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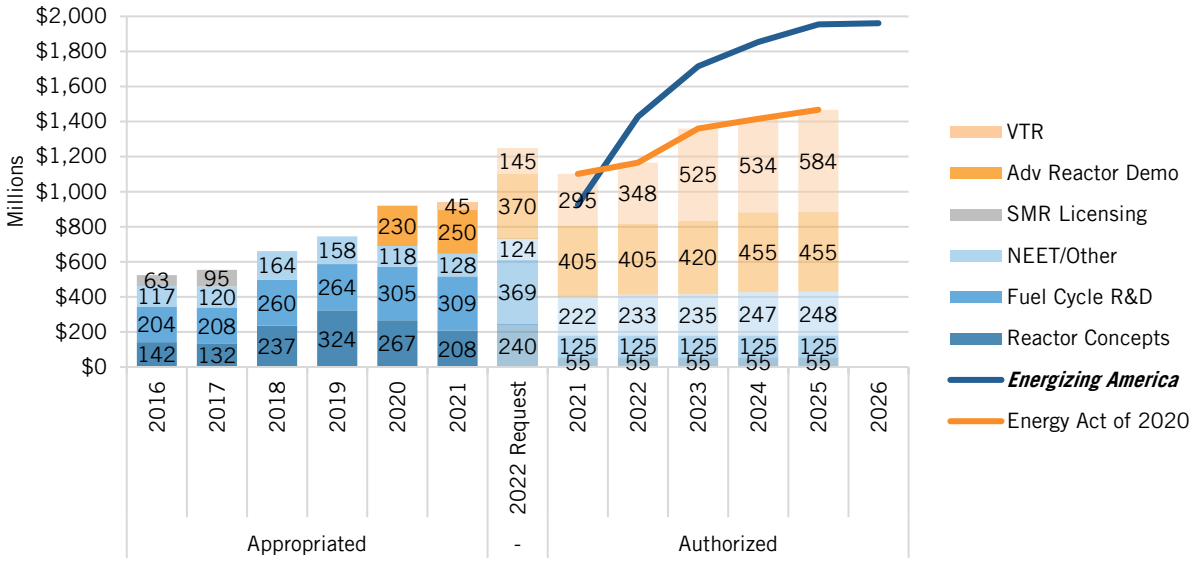
Federal Energy RD&D: Nuclear Energy

BY COLIN CUNLIFF AND LINH NGUYEN | JUNE 2021

Nuclear power accounts for 19 percent of the electricity generated in the United States, and 53 percent of all carbon-free electricity—more than hydropower, geothermal, wind, and solar combined.[1] Despite this success, the existing nuclear fleet is being challenged by low-cost natural gas and renewables, while at the same time Russia and China are outpacing the United States in the development of advanced next-generation nuclear reactors.[2] To address these challenges, the Department of Energy's (DOE) nuclear energy (NE) program conducts research, development, and demonstration (RD&D) on the technical challenges of maintaining the existing reactor fleet and pursues the development of a robust pipeline of advanced reactor designs and supply-chain capabilities.[3]

Figure 1: *Energizing America* recommends roughly doubling the funding for nuclear RD&D by FY 2026.[4]



What's at Stake

With 94 commercial reactors, the United States has the largest nuclear energy industry in the world. Yet, even though the United States took an early lead in this field in the 1950s and 1960s, its position has stagnated since then. Only two reactors have joined the fleet in the last 25 years. The rising costs of new nuclear plants combined with a wave of recent and planned retirements of existing plants has led some analysts to refer to nuclear power as "the vanishing low-carbon wedge."[5]

Technological innovation might address many of the challenges the current generation of nuclear power plants faces. DOE is exploring advanced, non-light-water-reactor designs that could operate at higher temperatures (allowing for greater efficiency and provision of other energy services, such as process heat for the chemicals industry), produce lower volumes of waste, incorporate passive safety features, and reduce proliferation risks. However, DOE has conducted research and development (R&D) in advanced reactors since the late 1990s, and so far, no advanced reactor concepts have progressed to full-scale demonstration, let alone commercialization.[6] A recent analysis of DOE's nuclear budget going back two decades to 1998

finds shifting priorities, inconsistent funding from Congress, and a focus on incumbent technologies have resulted in few advances. And even if the program had been well designed, federal investment has been insufficient to demonstrate a single non-light-water advanced reactor technology.[7]

Recent actions in Congress and DOE aim to jump-start innovation in advanced nuclear technologies. In 2016, DOE launched the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to help U.S. companies access experimental and computational capabilities at the national labs and other research facilities.[8] Congress passed the Nuclear Energy Innovation Capabilities Act (NEICA) in September 2018 to facilitate private-sector innovation in advanced reactor technologies. The Act authorized the National Reactor Innovation Center, which provides resources for testing, demonstration, and performance assessment to private sector technology developers.[9]

NEICA also authorized DOE to assess the need for a Versatile Test Reactor (VTR) user facility to enable testing in fast-neutron environments. Many advanced reactor designs are fast reactors that do not use a moderator to slow down neutrons. Development of these reactor concepts will require testing of materials and fuel designs in a fast-neutron environment; however, the United States currently has no fast-neutron research facilities that would enable developers to test their designs. In contrast, Russia has two operating commercial-scale fast reactors, and China launched a pilot-scale fast reactor for research and testing in 2011. The VTR would enable U.S. companies developing fast-reactor technologies to test them in domestic facilities rather than using the Bor-60 reactor in the Russian Federation.[10]

In FY 2019, the administration proposed a new R&D subprogram focused on advanced (non-light-water) Small Modular Reactors (SMRs), which Congress funded at $100 million.[11] And in the FY 2020 budget cycle, Congress established a new Advanced Reactor Demonstration Program to build and demonstrate two advanced reactor designs by the mid-2020s.[12] In October 2020, DOE funded its first awards to TerraPower LLC (Bellevue, WA) and X-energy (Rockville, MD) of $80 million each in initial funding to build two advanced reactors that are to be operational within seven years.[13] In December 2020, DOE selected five additional teams for "Risk Reduction for Future Demonstration" awards, which are intended to improve technology readiness and prepare those teams for future demonstrations in 10–14 years.[14]

The Energy Act of 2020 builds on the success of NEICA and provides the first reauthorization of DOE's Nuclear Energy program in over a decade. Notably, the act reauthorizes DOE's advanced reactor demonstration program, with $405 million for FY 2021, $405 million for FY 2022, $420 million for FY 2023, $455 million for FY 2024, and $455 million for FY 2025. It also authorizes $295 million for FY 2021, $348 million for FY 2022, $525 million for FY 2023, $534 million for FY 2024, and $584 million for FY 2025 for the VTR. The act reauthorizes reactor concepts RD&D, nuclear integrated energy systems RD&D, fuel cycle RD&D, nuclear integrated energy systems RD&D, and advanced reactor technologies R&D, and supports a radiological facilities management program and nuclear energy university program.[15]

Figure 1 shows historical DOE investment in nuclear energy RD&D by subprogram, for FY 2016 through FY 2021, the FY 2022 budget request. The orange line shows authorized funding levels from the Energy Act of 2020. The blue line shows recommended funding levels from the *Energizing America* report, which envisions a ramp-up in funding of 100 percent over the next five years (see box 1).

Box 1: An Innovation Agenda for Nuclear Energy

The *Energizing America* report coauthored by the Information Technology and Innovation Foundation (ITIF) and Columbia University's Center of Global Energy Policy offers several recommendations for DOE and Congress to drive nuclear energy innovation. Similarly, ITIF's 2018 report "An Innovation Agenda for Deep Decarbonization: Bridging Gaps in the Federal Energy RD&D Portfolio" makes recommendations to DOE and Congress to maximize the effectiveness of DOE's nuclear energy programs:

- Congress should follow through on its early support for the VTR, and commit to its construction to enable testing of materials and fuel designs in a fast-neutron environment, with a goal of making domestic fast-neutron testing capabilities available by 2026.[16]
- Congress should provide sufficient, stable multiyear funding for DOE to demonstrate at least two advanced reactor technologies by 2030.[17]
- DOE and the Department of Defense should partner to develop advanced microreactors. Fixed installations in remote areas are an ideal early market for stationary microreactors, which have the potential to supply reliable energy while reducing vulnerabilities associated with the fuel supply chain.[18]
- DOE should expand RD&D into other applications for nuclear energy, including desalination, industrial process heating, hydrogen and ammonia production, and other industrial applications.[19]

Nuclear Energy RD&D Subprograms

In FY 2021, NE has conducted RD&D in the following subprograms:[20]

- **Reactor Concepts RD&D** focuses on new and advanced reactor designs and technologies, including advanced SMRs, fast reactors using liquid-metal coolants, high-temperature reactors, and micro-reactor technologies.
- **Fuel Cycle R&D** studies advanced fuel-cycle technologies that have the potential to enhance safety, improve resource utilization, reduce waste generation, and limit risk of proliferation.
- **Nuclear Energy Enabling Technologies** works to develop cross-cutting technologies in reactor materials, advanced sensors and instrumentation, innovative manufacturing and construction technologies, advanced cooling concepts, and modeling and simulation—and provides support for nuclear science user facilities.
- **Advanced Reactor Demonstration** is a new subprogram established by Congress in FY 2020 to build and demonstrate two advanced reactor designs within the next five to seven years.

- **Supercritical Transformation Electric Power (STEP)** and other NE R&D (not shown in figure 1) include R&D on supercritical carbon dioxide Brayton-cycle technologies (which are potentially applicable to all steam electric generation), as well as nuclear-workforce training and education programs.

Key Elements of the FY 2022 Budget Proposal[21]

The budget proposal seeks $1,850.50 million for NE RD&D activities, a 23 percent boost from FY 2021 enacted levels. Some highlights include:

- **A 222 percent increase for VTR,** a user facility that will enable testing of materials and fuel designs common to many advanced, non-light-water-reactor designs.
- **A 48 percent increase for the Advanced Reactors Demonstration Program,** including increased funding for two advanced reactor demonstration projects; a $10 million increase in funding for risk reduction for future demonstrations; a $25 million increase for the National Reactor Innovation Center; and continued funding for regulatory development and advanced reactor safeguards research.
- **A 15 percent increase in Reactor Concepts R&D,** including advanced small modular reactor R&D; a $13 million increase for light-water reactor sustainability R&D; and a $19 million boost to advanced reactor technologies development.
- **A 19 percent increase in Fuel Cycle R&D,** including increased funding for accident-tolerant fuels, advanced nuclear fuels, material recovery and waste-form development, and used nuclear fuel disposition R&D, as well as the elimination of integrated waste management activities. Funding for TRISO fuel would remain unchanged.
- **A 1 percent increase in Nuclear Energy Enabling Technologies,** including a $19 million increase for crosscutting technology development; a $12 million increase for nuclear science user facilities; no change in funding for the joint modeling and simulation program; and discontinued funding for the Transformational Challenge Reactor program.
- **Elimination of the STEP and nuclear workforce development programs.**

Further Reading

- Varun Sivaram et al., *Energizing America: A Roadmap to Launch a National Energy Innovation Mission* (ITIF and Columbia University SIPA Center on Global Energy Policy, 2020), http://www2.itif.org/2020-energizing-america.pdf.
- Dorothy Robyn and Jeffrey Marqusee, "The Clean Energy Dividend: Military Investment in Energy Technology and What it Means for Civilian Energy Innovation" (ITIF, 2019), http://www2.itif.org/2019-clean-energy-dividend.pdf.
- Colin Cunliff, "An Innovation Agenda for Deep Decarbonization: Bridging Gaps in the Federal Energy RD&D Portfolio" (ITIF, 2018), http://www2.itif.org/2018-innovation-agenda-decarbonization.pdf.

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About the Authors

Colin Cunliff is a senior policy analyst for clean energy innovation with ITIF. He previously worked at the U.S. Department of Energy on energy sector resilience and emissions mitigation. He holds a Ph.D. in physics from the University of California, Davis.

Linh Nguyen is a research assistant for clean energy innovation with ITIF. She previously worked for Climate Advisers and Resource Energy. Linh holds a master's degree in energy policy from Johns Hopkins University.

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ENDNOTES

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