The Case for Continued Investment in the Advanced Reactor Demonstration Program

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Introduction

The United States needs a new generation of advanced nuclear reactors to help meet the growing need for clean and reliable energy for electricity as well as industrial heat and steam. Both the U.S. government and the private sector are investing billions of dollars to realize advanced nuclear energy's potential.

One key piece of the public and private investment portfolio is the U.S. Department of Energy (DOE) Advanced Reactor Demonstration Program (ARDP). Authorized under the bipartisan Energy Act of 2020, the ARDP competitively awarded cooperative agreements to multiple projects at various stages of technology development.[1] The ARDP projects have varying levels of cost-share between private companies and the federal government, multiplying the effect of taxpayer investment in advanced nuclear energy.

The two flagship ARDP projects are the X-Energy and TerraPower commercial-scale demonstrations. DOE competitively awarded these two companies financial support at a 50-50 public-private cost share to complete design and engineering activities, create critical component and fuel supply chains, and construct their first commercial demonstration projects.

Congress has provided both one-time and annual appropriations to fund the program. The bipartisan Infrastructure Investment and Jobs Act (IIJA) Infrastructure Law provided $2.47 billion for the two flagship ARDP projects and the projects have received $500 million in additional support through the annual appropriations process. All federal funding is matched one-for-one with private sector funding, highly leveraging taxpayers' investment.

Building a first-of-a-kind advanced nuclear reactor not only requires new reactor designs and analysis methods, but also supply chains for new components and infrastructure to produce novel nuclear fuels. Due to inflation in costs for all energy development[2,3,4] and the challenges of preliminary cost estimation for large projects, the total expected cost for these projects is increasing. Additional private investment and federal funding will be required to successfully complete the two demonstration reactors. As Congress and the private sector consider additional funding and investment, it is important to remember the case for ARDP and recognize the progress made thus far.

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[1] https://www.energy.gov/ne/articles/energy-departments-advanced-reactor-demonstration-program-awards-20-million-advanced

[2] https://www.reuters.com/sustainability/climate-energy/us-offshore-wind-projects-facing-inflation-headwinds-2023-09-11/

[3] https://www.fastcompany.com/91069902/inflation-high-interest-rates-renewable-energy-projects

[4] https://neutronbytes.com/2023/01/24/nuscales-smr-costs-hit-hard-by-inflation/

Providing new commercial use cases for advanced nuclear energy

TerraPower is building a 345-megawatt reactor called Natrium near a retiring coal plant site in Kemmerer, Wyoming. As the first coal-to-nuclear project in the world, it is a potential model for the hundreds of sites in the United States and other countries where coal plants are retiring and coal communities need new economic development. The Natrium reactor also incorporates a novel integrated molten salt thermal energy-storage system. This feature allows the reactor to run at a constant power output and provide energy to the storage system, which can then provide varying electricity generation to the grid as needed. Thus the reactor can maximize power generation while still providing flexible power output to match changing energy demand and renewable energy generation. This type of plant flexibility is a critical innovation that enables advanced nuclear energy to more efficiently complement variable renewable generation while still ensuring electrical grid reliability.

X-energy is partnering with Dow Chemical Company to build four Xe-100 reactors to provide steam and electric power to Dow's chemical production plant in Seadrift, Texas. The four reactors will be able to supply 100 percent of the site's steam and electricity needs, and provide the highly reliable energy services required by major industrial facilities. Unlike existing nuclear reactors, many advanced nuclear reactors (including the Xe-100) can produce the high-temperature heat and high-quality steam needed by many industrial processes. Industrial energy consumption accounts for roughly one third of U.S. emissions, and is expected to be the largest emitting sector by 2035. Many energy-intensive industrial processes including seawater desalination, chemical production, and hydrogen generation could be efficiently decarbonized using advanced nuclear energy. Demonstrating the role advanced nuclear energy can play at a complex chemical facility is a game changer for the traditionally "hard-to-decarbonize" industrial sector with its wide variety of sources.

Substantial progress has been made to date on both ARDP demonstration projects. TerraPower submitted its construction application for the Natrium project to the U.S. Nuclear Regulatory Commission (NRC) on March 29, 2024[5] and broke ground on June 10.[6] X-energy and Dow are working to complete the reactor design before construction begins and seeking to submit a construction permit application later this year.

[5] https://www.usnic.org/news/usnic-key-mover-update-terrapower-submits-construction-permit-application-to-the-u-s-nuclear-regulatory-commission-for-the-natriumtm-reactor-demonstration-project
6 https://terrapower.com/downloads/grounbreaking-press-release.pdf

Creating benefits for other advanced nuclear energy projects

Both ARDP demonstration projects will have major spillover benefits for future advanced nuclear energy development. They are helping to restart the supply chain for nuclear reactor fuels, services and components; pave the way for risk-informed and performance-based licensing of advanced nuclear reactors and fuel facilities at the NRC; and increase overall investment in new advanced nuclear energy technology.

Funding the ARDP demonstration projects has been vital in catalyzing the construction and operation of new infrastructure that can produce the novel nuclear fuels required for advanced nuclear reactors. The fuels produced by these new fuel facilities can be used not only to supply the first-of-a-kind demonstration reactor, but also to supply subsequent commercial units or other similar advanced reactor designs.

X-energy is working to construct the first new nuclear fuel facility in over 30 years in Oak Ridge, Tennessee. The Xe-100 reactor uses TRistructural ISOtropic (TRISO) fuel particles made up of poppy seed sized "kernels" of uranium encapsulated in layers of carbon. These particles are then fabricated into billiard ball-sized spheres called "pebbles" that can withstand extreme temperatures, reducing the likelihood of reactor meltdowns and preventing the release of fission projects during accidents. X-energy has been operating a pilot TRISO fuel facility at Oak Ridge National Laboratory since 2018. Based on that pilot, X-energy submitted their application to NRC to manufacture TRISO fuel in 2022 and aims to become the first-ever Category II-license fuel facility. It is now about half-way through the licensing process and expects to begin producing fuel in 2026-2027. X-energy's fuel fabrication facility helps pave the way for efficient NRC licensing of other new nuclear fuel facilities and could supply other advanced reactor developers that use TRISO fuels.

TerraPower is partnering with both Framatome and GE Hitachi on new advanced metal nuclear fuels. TerraPower's Natrium reactor will use metallic nuclear fuel, which is extremely resilient for a wide variety of plant operating conditions, and enables future implementation of innovative nuclear fuel cycles. Creating metallic fuels, however, requires development and commercialization of new fuel production and manufacturing processes. TerraPower is first partnering with Framatome to create a pilot process line for a novel uranium metallization process uranium at the existing Framatome nuclear fuel manufacturing facility in Richland, Washington. TerraPower is also partnering with GE-Hitachi to build their Natrium Fuel Facility in Wilmington, North Carolina to produce reactor fuel, with facility construction to begin in 2025. TerraPower is demonstrating the benefits of partnering with existing fuel companies to accelerate the delivery of new nuclear fuels and help commercialize metallic fuel technology needed for multiple advanced reactor developers.

While a significant focus has been on the major two demonstrations, the ARDP is providing federal assistance to many other developers, specifically those who are part of ARDP's Risk Reduction program. To date, all of these Risk Reduction awardees have garnered significant interest in their technologies.[7] This approach of taking multiple "shots on goal" is helping set up a more diverse advanced reactor portfolio that has a greater chance of unlocking the full suite of benefits that various advanced reactor technologies have to offer.

The largest Risk Reduction awardee, Kairos Power, received their construction permit from the NRC for their Hermes test reactor in December 2023.[8] Holtec is seeking to build its reactor technology at the existing Palisades nuclear plant in Michigan, Southern Company has brought online the largest molten salt test loop in the world, and interest in microreactors like BWXT and Westinghouse's technologies is growing among major industrial companies --- a completely new market. The entire advanced nuclear energy public-private investment portfolio is catalyzing innovation, accelerating U.S. leadership in advanced nuclear energy, and helping create the conditions for success for advanced nuclear energy to be a key climate and energy solution.

Accelerating U.S. NRC licensing of advanced nuclear reactors

Until it develops new rules better tailored to advanced reactors, NRC must use the existing licensing process optimized for large light water reactors to regulate advanced nuclear technology. ARDP awardees have effectively engaged with the NRC and helped catalyze discussions on important licensing topics for advanced reactors including on the use of more risk-informed, performance-based, and technology-inclusive licensing processes under existing regulation and NRC staff expectations for the content of applications for construction permits for advanced reactors. These projects have helped the NRC refocus and prioritize advanced reactor licensing activities. Kairos Power has received a construction permit for its test reactor, TerraPower has submitted its construction permit application, and X-energy's construction permit application is expected by the end of 2024. NRC staff experience reviewing these applications pave the way to effective, efficient, and predictable licensing of future advanced nuclear energy projects.

[7] Risk Reduction Awardees include: Kairos Power, Westinghouse, BWXT, Holtec, Southern Company, AR-20 awardees include: General Atomics, Advanced Reactor Concepts, and Massachusetts Institute of Technology. https://www.energy.gov/ne/articles/energy-departments-advanced-reactor-demonstration-program-awards-30-million-initial

[8] https://kairospower.com/external_updates/nuclear-regulatory-commission-approves-construction-permit-for-hermes-demonstration-reactor/

Attracting private capital

ARDP demonstration projects are attracting private investment to the advanced nuclear energy sector, further leveraging the public investment. In 2022, TerraPower concluded an equity raise of $830 million, the largest private raise among advanced nuclear companies. The fundraise was co-led by SK Inc. and SK Innovation and TerraPower's founder, Bill Gates. Additional investors include ArcelorMittal, the world's leading steel company, through its XCarb Innovation Fund, and Korea Shipbuilding and Offshore Engineering, the intermediate holding company of Hyundai Heavy Industries Group's shipbuilding sector. X-energy has also raised several hundred million dollars through their Series C capital raise to date from private investors including Dow, Ares Corporation, Ontario Power Generation, Curtiss-Wright Corporation, DL E&C, and Doosan Enerbility. The federal commitment to ARDP has encouraged private financing, which in turn has increased investor confidence in the commercial viability of advanced nuclear energy technology and will lead to even greater private investment.

Creating high quality jobs both locally and nationally

Perhaps most importantly, these ARDP reactor projects and fuel facilities are creating high-quality jobs. Nuclear projects are decades-long investments that provide high-quality jobs not just at a single site, but across the entire nuclear supply chain.

X-energy estimates it will take about 1200 workers to support the Dow reactor project's construction. The operational facility will employ approximately 200 workers continuously throughout the 60-year life of the plant. Building the new nuclear fuel facility at Oak Ridge will create approximately 500 jobs during construction, and operating it will create about 400 permanent jobs. X-energy expects similar jobs benefits at their subsequent Xe-100 projects. Their second commercial customer is Energy Northwest in Richland, Washington. X-energy has begun discussions with local unions there about workforce and skills needed for plant construction and operation. X-energy hopes that the project will demonstrate how to effectively leverage the considerable nuclear experience and workforce around existing DOE sites.

TerraPower estimates that around 1600 workers will be needed for Natrium's construction at the project's peak. Once the plant is operational, around 250 workers will support day-to-day activities, including plant security. Those 250 jobs will remain in the community for many decades to come. TerraPower's North Carolina fuel facility will support up to 100 new permanent jobs. The long-term operational jobs created by both X-energy and TerraPower are multi-generational employment opportunities. TerraPower's Natrium reactor in Kemmerer, Wyoming, will be built and staffed by union labor, demonstrating how to effectively partner with unions on new projects and leverage the existing workforce at retiring coal power plants to help transition communities to clean energy.

Conclusion

Existing reactors are economic workhorses for their communities and produce clean, reliable and affordable electricity for decades. The ARDP projects will provide similar economic and energy benefits while demonstrating new technologies that open new markets and pave the way for advanced nuclear energy to succeed.

The ARDP is a big bet, by both the federal government and private companies seeking to develop and deploy advanced nuclear energy. Federal funding of the ARDP is catalyzing billions of dollars in private investment in innovative nuclear technologies and creating a pathway for commercialization of new advanced nuclear reactors. These projects demonstrate the commercial uses of nuclear energy beyond simple firm electricity generation, while catalyzing new nuclear fuel infrastructure and regulatory innovation that support the commercialization and deployment of other advanced nuclear technologies. Maintaining momentum on advanced nuclear energy development through ARDP will allow U.S. companies to regain global leadership in advanced nuclear energy and move the world forward on the commercialization and deployment of advanced nuclear reactors as a climate and energy solution.