



September 2022

NUCLEAR ENERGY PROJECTS DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types

Accessible Version

Why GAO Did This Study

In 2021, nuclear energy accounted for almost 20 percent of the nation's electricity generation and provided about 50 percent of the carbon-free electricity. However, economic challenges have led to the closure or planned shutdown of multiple nuclear power plants. To address these challenges, DOE has made awards to projects that demonstrate first-of-a-kind small modular and advanced reactors. These are either smaller than existing reactors or use technologies expected to offer improvements over the most recent generation of nuclear reactors. According to DOE, the federal government has a unique role to play in reducing the financial and technical risks faced by companies seeking to develop these technologies.

GAO was asked to review DOE's management of nuclear energy demonstration awards. This report (1) describes awards DOE has made to support the demonstration of small modular and advanced reactors; and (2) examines actions DOE is taking to manage risks associated with awards.

To do this work, GAO assessed DOE's management of the awards against laws, regulations, guidance, and leading project management practices. GAO also interviewed DOE program and project management officials, awardees, and industry stakeholders.

What GAO Recommends

GAO is recommending that DOE institutionalize via documentation its processes for providing oversight for large nuclear energy demonstration projects, including the use of external independent reviews. DOE agreed with GAO's recommendation.

View [GAO-22-105394](#). For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

NUCLEAR ENERGY PROJECTS

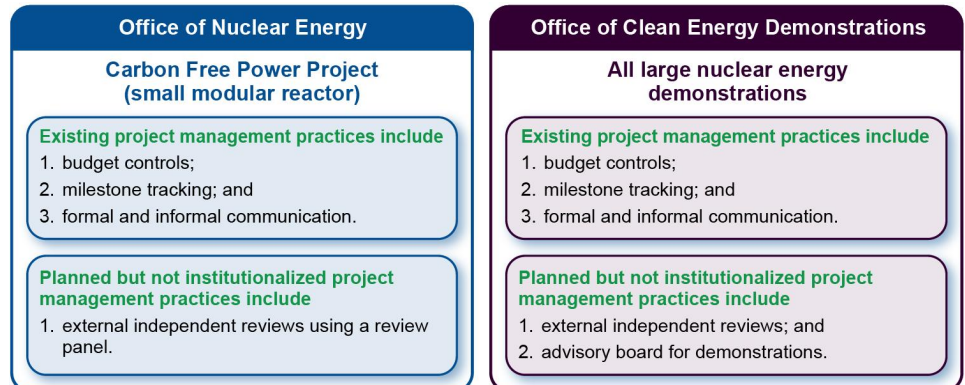
DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types

What GAO Found

The Department of Energy (DOE) supports the research, development, and demonstration of new types of nuclear reactors. In line with that role, in fiscal year 2021, the department made three multi-year awards totaling \$4.6 billion to support the demonstration of one small modular reactor and two advanced reactors. DOE awarded the Carbon Free Power Project about \$1.4 billion for a small modular reactor plant near Idaho Falls, Idaho. Under the Advanced Reactor Demonstration Program, DOE awarded TerraPower almost \$2 billion for the Natrium™ Demonstration in Wyoming and awarded X-energy about \$1.2 billion for the Xe-100 Demonstration in Washington State.

DOE has taken several actions to manage risks associated with the three demonstration awards, including using project management practices such as budget controls and milestone tracking. The two DOE offices managing the awards—the Offices of Nuclear Energy and Clean Energy Demonstrations—also plan to use additional project management practices, such as external independent reviews, to oversee the awards (see fig.). Office of Clean Energy Demonstrations officials said these additional project management practices will apply to all large DOE energy demonstration awards, regardless of which DOE offices are managing those awards. However, neither office has institutionalized its plans by documenting these additional project management practices. Documenting these processes, including the use of external independent reviews, would allow DOE to share best practices across offices during the course of these multi-year awards, potentially resulting in stronger federal oversight of the projects and improved project performance.

Existing and Planned Project Oversight Processes for Nuclear Energy Demonstration Awards, as of June 2022



Sources: Department of Energy documents, and interviews with agency officials. | GAO-22-105394

Contents

GAO Highlight		ii
	Why GAO Did This Study	ii
	What GAO Recommends	ii
	What GAO Found	ii
Letter		1
	Background	4
	DOE Has Made Three Awards Totaling \$4.6 Billion to Support the Demonstration of Small Modular and Advanced Reactors	8
	DOE Has Taken Several Actions to Manage Risks but Has Not Fully Institutionalized Oversight Plans for Its Nuclear Energy Demonstration Awards	15
	Conclusions	21
	Recommendation for Executive Action	21
	Agency Comments	21
Appendix I: Department of Energy (DOE) Support for NuScale, X-energy, and TerraPower		23
Appendix II: Department of Energy (DOE) Management of Awards Compared with Selected Financial Assistance Requirements		25
Appendix V: GAO Contact and Staff Acknowledgments		27
	GAO Contact	27
	Staff Acknowledgments	27
Tables		
	Table 1: Summary of Small Modular and Advanced Reactor Demonstration Program Awards	10
	Table 3: Department of Energy (DOE) Financial Assistance to Selected Companies for Small Modular and Advanced Reactor Technologies	23
	Table 2: Comparison of the Department of Energy's (DOE) Management of Three Small Modular and Advanced Reactor Demonstration Awards with Selected Financial Assistance Requirements	25
Figures		
	Figure 1: Traditional Reactors and New Reactor Types	5

Figure 2: Department of Energy Nuclear Energy Demonstration Award Characteristics	12
Figure 3: Key project milestones for the Carbon Free Power Project, Natrium™ Demonstration, and Xe-100 Demonstration, 2020-2030	14
Figure 4: Existing and Planned Project Oversight Processes for Department of Energy (DOE) Nuclear Energy Demonstration Awards, as of June 2022	20

Abbreviations

ARDP	Advanced Reactor Demonstration Program
DOE	Department of Energy
HALEU	High-Assay Low-Enriched Uranium
NRC	Nuclear Regulatory Commission

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September 8, 2022

The Honorable Diane Feinstein
Chair
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Eddie Bernice Johnson
Chairwoman
Committee on Science, Space, and Technology
House of Representatives

In 2021, nuclear energy accounted for almost 20 percent of the electricity generated in the United States and provided about 50 percent of the nation's carbon-free electricity. However, the existing commercial reactor fleet is aging, and economic challenges have led to the closure or planned shutdown of multiple nuclear power plants. To address these challenges, the Department of Energy (DOE) supports the research, development, demonstration, and deployment of new nuclear reactor types. These include small modular reactors, which are smaller than existing commercial reactors, and advanced reactors, which are expected to offer significant improvements over the most recent generation of nuclear reactors. According to DOE, the federal government has a unique role to play in reducing the financial and technical risks faced by companies seeking to develop these new, first-of-a-kind technologies.

In fiscal year 2021, DOE made awards to three multi-billion dollar projects to support the demonstration of first-of-a-kind small modular and advanced reactors.¹ First, DOE approved an award to the Carbon Free Power Project to help demonstrate and deploy a small modular reactor power plant. Second, DOE, through its Advanced Reactor Demonstration Program (ARDP), approved two awards to build power plants using

¹DOE made these awards subject to cost-share arrangements under which DOE would provide up to 50 percent of project costs, and the award recipient would pay the rest.

advanced reactors to be completed within 7 years of the issuance of the awards.²

In light of past and potential future federal government investments in nuclear technologies and the inherent risks associated with developing first-of-a-kind technologies, GAO was asked to review DOE's management of its three nuclear energy demonstration awards. This report (1) describes the awards DOE made to support the demonstration of small modular and advanced nuclear reactors and (2) examines actions DOE is taking to manage risks associated with these awards.

To address the first objective, we summarized award information by reviewing and analyzing award data from DOE, including award amounts, years, funding sources, and cost-share structures. We conducted a data reliability assessment for the award data collected—including by interviewing relevant agency officials and checking award data with available public information—and determined the data to be sufficiently reliable for our purposes. To describe how the awards contributed to DOE's nuclear energy goals, we reviewed the Office of Nuclear Energy's Strategic Vision document and award documentation and interviewed agency officials.

To address the second objective, we identified leading practices in managing risks of these types of awards by reviewing prior GAO reports on DOE management of demonstration projects,³ best practices from GAO's *Cost Estimating and Assessment Guide*,⁴ and GAO's *Standards for Internal Control in the Federal Government*.⁵ We also interviewed officials knowledgeable about DOE's project management practices, including officials from DOE's Office of Project Management, Office of

²The Carbon Free Power Project award was made in October 2020. The ARDP awards were announced in October 2020, but actual awards did not occur until February 2021 and May 2021.

³See GAO, *Carbon Capture and Storage: Actions Needed to Improve DOE Management of Demonstration Projects*, [GAO-22-105111](#) (Washington, D.C.: December 2021); and *Department of Energy: Consistent Application of Requirements Needed to Improve Project Management*, [GAO-07-518](#) (Washington, D.C.: May 2007).

⁴GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs*, [GAO-20-195G](#) (Washington, D.C.: March 2020).

⁵GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: September 2014).

Science, and Loan Programs Office. We then assessed DOE's management of these awards against relevant leading practices.

We also reviewed relevant laws, regulations, and agency guidance regarding financial assistance awards and identified selected requirements that we determined will likely have a significant impact on the supported projects' goals and operations or financial risks to the federal government.⁶ We then assessed DOE's management of the awards against the selected requirements.

Further, we interviewed officials from DOE's Office of Nuclear Energy and Office of Clean Energy Demonstrations, which oversee the three demonstration projects, and the Nuclear Regulatory Commission (NRC) regarding DOE's management of these projects.⁷ In addition, we interviewed representatives from the three awardees. We also interviewed stakeholders from a company that had received prior DOE support for the technology being demonstrated in one of the projects, another company that received an award for a different advanced reactor technology, and a nuclear industry trade organization. We identified these stakeholders using a "snowball sampling" technique. We then selected a subset of these groups to interview based on their knowledge of DOE's management of small modular and advanced reactor demonstrations.⁸ Views from the selected stakeholders cannot be generalized.

We conducted this performance audit from September 2021 to September 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We

⁶In this report, we define "requirements" as both legal requirements and other criteria in DOE guidance, specifically the department's *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020).

⁷NRC is the federal agency that regulates commercial nuclear power plants and other commercial uses of nuclear materials through licensing, inspection, and enforcement of its requirements.

⁸In snowball sampling, the methodology begins with an initial list of contacts and asks each person interviewed to refer the interviewer to additional cognizant persons. The group of referred contacts (or "snowball") grows larger and then narrows as a group of individuals are identified frequently.

believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

New Nuclear Reactor Types

Existing light water nuclear reactors are generally large and expensive to build.⁹ New nuclear reactor types include light water designs that are far smaller than existing reactors, with fewer parts, systems, and components. They also include advanced reactor types with similar simplicity in design that use different moderators, coolants, or types of fuel. Small modular reactors are those that generate 300 megawatts of electricity or less—compared with existing commercial reactors that have an average generating capacity of over 1,000 megawatts of electricity—and average about 1/10 to one-quarter the size of a traditional nuclear reactor.¹⁰ Advanced reactors are defined as nuclear reactors with significant improvement over the most recent generation of nuclear reactors, such as improved efficiency or simpler reactor design. Most non-light water advanced reactors will rely on the use of high-assay low-enriched uranium (HALEU) fuel.¹¹ Currently, no small modular or

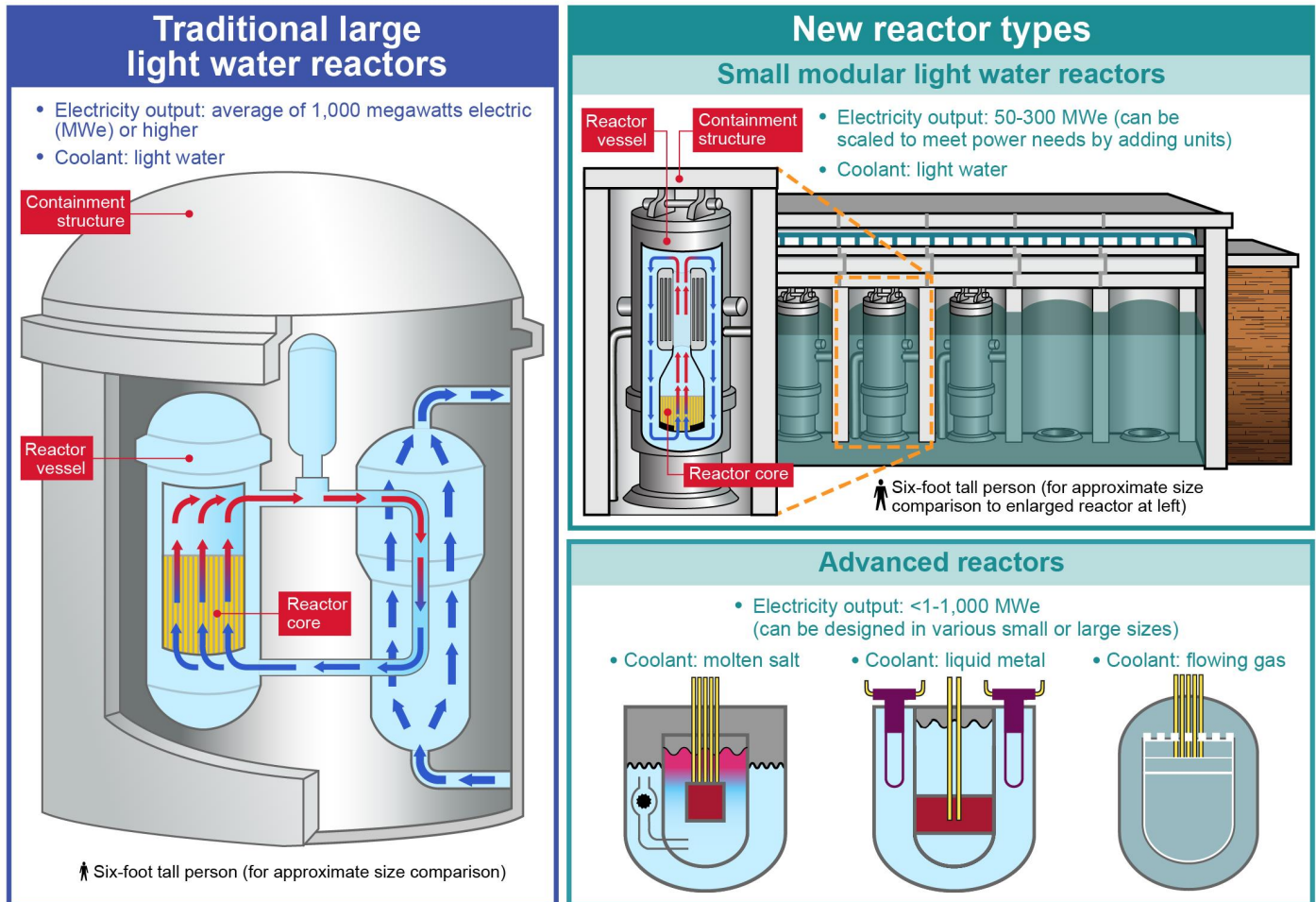
⁹The nuclear reactors currently operational in the United States are referred to as “light water reactors,” meaning reactors that use light water (ordinary water) to cool and moderate the reactor, as opposed to heavy water, which contains deuterium, an isotope of hydrogen.

¹⁰A small modular reactor is a nuclear fission reactor that features factory-built-and-assembled modules in a variety of configurations and electricity outputs. Small modular reactors are envisioned to vary in size according to configuration. Modular designs make it possible to assemble major reactor components in a factory and add reactor modules, as needed. Small modular reactors can be designed for power generation or to process heat for desalination, or for other industrial applications. Designers of small modular reactors plan to decrease the overall cost and time for reactor construction, compared with existing large light water reactors, without significantly increasing ongoing operational costs. See GAO, *Technology Assessment: Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts*, [GAO-15-652](#) (Washington, D.C.: July 2015).

¹¹Existing nuclear power plants in the United States generally use low-enriched uranium fuel, enriched up to around 3 percent to 5 percent of the uranium-235 isotope. HALEU is uranium fuel that is enriched to higher levels, up to 20 percent uranium-235. Most of the advanced reactors under development in the United States will use HALEU to enable them to achieve more compact designs, longer operating cycles, and higher efficiencies than previous reactor designs, but HALEU is not currently available at commercial scale from domestic suppliers.

advanced reactors are operational in the United States. See figure 1 for a comparison of traditional reactors and new reactor types.

Figure 1: Traditional Reactors and New Reactor Types



Sources: GAO illustration, using materials from Nuclear Regulatory Commission (traditional large reactors); NuScale Power (small modular reactors); and Department of Energy Office of Nuclear Energy (advanced reactors). Nuscale image © 2007 or later by NuScale Power, LLC. All rights reserved. | GAO-22-105394

As we have previously reported, DOE officials and reactor designers expect advanced reactors to operate at higher temperatures and, therefore, to generate electricity more efficiently.¹² In addition, the relatively high temperatures of advanced reactors could supply process heat, which is heat used for industrial processes such as in desalination

¹²GAO-15-652.

operations, oil refineries, chemical plants, and the production of hydrogen. This could expand nuclear energy's role in the energy sector beyond just electricity production by providing an alternative for industrial processes currently using fossil fuels to supply their process heat. These alternative applications could also provide additional revenue streams that could help improve the overall economics of the reactors, according to DOE. Further, some advanced reactors may also allow for improved spent nuclear fuel recycling and management. For example, some advanced reactors are designed to use reprocessed spent fuel from other nuclear reactors as fuel and, therefore, may reduce the need for long-term spent fuel disposal.

DOE Support for New Nuclear Reactor Types

Two DOE offices oversee nuclear demonstration projects:

- The Office of Nuclear Energy's mission is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. In particular, the office supports technologies, including first-of-a-kind nuclear reactors, that otherwise could be too costly or large scale for the private sector or other non-government stakeholders. Its support can also accelerate development of technologies that the private sector was already funding. The Office of Nuclear Energy made the three fiscal year 2021 awards for the demonstration of small modular and advanced reactor projects.
- The Office of Clean Energy Demonstrations' mission is to deliver clean energy demonstration projects at scale in partnership with the private sector to launch or accelerate market adoption and deployment of technologies, as part of an equitable transition to a decarbonized energy system. The office was established in November 2021 under the Infrastructure Investment and Jobs Act, which requires the Office of Clean Energy Demonstrations to manage the two ARDP awards but not the Carbon Free Power Project.¹³

According to DOE, the department generally uses competitive funding opportunity announcements for federal financial assistance to solicit applications for early-stage nuclear research, development, and demonstration projects. In particular, DOE seeks applicants who will (1) enhance the long-term viability and competitiveness of the existing U.S. reactor fleet, (2) develop an advanced reactor pipeline, or (3) implement and maintain the national strategic fuel cycle and supply chain

¹³Infrastructure Investment and Jobs Act, Pub. L. No. 117-58, 135 Stat. 429 (2021).

infrastructure. Each year, DOE sets priorities for advancing nuclear power based, in part, on the amount of funding appropriated by Congress, as well as any direction that Congress may have specified for certain types of technology research and development, and DOE's own research and development plans. For example, DOE is currently soliciting proposals for projects to develop innovative industry-driven reactor designs and technologies to advance nuclear power in the United States.

DOE may award financial assistance on a noncompetitive basis only if the application satisfies certain criteria in the department's financial assistance regulations. For example, a noncompetitive award can be made if the activity to be funded is necessary to the satisfactory completion of, or is a continuation or renewal of, an activity presently being funded by DOE or another federal agency, and for which competition for support would have a significant adverse effect on continuity or completion of the activity.¹⁴ Noncompetitive awards also undergo merit review.

Both competitively and non-competitively awarded projects typically require multiple years to complete and involve cost share agreements between DOE and the awardee. Cost shares are calculated as a percentage of total project costs shared between DOE and industry partners in which DOE will fund a portion of a demonstration award. The Energy Policy Act of 2005, as amended, generally requires a non-federal cost share of not less than 50 percent for demonstration and commercial application activities.¹⁵ DOE officials and the awardee agree on technical milestones for each phase of a project—project definition or preliminary design, design, construction, and operations—to help ensure that projects accomplish an objective or set of objectives.¹⁶

Developing first-of-a-kind nuclear technologies comes with technological, cost, and schedule risks. To manage risks inherent to these types of projects and to guide project management, DOE uses its *Guide to Financial Assistance*, which compiles DOE regulations for managing financial assistance awards with guidance for implementing those

¹⁴2 C.F.R. § 910.126(c).

¹⁵The Secretary of Energy may reduce the non-federal cost share upon determining that the reduction is necessary and appropriate, taking into consideration any technological risk relating to the activity.

¹⁶These agreements are known as "cooperative agreements."

regulations.¹⁷ The guide states that, while DOE's project management order does not apply to financial assistance like these three cost-share awards, the basic principles in that order can be applied.¹⁸ One such principle is the identification and management of project risks.¹⁹ Several offices within DOE—including the Office of Project Management, the Office of Science, and the Loan Programs Office—described to us how external independent reviews and other project management practices outlined in DOE's project management order might be useful for managing risks for large demonstration awards.²⁰

DOE Has Made Three Awards Totaling \$4.6 Billion to Support the Demonstration of Small Modular and Advanced Reactors

DOE has made three awards totaling \$4.6 billion to support the demonstration of one small modular reactor—the Carbon Free Power Project—and two advanced reactors, through the ARDP awards.²¹ The Carbon Free Power Project and the two ARDP awards were different from each other in three ways: the competitive award process, award

¹⁷Department of Energy, *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020); see also 2 C.F.R. pts. 200 and 910.

¹⁸Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: Nov. 29, 2010). All DOE offices, including the Office of Nuclear Energy and the Office of Clean Energy Demonstrations, are to use DOE's project management order to manage capital asset projects.

¹⁹DOE's project management order defines risks as factors, elements, constraints, or courses of action that introduce an uncertainty of outcome, either positively or negatively, that could impact project objectives. Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*. A risk with negative consequences is referred to as a "threat," and a risk with positive consequences is considered an "opportunity."

²⁰DOE's Office of Project Management serves as DOE's Enterprise Project Management Organization and conducts independent reviews of DOE capital projects, the Office of Project Assessment conducts independent reviews of Office of Science construction projects, and the Loan Programs Office is DOE's financier of large-scale energy infrastructure projects. DOE officials told us that they define large demonstration awards as those with a federal cost share of \$100 million or more.

²¹DOE has also supported earlier phases of project design and development for these technologies over the last 8 years. See app. I for more information and a table summarizing this financial support.

term, and cost-share structure. These three projects support two of DOE's nuclear energy goals: (1) to enable the deployment of advanced nuclear reactors and (2) to maintain U.S. leadership in nuclear energy technology.

DOE Has Made Awards for Three Nuclear Demonstration Projects

DOE has made three awards totaling \$4.6 billion to support the demonstration of one small modular reactor and two advanced reactor demonstration projects. Specifically, DOE awarded the Carbon Free Power Project about \$1.4 billion over 10 years to demonstrate the NuScale small modular reactor technology near Idaho Falls, Idaho.²² The Carbon Free Power Project expects to complete construction in August 2029 and begin delivering power by December 2029. Under the competitive ARDP Funding Opportunity Announcement, DOE awarded TerraPower about \$2 billion to complete the Natrium™ Demonstration in Wyoming by 2028²³ and awarded X-energy about \$1.2 billion to complete the Xe-100 Demonstration in Washington State by 2027.²⁴ All three awards use a cost-share structure, meaning the awardee contributes

²²The Carbon Free Power Project is an entity wholly owned by Utah Associated Municipal Power Systems. According to its website, the Utah Associated Municipal Power Systems is a political subdivision of the state of Utah that provides comprehensive wholesale electric energy, transmission, and other energy services, on a nonprofit basis, to community-owned power systems throughout the Intermountain West. Its members are located in Utah, California, Idaho, Nevada, New Mexico, Oregon, and Wyoming. The Carbon Free Power Project plans to construct a small modular reactor power plant on DOE's 890-square-mile Idaho National Laboratory Site, using a small modular reactor technology developed by NuScale Power. The proposed small modular reactor plant design is available in several configurations and would feature 60- to 77-megawatt modules.

²³TerraPower's Natrium™ Demonstration reactor is a sodium fast reactor combined with a molten salt energy storage system that is designed to produce around 345 megawatts of electric power. The thermal storage has the potential to boost the system's output to 500 megawatts of power for more than 5-1/2 hours, when needed, according to TerraPower, which could allow for changes to daily electric load and the ability to scale electricity generation based on needs driven by renewable energy fluctuations.

²⁴X-energy's Xe-100 is an advanced small modular reactor with each unit designed to produce around 76 megawatts of electric power. The reactor core is made of graphite and filled with 15.5 percent uranium-enriched fuel pebbles. Each pebble (roughly the size of a billiard ball) contains thousands of coated tristructural isotropic uranium fuel particles. The coating creates an airtight seal around the uranium kernel.

funds alongside the federal funding. See table 1 for a summary of these three awards.

Table 1: Summary of Small Modular and Advanced Reactor Demonstration Program Awards

Project	Years of award	DOE funding (in billions)	Awardee cost-share (in billions)	DOE cost-share
Carbon Free Power Project	2020-2030	\$1.355	\$4.645	23%
Terra Power Natrium TM Demonstration	2021-2028	\$1.979	\$2.017	50%
X-energy Xe-100 Demonstration	2021-2027	\$1.232	\$1.232	50%

Source: The Department of Energy (DOE) Office of Nuclear Energy | GAO-22-105394

Note: The Carbon Free Power Project award was made in October 2020, and the Advanced Reactor Demonstration Program awards were announced in October 2020, as well. However, the actual awards to X-Energy and TerraPower did not occur until February 2021 and May 2021, respectively. TerraPower was to cover 60 percent of project costs during the first year of the award, and DOE was to cover the remaining 40 percent. For the remainder of the award term, TerraPower and DOE are to cover 50 percent of project costs.

The three awards differ across three characteristics: competition, award term, and cost-share structure.

- Competition.** The Carbon Free Power Project was awarded non-competitively. The ARDP awards were awarded competitively under the ARDP Funding Opportunity Announcement. According to the Carbon Free Power Project award documentation, justifications for a non-competitive award included NuScale’s position at the forefront of reactor development and that, at the time of the award, the Carbon Free Power Project was the only project on path to deploy a first-of-a-kind NuScale small modular reactor. Award documentation also notes that the funding was necessary to assure the satisfactory continuation and completion of activities that were already being funded by DOE.²⁵ In addition, only two other entities initially expressed interest in domestically deploying a NuScale small modular reactor within the same time frame as the Carbon Free Power Project. According to the award documentation, one of these entities was not interested in deploying a first-of-a-kind technology, and the other was not interested in a cost-share agreement.

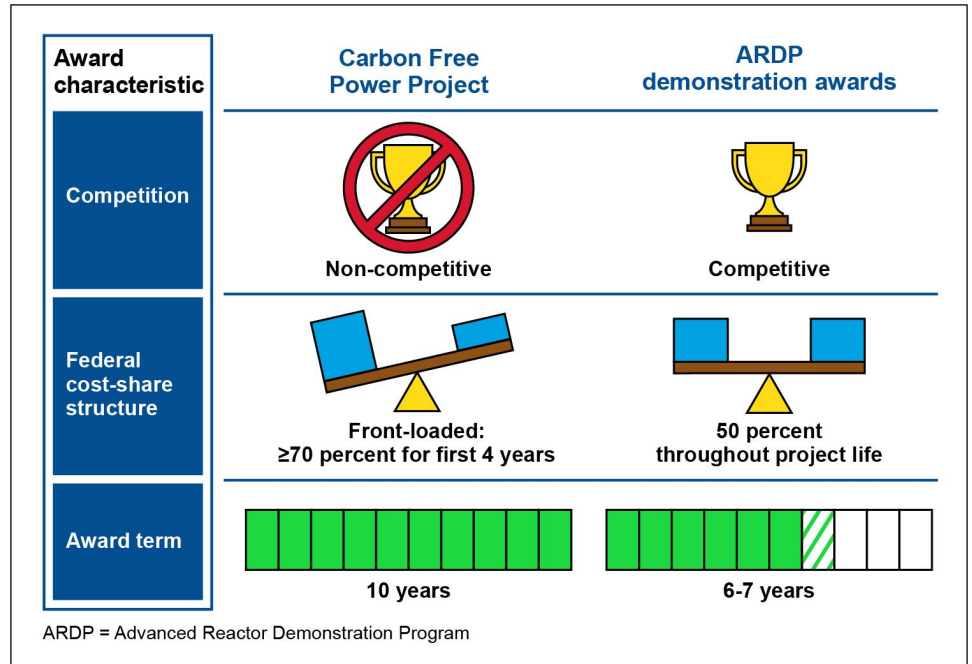
²⁵Specifically, DOE funded small modular reactor development by NuScale. Some of this funding was provided competitively. See app. I for additional information on other DOE support for NuScale, X-energy, and TerraPower.

- **Award term.** The Carbon Free Power Project award term is 10 years. The ARDP award terms are between 6 and 7 years.
- **Cost-share structure.** The Carbon Free Power Project front-loads the federal cost share so that the federal share of project costs is greater than, or equal to, 70 percent for the first 4 years, with federal support tapering off in later years. The total federal cost share will be 23 percent over the life of the project. By contrast, DOE structured the ARDP funding opportunity to require the non-federal share to be at least 50 percent for each invoice each year. Front-loading the federal cost share provides more support during earlier phases of development and decreases risk to the awardee. The awardee told us that this was important for gaining support of its members and the ability to secure financing for a first-of-a-kind project. At the same time, front-loading the federal cost share increases risk to the taxpayer because the government pays more in earlier years and may have to take action to recoup funds if the project terminates before the overall awardee cost share is met.²⁶

See figure 2 for a summary of the award characteristics for the Carbon Free Power Project and two ARDP awards.

²⁶Regardless of project termination, the federal government retains a license to use any invention developed in the performance of the agreement.

Figure 2: Department of Energy Nuclear Energy Demonstration Award Characteristics



Source: Department of Energy (DOE) documents. | GAO-22-105394

Note: One of the ARDP demonstration awardees, TerraPower, was to cover 60 percent of its project costs during the first year of the award, and DOE was to cover the remaining 40 percent. For the remainder of the award term, TerraPower and DOE are each to cover 50 percent of project costs. The federal cost share for the Carbon Free Power Project is front-loaded for the first 4 years, but federal support tapers off in the later years of the project, for a total federal cost share of 23 percent.

As part of their demonstration projects, both X-Energy and TerraPower plan to develop fuel fabrication facilities. One of the awardees we interviewed explained the importance of a reliable supply of HALEU to the success of advanced reactor demonstrations and expressed concern over the availability of HALEU needed to demonstrate its technologies. The primary source of commercially available HALEU today is from Russia, but a domestic supply of HALEU could become available in the near future. Specifically, two facilities in the United States could be

licensed to enrich HALEU for commercial purposes by the time the advanced reactors are deployed.²⁷

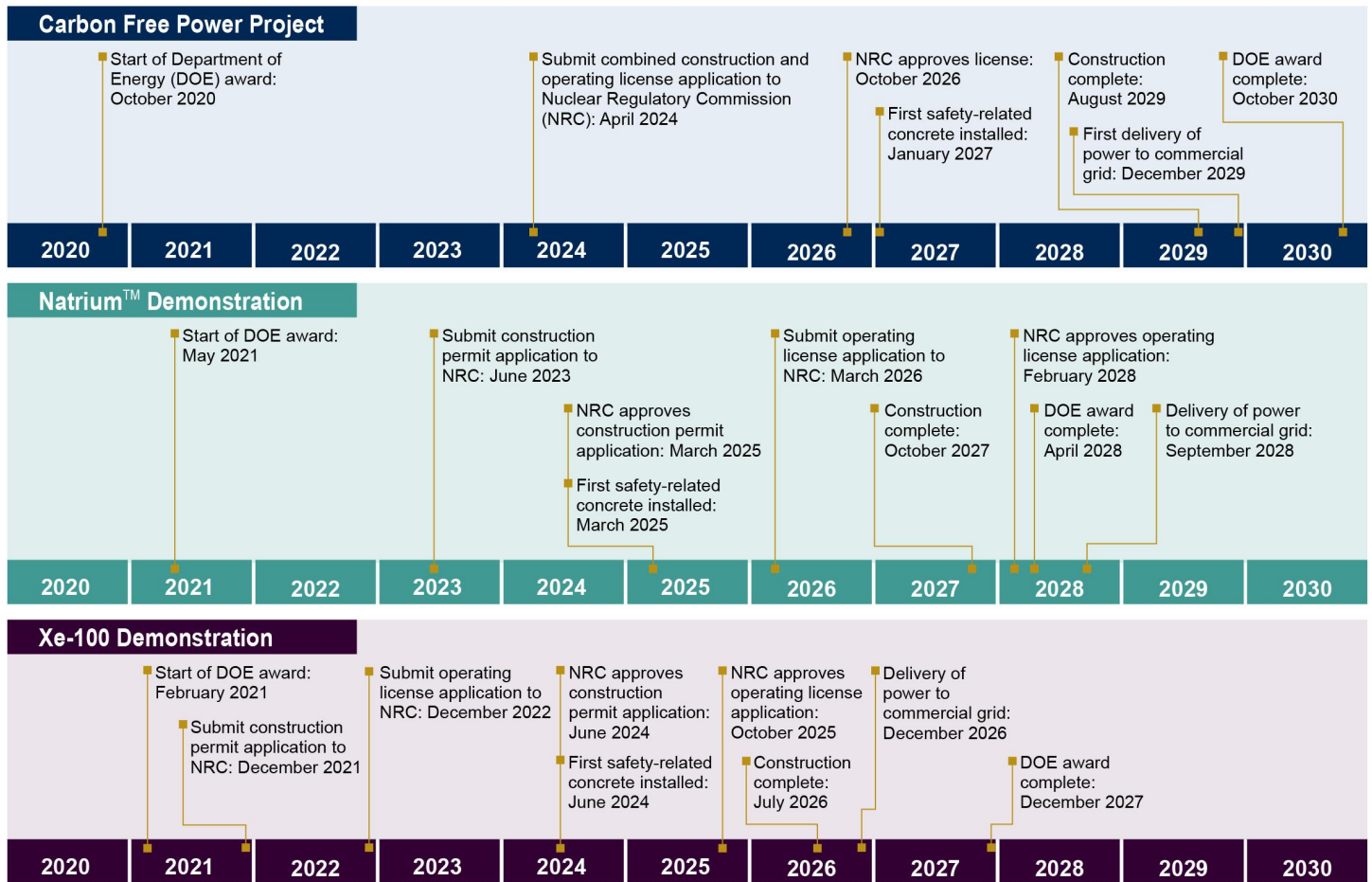
The Three Demonstration Projects Support DOE's Nuclear Energy Goals

The Office of Nuclear Energy's Strategic Vision describes how the three demonstration projects support two of DOE's nuclear energy goals.²⁸ First, the documents state that these demonstration projects support the goal of enabling the deployment of small modular and advanced nuclear reactors. In particular, the performance indicators for this goal include demonstrating two U.S. advanced reactor designs through cost-share partnerships with industry by 2028. The performance indicators for this goal also include enabling the operation of the first commercial U.S. small modular reactor by 2029. DOE officials said that these performance indicators outline the Office of Nuclear Energy's priorities and are not necessarily indicative of firm time lines. According to one of the stakeholders we interviewed, the time lines for these demonstration projects are challenging, in part because of how long it may take to get through the NRC licensing process. DOE officials said that they are currently on target to meet these time lines but that the time lines are subject to change. See figure 3 for a summary of key project milestones for the three demonstrations.

²⁷In October 2019, Centrus Energy, a U.S. company, received a \$115 million award from DOE to demonstrate production of HALEU at its plant in Ohio and received NRC license approval to produce HALEU for demonstration purposes in 2021. Also in 2019, Urenco USA, Inc., a U.S. subsidiary of a European company, said that it is capable of producing HALEU and meeting industry needs and that a new enrichment module for such purposes could be operational within 24 months of NRC licensing. In addition, in December 2021, DOE issued a request for information related to the establishment of a DOE HALEU Availability Program authorized by the Energy Act of 2020.

²⁸Department of Energy, *Office of Nuclear Energy Strategic Vision* (Washington, D.C.: January 2021).

Figure 3: Key project milestones for the Carbon Free Power Project, Natrium™ Demonstration, and Xe-100 Demonstration, 2020-2030



Source: DOE award documents and officials. | GAO-22-105394

Note: The milestones and dates in this figure reflect the projects' schedules at a point in time and are subject to change. The Carbon Free Power Project and Natrium™ Demonstration milestones and dates reflect the projects' schedules as of May 2022. The Xe-100 Demonstration's milestones and dates reflect the original schedule as accepted by DOE under the original Advanced Reactor Demonstration Program application and have not been updated to reflect certain delays. According to DOE officials, the project has experienced several challenges since its inception, such as pandemic-related delays. X-energy is actively working to resolve these issues.

Second, these demonstration projects support the goal of maintaining U.S. leadership in nuclear energy technology, specifically to facilitate global opportunities for the U.S. nuclear sector. According to DOE officials we interviewed, the development and demonstration of U.S.-based reactor technologies, including the ability to obtain an NRC license, will facilitate fleet-level deployment of the designs. DOE officials told us that the demonstration of these designs would allow U.S. utilities to

recognize the safety, affordability, and environmental benefits of these technologies and build them into their integrated resource planning processes as potential replacements for their aging fossil fuel generation assets.²⁹ DOE officials also stated that there is significant foreign interest in these technologies. The officials said that they expect the successful licensing and safe demonstration of the projects to result in significant export potential.³⁰

DOE Has Taken Several Actions to Manage Risks but Has Not Fully Institutionalized Oversight Plans for Its Nuclear Energy Demonstration Awards

DOE has taken several actions to manage risks associated with its three nuclear energy demonstration awards. Specifically, DOE uses existing project management practices such as budget controls, milestone tracking, and other procedures to manage risks. In addition, the Office of Nuclear Energy and the newly established Office of Clean Energy Demonstrations plan to use additional project management practices, such as external independent reviews, to oversee the awards. However, neither office has institutionalized its plans for implementing these additional practices.

DOE Has Managed Risks Using Budget Controls, Milestone Tracking, and Other Procedures

DOE has managed the risks of the three nuclear energy demonstration awards through existing project management practices such as budget controls, milestone tracking, and other procedures.

²⁹The purpose of integrated resource planning is to meet future power demand by identifying the need for generating capacity and determining the best mix of resources to meet the need on a least-cost, system-wide basis. The integrated approach considers a broad range of feasible supply-side and demand-side options and assesses them with respect to financial, economic, and environmental impacts.

³⁰According to its website and officials we interviewed, NuScale has collaborative partnerships around the world, including agreements with entities in Poland, Romania, and Ukraine regarding the development of NuScale small modular reactor technology in those countries.

First, DOE documents outline budget controls, including procedures for reimbursing allowable costs and reviewing whether a project should continue at the conclusion of each award budget period.³¹ For example, according to the ARDP Funding Opportunity Announcement, awardees must submit invoices to DOE before being reimbursed for allowable project costs. In addition, under DOE's *Guide to Financial Assistance*, awardees must submit an application to continue a project at the end of each award budget period. These continuation applications contain progress reports, requests for revisions to the project schedule, and adjustments to the budget for the coming budget period. A DOE reviewer evaluates the continuation applications and determines if requested changes to performance targets or budget are appropriate and acceptable for the project. If DOE concurs with the continuation application, the award is formally extended to the next budget period, and the awardee has official authorization to spend award funds, subject to congressional appropriations. If DOE does not concur with the application, then DOE works with the awardee to come to agreement on acceptable targets and next steps for the project, according to DOE officials. DOE officials told us if they are unable to come to agreement, the award ends and DOE begins the closeout process, which is outlined in regulations and DOE's *Guide to Financial Assistance*.³²

Second, DOE uses milestone tracking to manage project risks. For example, the Office of Nuclear Energy uses the Program Information Collection System as a way to track project progress against set milestones and to provide oversight. Finally, DOE uses other procedures to manage risks—including through managing award requirements, terms, and conditions; consulting with industry experts; and regular communications with awardees. Specifically:

- **Managing award requirements, terms, and conditions.** DOE's management of these awards has generally been consistent with requirements to address risk, for example, through following an approval process for project changes, such as changes to scope and budget. For more information on how DOE managed risks consistent with award documentation requirements, see appendix II. In addition, DOE officials outline specific oversight requirements in both the

³¹The Carbon Free Power Project 's budget period is every 2 years, and the budget period for the two ARDP awards is every year.

³² C.F.R. § 200.344; see also Department of Energy, *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance*.

Statement of Substantial Involvement and the Special Terms and Conditions documents. For example, the Carbon Free Power Project's cooperative agreement contains provisions that allow DOE to hold the award recipient responsible for 77 percent of the total allowable project costs, even if the project ends early or is not funded to completion.

- **Consulting experts from government and industry.** DOE consults with industry and other experts for their knowledge and expertise. For example, for the two ARDP awards, the Office of Nuclear Energy relied on NRC expertise. Specifically, NRC provided input on the reactor licensing process to help DOE determine whether the demonstration award time lines were reasonable, which officials said helped mitigate potential scheduling risks.
- **Communication with awardees.** DOE's *Guide to Financial Assistance* outlines how the department is to communicate with awardees via informal and formal channels. In addition, the Office of Nuclear Energy uses its information reporting system, the Program Information Collection System, to communicate about project management, milestones, desired changes to project scope and budget, and potential problems that the projects may encounter during these interactions. DOE officials also said that they discuss these issues at regularly scheduled and informal calls.

DOE Plans to Use Additional Practices to Manage Risks but Has Not Institutionalized These Oversight Mechanisms

Officials from the Office of Nuclear Energy, which manages the Carbon Free Power Project, and the Office of Clean Energy Demonstrations, which took over management of the two ARDP awards in May 2022, told us that they plan to implement additional project management practices, such as external independent reviews, to provide oversight for all three projects. According to DOE's project management order, an external independent review is a project review performed by personnel from DOE and augmented by individuals outside DOE at critical decision points of a

project. These reviews primarily support validation of the performance baseline phase or the construction and execution phase.³³ Specifically:

- Office of Clean Energy Demonstrations officials told us they plan to implement external independent reviews for the two ARDP awards because they want to do their due diligence and implement more robust oversight mechanisms.³⁴ In particular, the officials told us that the office had established a technology and engineering support division that will oversee the implementation of these external reviews. According to an April 2022 DOE statement of work, the Office of Clean Energy Demonstrations will conduct external independent reviews for the X-Energy demonstration project in June 2022 and for the TerraPower demonstration project shortly afterwards. The office intends to issue a final report on both projects in late summer or early fall 2022. Office of Clean Energy Demonstrations officials told us that they plan to use some of the money appropriated to the two ARDP awards in the Infrastructure Investment and Jobs Act to help establish the office's oversight practices, including funding for subject matter experts and independent project reviewers.
- Office of Nuclear Energy officials told us that they also plan to implement external independent reviews for the Carbon Free Power Project but that they are still developing their oversight plans.³⁵ Specifically, officials said that they expect to finalize plans for an

³³Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*. Officials from the Offices of Nuclear Energy and Clean Energy Demonstrations told us that because DOE's project management order does not apply to financial assistance agreements, their oversight process for the Carbon Free Power Project and the ARDP projects may differ from that mandated in DOE's project management order because of the difference in the structure of the projects.

³⁴The officials told us that they decided to implement external independent reviews in part after reading prior GAO work on large-scale demonstration projects and applying lessons learned from that work. Specifically, the officials said they reviewed GAO's December 2021 report on DOE carbon capture demonstration projects for lessons learned. See [GAO-22-105111](#).

³⁵Office of Nuclear Energy officials told us they decided to use external independent reviews for the Carbon Free Power Project after internal discussions and consultations with DOE's Loan Programs Office. According to the officials, the decision stemmed from the high visibility, significance, and magnitude of the project, and the desire to look at the project from a different vantage point to identify risk areas not previously captured in their project management processes. They also said that GAO's work on this report accelerated their decision-making process on using external independent reviews as an oversight mechanism for the Carbon Free Power Project.

independent external review panel for the Carbon Free Power Project and add them to the terms of the award by September 2022.

In addition, Office of Clean Energy Demonstrations officials told us that they are developing other project management practices that will apply to all large DOE energy demonstration awards, regardless of which DOE offices are managing those awards. For example, the office is developing an advisory board for demonstrations to provide independent oversight of these projects that will align with the key oversight practices in DOE's project management order.³⁶ The board would review results of the independent project reviews and all major go/no go project decisions.

External independent reviews and other project management practices can help manage risk by addressing organizational biases. According to DOE project management officials, program offices have a bias for optimistic rather than realistic views of events, including potential cost and schedule risks, because program offices both manage and provide oversight to awards and want them to succeed.³⁷ GAO's *Cost Estimating and Assessment Guide* states that organizational optimism can result in an underestimation of risks, which can lead to the development of unrealistic cost and schedule estimates.³⁸ Performed by either inside or outside analysts, an "honest broker" approach, such as an external independent review, helps bring to light actions that can potentially limit the likelihood of success and can help mitigate this optimism. DOE officials told us that because the Office of Clean Energy Demonstrations is not a technology-focused office, like the Office of Nuclear Energy, its processes could help mitigate optimism bias when conducting oversight of DOE's large demonstration projects. Additionally, strong oversight in the form of external independent reviews for the Carbon Free Power Project could further manage the financial risks associated with front-loading the federal cost share for that project.

While the Office of Nuclear Energy and the Office of Clean Energy Demonstrations plan to use additional project management practices such as external independent reviews for current and future nuclear demonstration awards, neither office has institutionalized its plans

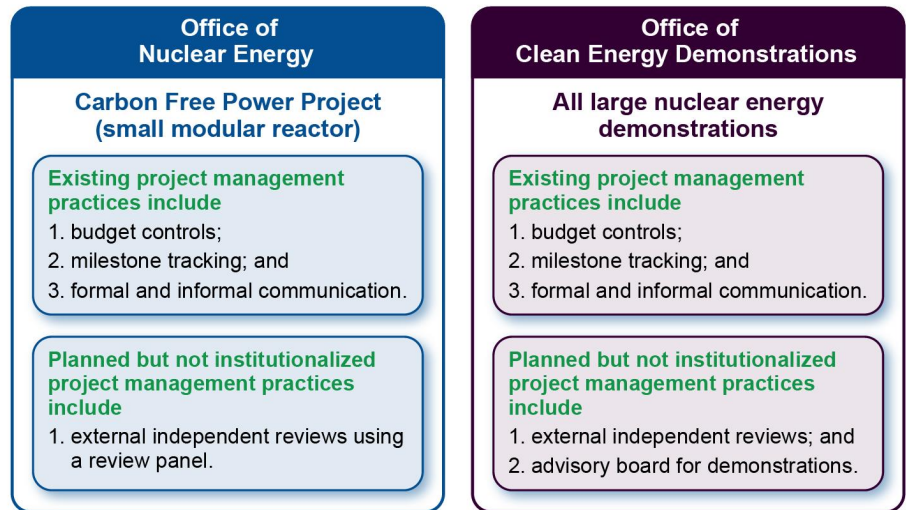
³⁶ Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*.

³⁷ Prior GAO work has identified overly optimistic assessments of cost, schedule, and technical risks in DOE demonstration projects, leading to cost overruns and failed projects. See [GAO-22-105111](#).

³⁸ [GAO-20-195G](#).

through documentation (see fig. 4). Office of Nuclear Energy officials said that their internal communication about implementing external independent reviews has been limited to biweekly discussions of their plans but that they hope to document their approach by September 2022. Office of Clean Energy Demonstrations officials told us that they are in the process of finalizing a contract with an external firm to help develop project management policies, processes, and procedures, including business rules for the external independent reviews. Officials told us that they hope to have the basic outline for these business rules finalized by the end of fiscal year 2022.

Figure 4: Existing and Planned Project Oversight Processes for Department of Energy (DOE) Nuclear Energy Demonstration Awards, as of June 2022



Sources: DOE documents, and interviews with agency officials. | GAO-22-105394

Standards for Internal Control in the Federal Government state that effective agency management develops and maintains documentation of its internal control system.³⁹ Documenting oversight processes, including external independent review processes, steps for addressing risks identified in these reviews, and criteria for which projects should use these processes, would institutionalize DOE’s plans and help to ensure consistent implementation of these processes across all large DOE nuclear energy demonstration awards. Doing so would also allow DOE to share best practices across offices and during the course of these multi-

³⁹GAO-14-704G.

year projects. Consistently applying project management practices, such as external independent project reviews at critical decision points, could result in stronger federal oversight and improved project performance.⁴⁰

Conclusions

DOE has awarded billions of dollars to demonstrate new types of nuclear reactors and has sought to manage risks associated with these first-of-a-kind technologies by implementing some project management practices and planning to implement more. However, the Offices of Nuclear Energy and Clean Energy Demonstrations have not fully institutionalized these processes, such as conducting external independent reviews, for current or future nuclear energy demonstration awards via documentation. Documenting these processes, including steps for addressing any risks they identify and criteria for which projects should use them, could help to ensure consistent implementation of the processes across these large, multi-year projects. In so doing, DOE could provide stronger federal oversight and improve project performance.

Recommendation for Executive Action

The Secretary of Energy should ensure that the Assistant Secretary for Nuclear Energy and the Director of the Office of Clean Energy Demonstrations coordinate and institutionalize via documentation their processes for providing oversight for large nuclear energy demonstration projects, including the use of external independent reviews, steps for addressing any risks identified, and criteria for which projects should use these processes. (Recommendation 1)

Agency Comments

We provided a draft of this report for review and comment to DOE and NRC.

⁴⁰Prior GAO work has identified significant schedule and technical problems that resulted from DOE not consistently meeting performance goals against institutionalized project management requirements, including using independent project reviews. See [GAO-07-518](#).

In its comments, reproduced in appendix III, DOE stated that it agreed with our recommendation that the Office of Nuclear Energy and Office of Clean Energy Demonstrations coordinate and institutionalize via documentation their processes for providing oversight for large nuclear energy demonstration projects. In its comments, reproduced in appendix IV, NRC stated it was in general agreement with this report. DOE and NRC also provided technical comments, which we incorporated throughout this report as appropriate.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 5 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees, the Secretary of Energy, and the Chairman of NRC. In addition, the report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.



Frank Rusco
Director, Natural Resources and Environment

Appendix I: Department of Energy (DOE) Support for NuScale, X-energy, and TerraPower

DOE has supported earlier phases of project design and development for the NuScale, X-energy, and TerraPower technologies from 2014 to 2022. See table 3 for a summary of this assistance.

Table 3: Department of Energy (DOE) Financial Assistance to Selected Companies for Small Modular and Advanced Reactor Technologies

Awardee	Award years	Competition	Award purpose	DOE funding (dollars in millions)
NuScale/Carbon Free Power Project	2014-2018	Competitive	NuScale Design Development and Certification Project	226
	2015-2021	Non-competitive	Site permitting and licensing of the NuScale small modular reactor	8
	2018	Competitive	Phase one - NuScale Nuclear Demonstration Readiness Project	48
	2018-2019	Competitive	Phase two - NuScale Nuclear Demonstration Readiness Project	43
	2020-2024	Non-competitive	NuScale Nuclear Demonstration Readiness Project completion	263
	2020-2030	Non-competitive	Commercialization and deployment of the first NuScale small modular reactor in the U.S.: The Carbon Free Power Project	1,355
Total NuScale/Carbon Free Power Project				\$1,944
TerraPower	2020-2022	Competitive	Advanced Fuel Qualification Methodology Report for Traveling Wave Reactor	0.49
	2021-2028	Competitive	Natrium™ Demonstration Project	1,979
Total TerraPower				\$1,980
X-energy	2016-2022	Competitive	XE-100 Pebble Bed: Solving Critical Challenges to Enable the XE-100 Pebble Bed Advance Reactor Concept	40

**Appendix I: Department of Energy (DOE)
Support for NuScale, X-energy, and
TerraPower**

2018-2022	Competitive	Design and license application development for high assay low-enriched uranium fuel fabrication facility	19
2020-2022	Competitive	Xe-100 conceptual design and risk-informed licensing	3
2021-2027	Competitive	X-energy deploy first commercial-scale advanced reactor by 2027	1,232
Total X-energy			\$1,294

Source: DOE Office of Nuclear Energy. | GAO-22-105394

Note: Totals may be off because of rounding.

Appendix II: Department of Energy (DOE) Management of Awards Compared with Selected Financial Assistance Requirements

This appendix shows the results of our comparison of DOE’s management of the three small modular and advanced reactor demonstration awards—the Carbon Free Power Project, the TerraPower Natrium™ Demonstration, and the X-energy Xe-100 demonstration—with selected financial assistance requirements (see table 2).⁴¹

Table 2: Comparison of the Department of Energy’s (DOE) Management of Three Small Modular and Advanced Reactor Demonstration Awards with Selected Financial Assistance Requirements

Requirement	Requirement met?		
	Carbon Free Power Project	TerraPower Natrium™ Demonstration	X-energy Xe-100 Demonstration
Competition: DOE must determine whether an award will be competitive or noncompetitive; in circumstances under which an award is allowed to be noncompetitive, DOE is required to complete a Determination of Noncompetitive Financial Assistance. ^a	Checked	Checked	Checked
Selection of financial instrument: DOE must select among various financial assistance instruments, such as grants or cooperative agreements. For each of these awards, DOE chose a cooperative agreement.	Checked	Checked	Checked
Statement of substantial involvement: For each cooperative agreement, DOE must prepare a statement that explicitly describes the nature, character, and extent of anticipated federal involvement. An example of substantial involvement would be the power to immediately halt project activities if certain performance metrics are not met (e.g., construction specifications).	Checked	Checked	Checked
Merit review: For discretionary federal awards, DOE must design and execute a merit review process for applications, with the objective of selecting recipients most likely to be successful in delivering results based on the program objectives.	Checked	Checked	Checked

⁴¹In this report, we define “requirements” as both legal requirements and other criteria in DOE guidance, specifically the department’s *Guide to Financial Assistance: A Guide to the Award and Administration of Financial Assistance* (Oct. 1, 2020).

**Appendix II: Department of Energy (DOE)
Management of Awards Compared with
Selected Financial Assistance Requirements**

Requirement	Requirement met?		
	Carbon Free Power Project	TerraPower Natrium™ Demonstration	X-energy Xe-100 Demonstration
Application review: DOE must review applications, including those that were submitted in response to a competitive Funding Opportunity Announcement and those that are not competed.	Checked	Checked	Checked
Budget review: DOE must conduct a budget review to verify cost data; evaluate specific elements of the budget; examine data to determine allowability, allocability, and reasonableness; and determine that proposed costs are consistently treated in accordance with generally accepted accounting principles and applicable cost principles.	Checked	Checked	Checked
Cost share: DOE must, generally, establish a cost share of not less than 20 percent for research and development activities and not less than 50 percent for demonstration and commercial application activities. The applicable cost share may be reduced if necessary and appropriate, taking into consideration any technological risk relating to the activity.	Checked	Checked	Checked
Project scope or budget changes: DOE must follow an approval process for certain project changes, including changes to the project scope or budget.	Checked	Checked	Checked
Intellectual property: DOE must ensure that applicable intellectual property requirements are included in agreements, including patent and data requirements.	Checked	Checked	Checked

Source: GAO analysis based on the Department of Energy Guide to Financial Assistance, federal law and regulations, and award documents. | GAO-22-105394

^aIt is DOE policy to use competition to the maximum extent feasible.

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, David Marroni (Assistant Director), Marissa Dondoe (Analyst-in-Charge), Bethany Benitez, Brian Bothwell, Antoinette Capaccio, John Delicath, Cindy Gilbert, Richard Hung, Tom James, Madeline Kasik, Katrina Pekar-Carpenter, Dan C. Royer, and Matthew Tabbert made significant contributions to this report.

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