evaluate options to establish an integrated waste management system.

NE is responsible for the eventual disposal and associated transport of commercial used nuclear fuel, which is currently stored at 76 reactor or storage sites in 34 states. For the foreseeable future, this fuel can safely remain at these facilities until a permanent disposal solution is identified. NE will continue to provide the scientific basis for storage, transportation, and disposal solutions. To support consolidated interim storage of used fuel, NE is developing plans to identify activities, milestones, and resources needed to develop a consolidated storage facility. To support a transportation capability, NE is developing new, specially designed railcars to support large-scale transport of used nuclear fuel in the future. We are also building strong partnerships with state, regional, and tribal organizations to prepare for future transport. Finally, to support the continued storage of used nuclear fuel, NE is performing R&D on the performance of high-burnup fuel. Addressing the nation's inventory of commercial used nuclear fuel and high-level radioactive waste is essential to the long-term sustainability of nuclear energy.

Goal 4: Maintain U.S. leadership in nuclear energy technology.

Globally, more than 450 nuclear reactors operate in 30 countries. More than 50 reactors are under construction and that number could grow to more than 400 as countries assess their energy options. As global energy demand continues to rise, countries are faced with the challenging task of meeting those needs while simultaneously lowering emissions. Nuclear technology can help solve that problem. It stimulates economies, creates abundant clean energy, and makes electric grids more secure.

The United States has the best nuclear technology in the world and the most operational experience. In fact, much of the nuclear energy technology in operation internationally traces its roots back to American technology. However, as nuclear energy continues to expand internationally, countries such as Russia and China are quickly becoming the dominant suppliers of nuclear technologies and services. State sponsorship, attractive financing options, and bundled services (such as fuel supply and used fuel takeback programs) help these countries achieve a significant competitive advantage over

Goal 4 Performance Indicators

1. By 2021, award up to 50 university R&D projects and $5 million in student scholarships and fellowships.
2. By 2021, support restart of sole source TRIGA fuel used in university reactors.
3. By 2021, establish formal cooperation with five countries seeking to develop their nuclear energy programs.
4. By 2021, create a comprehensive approach to assist countries developing their nuclear energy programs.
5. By 2022, increase U.S. leadership and participation in multilateral organizations promoting the peaceful uses of nuclear energy.
6. By 2026, build the Versatile Test Reactor.
7. By 2026, complete the Sample Preparation Laboratory.
8. By 2030, work with NASA to demonstrate fission power systems for surface power and propulsion.

U.S. nuclear vendors. Russian and Chinese nuclear technologies do not maintain the same levels of innovation, quality, safety, and reliability that U.S. commercial vendors inherently design into advanced nuclear systems.

U.S. industry is developing a suite of options to meet the needs of any country. These designs include large-scale reactors for baseload generation to smaller, more flexible units that can be scaled up as energy demand grows. In 2017, the U.S. Department of Commerce estimated the global civil nuclear market to be valued between $500 and $740 billion over the next 10 years with the potential to generate more than $100 billion in U.S. exports and thousands of new jobs. We cannot afford to cede that market to our competitors.

Nor can we afford to lose our position as a leader in nuclear energy technology. Our leadership role and the availability of U.S. technology in the international market are some of our greatest tools in ensuring other countries choose to use nuclear technology for peaceful purposes and in a manner that promotes safety and nonproliferation.

NE works with many international organizations promoting nuclear energy, including IFNEC and the NICE Future Initiative.

NE supports international cooperation on nuclear energy.

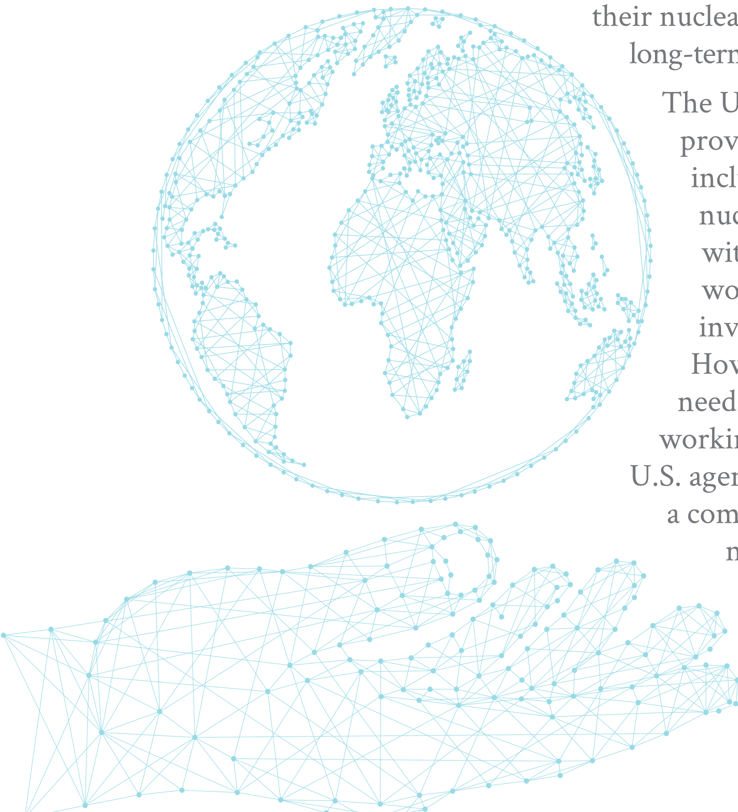
Objective 1: Facilitate global opportunities for U.S. nuclear sector.

The global nature of nuclear energy—both in its benefits and challenges—makes broad international collaboration extremely important. NE cooperates with international partners through bilateral technical cooperation, as well as through participation in multilateral organizations promoting the peaceful uses of nuclear energy.

Bilateral agreements are used primarily to strengthen ties and relationships with countries that have existing nuclear energy markets, as well as establish new relationships with countries exploring a new nuclear program. Bilateral agreements allow a country to work collaboratively with the United States to pursue common goals in the development of nuclear technology. These are trusted, long-term partnerships between the two countries. NE uses bilateral agreements to enhance R&D on nuclear technology and help bring the benefits of nuclear technology—such as environmental sustainability, energy security, and economic prosperity—to the world. By 2021, NE aims to establish additional formal cooperation agreements with five countries seeking to develop their nuclear energy programs.

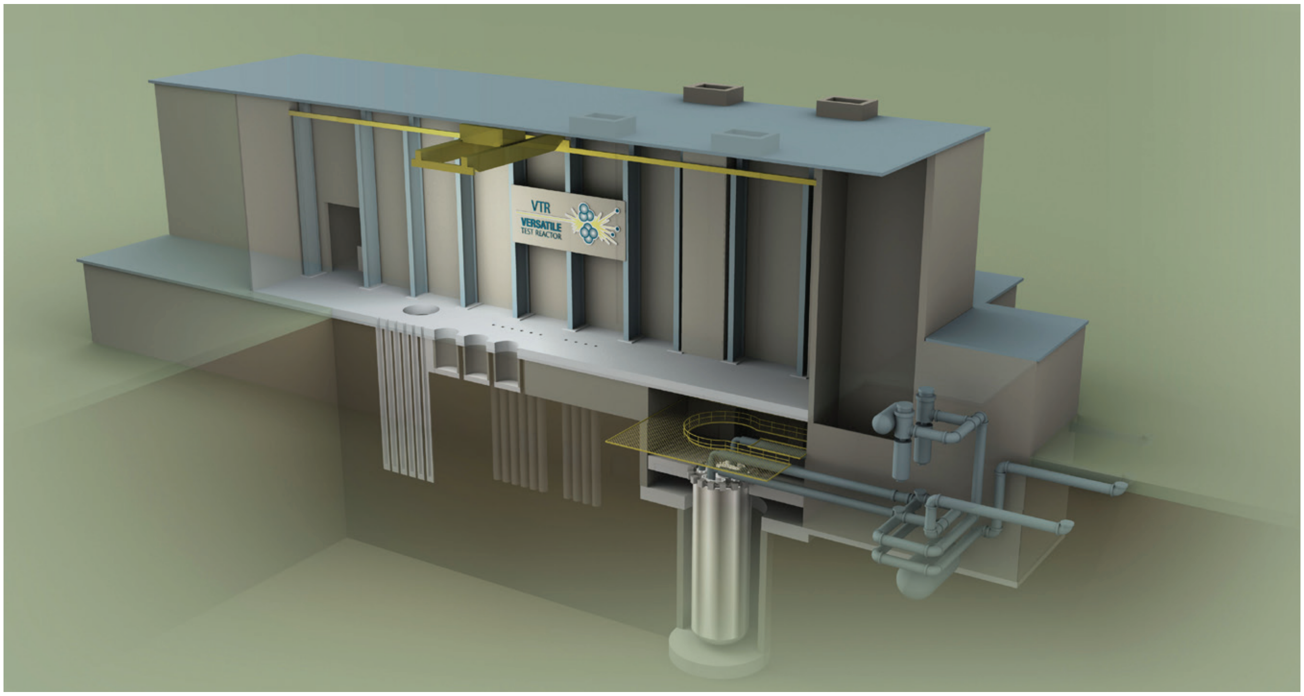
NE also participates in multilateral organizations to strengthen U.S. leadership and influence in nuclear technology globally. NE actively participates in the International Atomic Energy Agency (IAEA), the International Framework for Nuclear Energy Cooperation (IFNEC), the NICE Future Initiative of the Clean Energy Ministerial (CEM), the Generation IV International Forum (GIF), and the Organisation for Economic Co-operation and Development's Nuclear Energy Agency (NEA). NE leverages engagement in these organizations to build advocacy for the U.S. nuclear sector, including its education systems, nuclear supply chain, regulatory basis, and safety and nonproliferation policies.

The U.S. government is developing a streamlined approach to assisting countries in their pursuit of nuclear energy capabilities. By partnering with the United States, countries will not only get the best technology but also the best regulatory guidance, security and nonproliferation assistance, research and development infrastructure, and resources they need to expand or begin their nuclear programs. These are not singular transactions. They are long-term, strategic partnerships that may last 100 years or more.



The United States needs to compete with other countries that provide comprehensive build, own, and operate packages; include attractive financing options; and offer take back of used nuclear fuel. A fully operational Export-Import Bank, along with other financing mechanisms, allows U.S. companies to work with countries to fund new nuclear projects. NE is also investigating comprehensive fuel management solutions. However, in order to be truly competitive, the United States needs a streamlined process and a consolidated approach to working with other countries. NE will collaborate with other U.S. agencies, national laboratories, academia, and industry to create a comprehensive approach to assist countries developing their nuclear energy programs by 2021.

VTR will feature a sodium-cooled fast reactor that will accelerate testing of advanced nuclear technologies.



Objective 2: Maintain world-class research and development capabilities.

The United States has been a leader in nuclear energy research and development for decades. Our national laboratories are unmatched in their R&D capabilities and have proven the ideal test beds for transformative technology. To provide the best possible support to technology developers and retain our leadership role globally, the United States must maintain world-class nuclear energy research, development, and demonstration infrastructure. NE aims to identify and fill gaps in capabilities needed to bring new technology to market quickly, efficiently, and cost effectively.

To address a gap in U.S. R&D capabilities needed to commercialize advanced reactors, NE is developing the Versatile Test Reactor (VTR). Many of the advanced reactor designs will be fast reactors, which interact differently with materials. Because the United States has not operated a fast test reactor in nearly 30 years, U.S. developers are limited in the data they can currently use to characterize these materials.

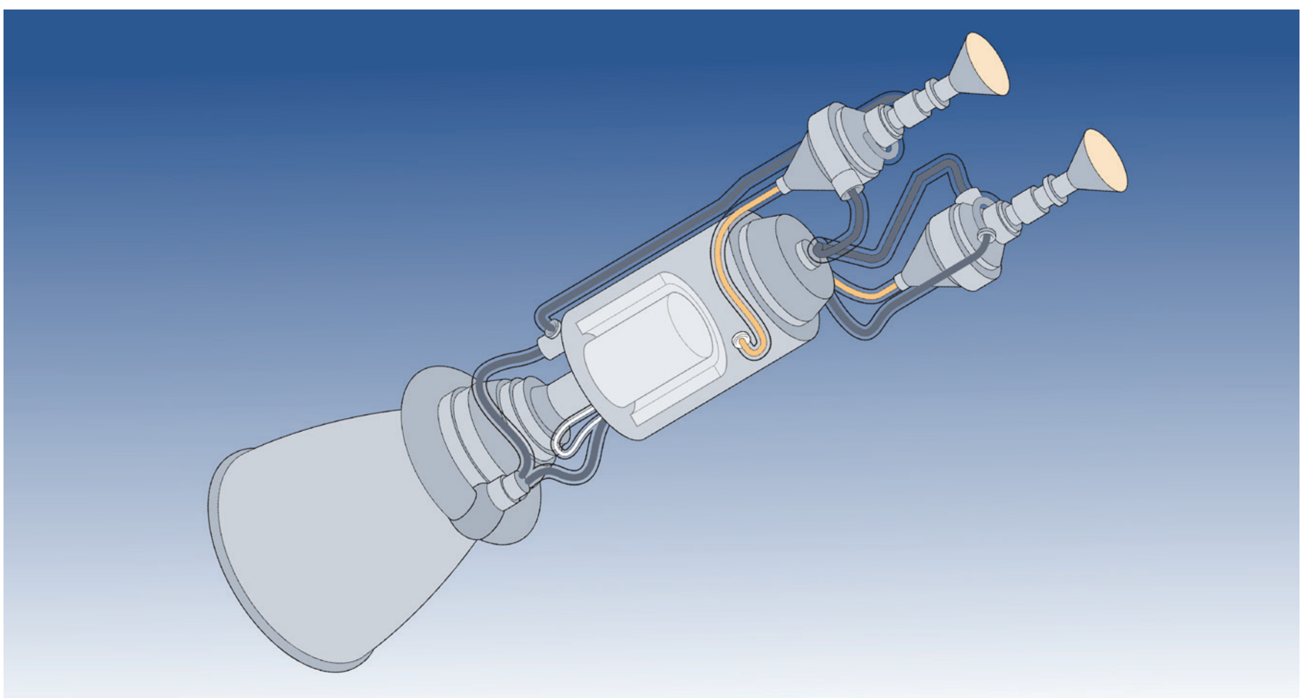
VTR will use high-energy neutrons to accelerate testing of advanced technologies needed for new reactor designs, as well as for our existing fleet. It will drastically reduce the time it takes to test, develop, and qualify advanced reactor technologies. It will be pivotal in creating new fuels, materials, instrumentation, and sensors that could position the United States as a global leader in advanced nuclear technology. These innovations could extend the lifetime of reactor cores, boost fuel performance, and even accelerate fusion research.

Idaho National Laboratory (INL) will lead a dedicated multi-disciplinary team of experts from national laboratories, industry, and universities to develop VTR. NE released a draft Environmental Impact Statement to ensure environmental factors and public comments are considered before making a final decision to move forward with the project. The VTR team has developed a schedule and funding profile to ensure VTR is operational by 2026.

INL's Sample Preparation Laboratory will allow for windowless operations controlled with robotics to support irradiated structural material testing.

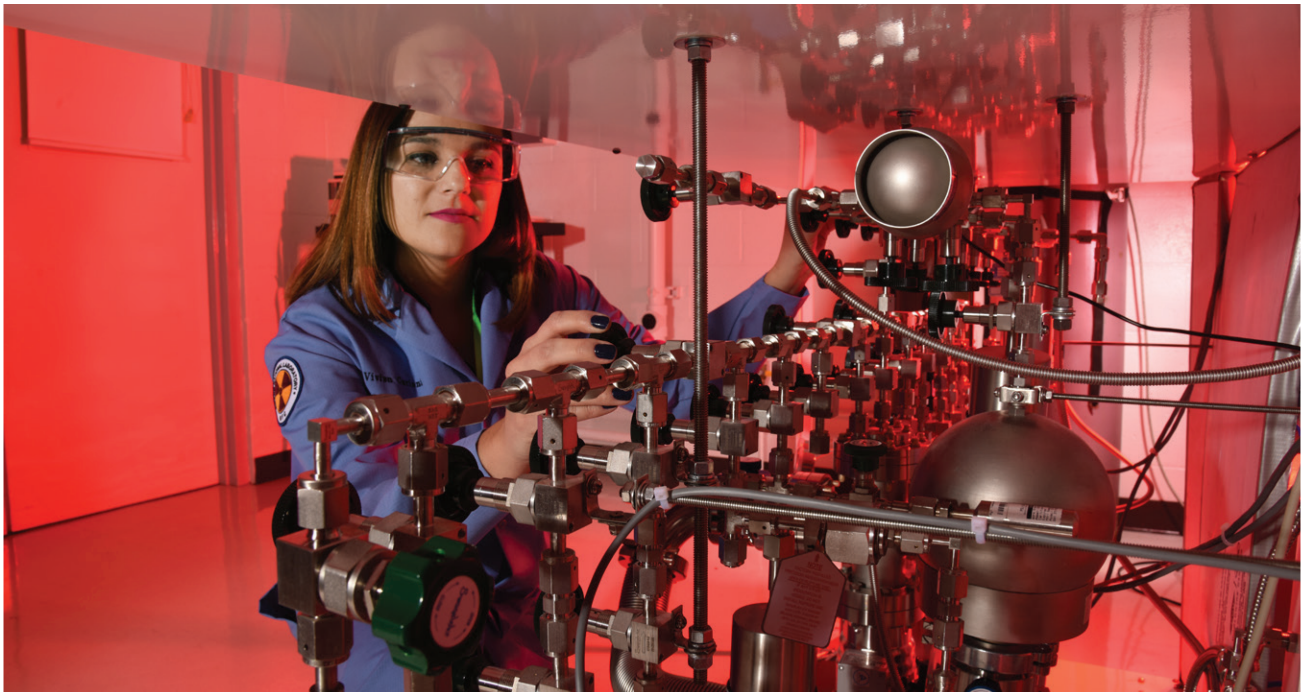
To fill another gap in R&D capabilities that will assist advanced reactor developers in commercializing their technology, INL is establishing the Sample Preparation Laboratory (SPL). SPL will enable enhanced analysis of irradiated materials, which will improve materials for use in advanced nuclear energy systems. SPL will also support the long-term operation of the existing fleet by enhancing our understanding of issues related to the aging of materials. We expect to complete the SPL by 2026, satisfying the near-term gap for post-irradiation and examination capabilities.

NE and INL are also working with NASA to develop fission power systems for surface power and propulsion to support space exploration to the Moon and Mars. NASA is working to develop scientific instruments and technology to explore the surface of the Moon, as well as technology to power missions. Nuclear thermal propulsion systems could reduce travel times to Mars by 25 percent and carry greater payloads than today's top chemical rockets. NE will work with NASA to demonstrate fission power systems for surface power and propulsion by 2030.



Rendering of nuclear thermal propulsion technology, which could reduce travel time to Mars by up to 25 percent.

NE funds students, colleges, and universities to support the next generation of nuclear scientists and engineers.



Objective 3: Develop highly trained scientists to support the future nuclear workforce.

NE funds U.S. colleges and universities to conduct research, upgrade infrastructure, and support student education. Not only does this advance outstanding, cutting-edge research, it helps to develop a top-notch nuclear workforce for the future. NE supports R&D at colleges and universities all over the United States, as well as graduate fellowships and undergraduate scholarships as part of our ongoing commitment to educate the next generation of nuclear scientists and engineers. These colleges and universities often collaborate with the national laboratories, thereby expanding the base of highly qualified engineers and scientists in the future. NE will award up to 50 university R&D projects and $5 million in student scholarships and fellowships by 2021.

Training, Research, Isotopes, General Atomics (TRIGA) reactors are used to perform research and train students at several U.S. universities. To enable continued operation of 12 of the nation's 24 university research reactors, NE will support the restart of sole source fuel for TRIGA reactors by 2021. Due to the designs of these reactors, the required fuel is only available from a single vendor. NE is collaborating with that vendor to provide the lifetime fuel needs of these reactors, so that these universities can continue to train highly qualified scientists and engineers.

Goal 5: Enable a high-performing organization.

To deliver on our mission, NE must enable a high-performing organization with a capable workforce, well-managed programs, and regular stakeholder communications. A high-performing organization is key to providing the greatest value of our programs to U.S. taxpayers.

Goal 5 Performance Indicators

1. By 2020, develop a multi-year program plan for each program office in NE.
2. By 2020, meet 95 percent of high-level milestones on time and within budget.
3. By 2021, fill key personnel gaps, in accordance with the NE hiring plan.
4. By 2022, update the NE Strategic Vision to reflect any changes to goals, objectives, and performance indicators.
5. By 2022, increase the number of active NETWG Tribal members from 11 to 13.

Objective 1: Support and invest in the Office of Nuclear Energy workforce.

People are the most important asset in executing the NE mission. To be successful, NE must attract and retain a highly capable workforce with the technical skills and experience required to accomplish our science-driven programs. NE must compete with other technical organizations for top scientists, engineers, and management professionals. To ensure the continued excellence of our workforce, NE is committed to proactively recruiting highly qualified and diverse employees from within and outside of the federal government. We have developed a detailed hiring plan to address key staffing needs. This plan is monitored closely to ensure hires are prioritized and managed within available resources. In accordance with that plan, NE aims to fill all key personnel gaps by 2021. NE will update the hiring plan annually, at the beginning of the fiscal year.

NE will also invest in its existing workforce to ensure we maintain world-class expertise in executing our programs. This will include supporting continued education and training for our employees, as well as developing career plans, succession planning, and employee recognition programs.

NE places great value in the annual Federal Employee Viewpoint Survey (FEVS) as a tool for continuous improvement throughout the organization. Overall, NE has earned high scores in the FEVS, particularly in the areas of employee willingness to put in extra effort, supervisors valuing work/life balance, and supervisors treating employees with respect. Last year, NE scored in the top 10 percent of DOE programs and 3 NE offices were in the top 30 of 625 organizations in DOE. NE will strive for 100 percent participation in FEVS each year. We will continue to address issues identified in FEVS and incorporate actions derived from FEVS into the annual performance plans of senior executives to ensure they are addressed.

Objective 2: Effectively manage programs, projects, R&D investments, and contracts.

NE has a diversified portfolio of R&D programs. To be successful in executing our mission, we must manage our programs effectively and efficiently with a constant focus on performance. NE uses the Program Information Collection System for Nuclear Energy (PICS:NE) to provide a clear picture of performance at all times. PICS:NE is a web-based program management tool that describes the planning basis (i.e., objectives, assumptions, technical scope, deliverables, and milestones) for NE's R&D programs. More than 2,000 individual work packages are assigned directly to a specific site and organization. Cost and schedule data is tracked each month as earned value and milestone performance. NE aims to meet 95 percent of high-level milestones on time and within budget.

NE continuously assesses risk to program objectives using the Quarterly Program Risk Management Profile. When program managers detect upcoming risks, they flag them and develop detailed plans to mitigate the risks to success. Combined with the DOE-wide risk management process outlined in the Federal Managers Financial Integrity Act of 1982 (FMFIA) Assurance Statement, the NE Quarterly Program Risk Management Profile allows NE leadership to address program risk effectively.

The national laboratories are key partners in executing our programs. We work closely with the laboratories to further the mission of NE, maximize the impact of NE R&D investments, and maintain world-class R&D capabilities. NE serves as the steward of our nation's leading nuclear energy lab, INL. INL combines the expertise of government, industry, and academia in a single lab under the leadership of Battelle Energy Alliance (BEA). BEA manages the lab under a management and operating contract that requires safe and efficient operation of all INL facilities, cost reduction by better use of resources, and cost-effective accomplishment of mission objectives.

In addition to our partnerships with the national laboratories, NE collaborates closely with industry and academia to perform R&D, advance technological breakthroughs, and develop scientific understanding. NE allocates funding to the best-qualified entities to conduct work in support of NE's mission. NE also collaborates with international partners and Tribal Nations to leverage U.S. research investments and pursue common goals. We engage the Tribes in NE activities through the Nuclear Energy Tribal Working Group (NETWG). We aim to increase the number of active NETWG Tribal members from 11 to 13 by 2022.

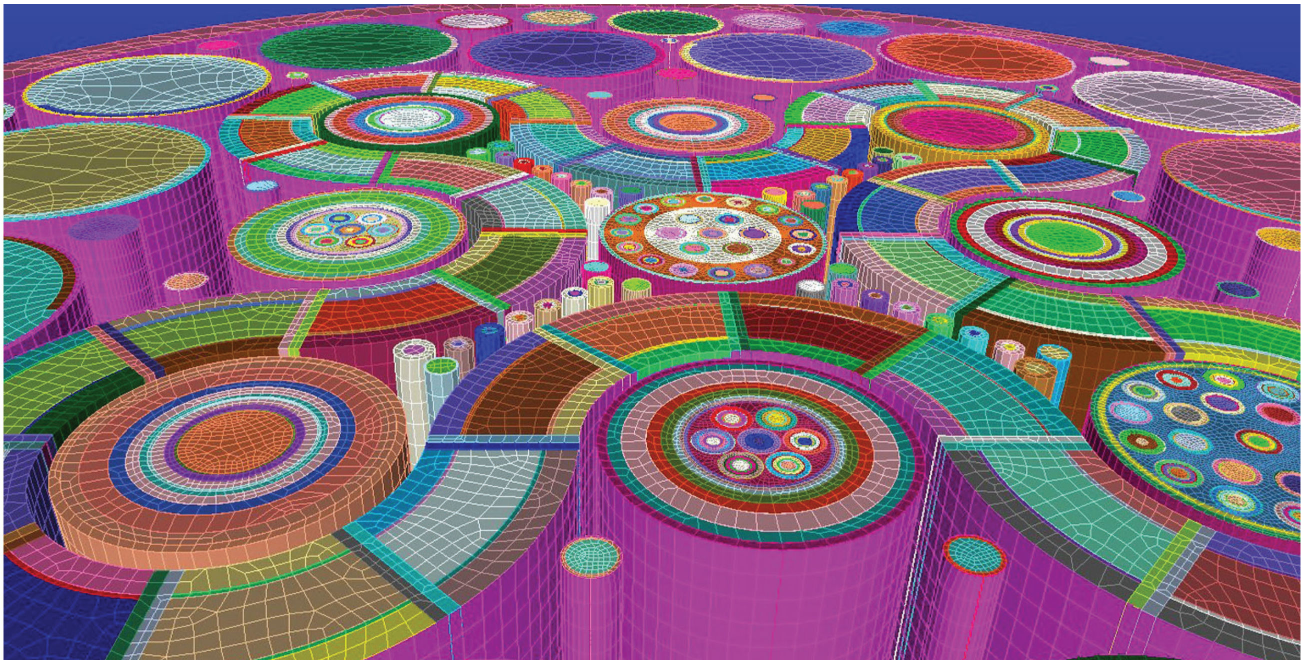
Objective 3: Communicate regularly with stakeholders.

NE will continue to communicate its plans, program priorities, and activities both internally and externally. Management of successful R&D programs necessitates regular prioritization of activities with the greatest potential and highest likelihood of impact. As we reprioritize activities and shift focus to meet our mission and goals, we will reflect those changes in updates to this Strategic Vision. NE plans to deliver an updated version of the Strategic Vision in 2022.

Building on the goals, objectives, and performance indicators laid out in this plan, each NE program office will develop a multi-year program plan by the end of 2021. The multi-year program plans will describe program goals, R&D priorities, and roadmaps for success.

NE and its employees also serve an important role as an authority on nuclear energy technology. Commercial nuclear power has suffered from a public perception problem for decades. NE is committed to providing accurate, fact-based information about nuclear energy through its social media, STEM programs, and stakeholder outreach efforts to educate the public on the uses and benefits of nuclear energy. In addition, NE and lab experts regularly participate in technical workshops, speaking events, and collaborative working groups to discuss technology developments and address challenges. These efforts are pivotal to the success of our mission to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs.

CONCLUSION



NE is working diligently to solve challenges and remove barriers for the U.S. nuclear energy sector. With strategic investments in advanced nuclear technology and R&D capabilities to support both the existing fleet and advanced reactors, we can enable a thriving U.S. nuclear energy sector. We can develop a global market for U.S. nuclear technology, maintain U.S. technology leadership, and increase access to clean, carbon-free energy.

This Strategic Vision provides the framework for achieving these goals. The result will be a more prosperous and secure United States.

U.S. DEPARTMENT OF ENERGY

Office of NUCLEAR ENERGY