



February 2022

ADVANCED RESEARCH PROJECTS AGENCY-ENERGY

Agency Has Practices for
Avoiding Duplication and
Involving Stakeholders in the
Development of Research
Programs

Accessible Version

GAO Highlights

Highlights of [GAO-22-104775](#), a report to the Committee on Science, Space, and Technology, House of Representatives.

Why GAO Did This Study

Congress established ARPA-E in 2007 as an agency dedicated to developing energy technology that may otherwise be too high-risk for private industry to undertake.

GAO was asked to review ARPA-E's efforts to coordinate its research with other DOE offices. This report examines (1) the practices ARPA-E uses to manage overlap and duplication of its energy research with DOE's other research efforts, and (2) the actions ARPA-E takes to coordinate with DOE stakeholders in conducting its energy research and development activities.

GAO reviewed DOE policies and other agency documents; interviewed DOE officials; and collected and analyzed data on selected ARPA-E projects since ARPA-E's first appropriation in 2009.

View [GAO-22-104775](#). For more information, contact Frank Rusco at (202) 512-3841 or RuscoF@gao.gov.

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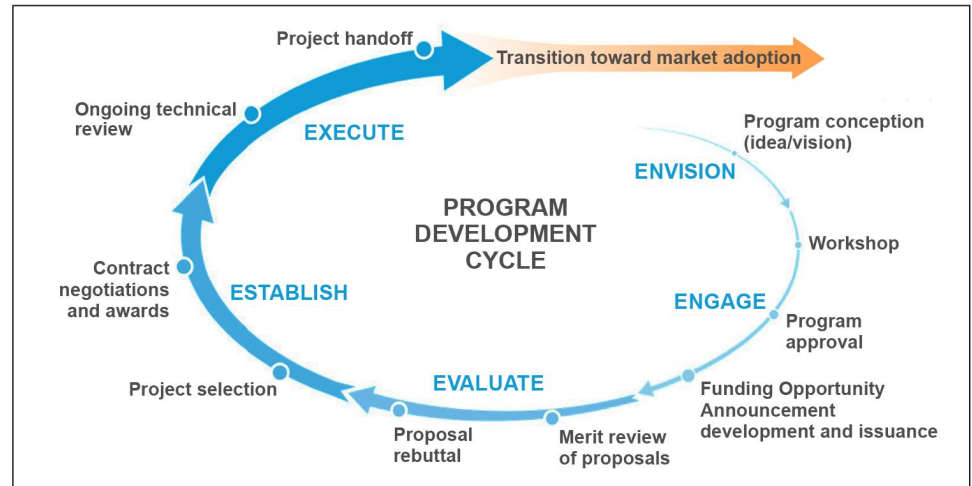
Agency Has Practices for Avoiding Duplication and Involving Stakeholders in the Development of Research Programs

What GAO Found

The potential to transform the energy sector through transformative research and development, and the Advanced Research Projects Agency-Energy (ARPA-E) supporting efforts, are critical to enhancing the United States' economic and energy security. ARPA-E is tasked with carrying out transformative energy-related research that does not duplicate work being done by other agencies.

GAO found ARPA-E has practices in place to help manage overlap and duplication during its program development cycle. ARPA-E coordinates with other stakeholders in the Department of Energy (DOE), as well as those at other agencies, by inviting officials from those offices to participate early in the program development process. These opportunities occur primarily in the initial stages of the program development cycle (see figure), which ARPA-E calls the "envision," "engage," and "evaluate" stages. This participation has occurred on an ongoing basis and has helped manage overlapping research efforts while identifying potential duplication.

ARPA-E's Five-Stage Cycle for the Development of New Research Programs, including Project Selection



Source: Advanced Research Projects Agency-Energy (ARPA-E). | GAO-22-104775

ARPA-E officials participate in DOE working groups, coordinate on announcements for open funding opportunities, and participate in other strategic coordination efforts to inform DOE stakeholders of the agency's energy-related research and development efforts. In addition, ARPA-E's Strategic Vision was developed in 2013, as required by the America COMPETES Act, to guide future investments. The act was amended in 2020 to require an updated Strategic Vision by October 1, 2021. According to officials from DOE's applied science offices, an up-to-date Strategic Vision could provide them a better understanding of the issue areas on which ARPA-E is focused, allowing DOE stakeholders to ensure that they are appropriately coordinating with ARPA-E on relevant research efforts. ARPA-E officials are working with DOE to issue a new Strategic Vision by February 2022.

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	ARPA-E Advanced Research Projects Agency-Energy	
	ATLANTIS Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control	

BRDI	Biomass Research and Development Initiative
CIRCUITS	Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors
DOD	Department of Defense
DOE	Department of Energy
ED	Office of Economic Impact and Diversity
EERE	Office of Energy Efficiency and Renewable Energy
EO	Executive Order
FECM	Office of Fossil Energy and Carbon Management
IMPACCT	Innovative Materials and Processes for Advanced Carbon Capture Technologies
NETL	National Energy Technology Laboratory
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
OE	Office of Electricity
RTIC	Research and Technology Investment Committee
SETO	Solar Energy Technologies Office
SETT	Science and Energy Tech Teams
ULTIMATE	Ultrahigh Temperature Impervious Materials Advancing Turbine Efficiency

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February 3, 2022

The Honorable Eddie Bernice Johnson
Chairwoman
The Honorable Frank D. Lucas
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

Innovations in energy technology have the potential to address some of society's most pressing challenges and the potential to transform the energy sector. In 2007, to support and encourage energy innovation in the U.S., Congress established the Advanced Research Projects Agency-Energy (ARPA-E) within the Department of Energy (DOE). ARPA-E's mission is to help develop technologies to enhance the economic and energy security of the U.S. and to ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies.

ARPA-E is required by statute to achieve its goals through energy technology projects that, among other things, accelerate transformational technological advances in areas that industry is not likely to undertake due to technical or financial uncertainty. At the same time, the Director of ARPA-E is required to ensure, to the maximum extent practicable, that ARPA-E's activities are coordinated with, and do not duplicate the efforts of, programs and laboratories within DOE and other relevant research agencies. Since receiving its first appropriation in 2009, ARPA-E has supported more than 60 programs at universities, public and private companies, and national laboratories.¹ The agency has funded more than 1,000 projects that attempt to make transformational—rather than incremental—advances to a variety of energy technologies, including high-energy batteries and renewable fuels.

You asked us to review ARPA-E's efforts to coordinate its research with other DOE offices. This report examines (1) the practices ARPA-E uses to manage overlap and duplication of its energy research with DOE's other research efforts, and (2) the actions ARPA-E takes to coordinate

¹ARPA-E received its first appropriation in the American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, Div. A, tit. IV, 123 Stat. 115, 140.

with DOE stakeholders in conducting its energy research and development activities.

To examine ARPA-E's practices for managing overlap and avoiding duplication of research, we reviewed DOE and ARPA-E guidance, such as new program development and project selection guidance for program directors and templates for project solicitation and review. We reviewed supporting documentation from six ARPA-E research programs to understand how ARPA-E has applied these practices to existing programs. We selected the six programs by identifying programs that appear to be, or could potentially be duplicative, in that they involve research in the same or similar technological area as other DOE applied science offices.²

To examine the actions ARPA-E takes to coordinate with other DOE stakeholders, we reviewed relevant laws, such as the America COMPETES Act,³ the Department of Energy Research and Innovation Act,⁴ and standards for internal controls. We also selected leading best practices for coordination and collaboration. We examined the extent to which ARPA-E's coordination activities are consistent with these laws, standards, and best practices.⁵

For both objectives, we interviewed officials from ARPA-E and DOE applied science offices about the agency's efforts to manage overlap and potential duplication and coordinate research efforts. See appendix I for more details on our scope and methodology.

We conducted this performance audit from February 2021 to February 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 believe

²For the purposes of this report, we refer collectively to DOE's Office of Electricity, Office of Science, Office of Energy Efficiency and Renewable Energy, and the Office of Fossil Energy and Carbon Management as "applied science offices."

³America COMPETES Act, Pub. L. No. 110-69, 121 Stat. 572 (2007).

⁴Department of Energy Research and Innovation Act, Pub. L. No. 115-246, 132 Stat. 3130 (2018).

⁵GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: Sept. 2014); *Fragmentation, Overlap, and Duplication: An Evaluation and Management Guide*, [GAO-15-49SP](#) (Washington, D.C.: April 14, 2015).

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

Background

In 2005, Congress asked the National Academies of Science, Engineering, and Medicine to identify the most urgent challenges the U.S. faces in maintaining leadership in key areas of science and technology, as well as specific steps policymakers could take to help the U.S. compete, prosper, and stay secure into the future. The National Academies 2007 report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, called for decisive action, warning policymakers that U.S. advantages in science and technology had already begun to erode.⁶ The report recommended the creation of ARPA-E to spur technological breakthroughs in the energy sector. ARPA-E was created, within DOE, shortly after as part of the America COMPETES Act in 2007.

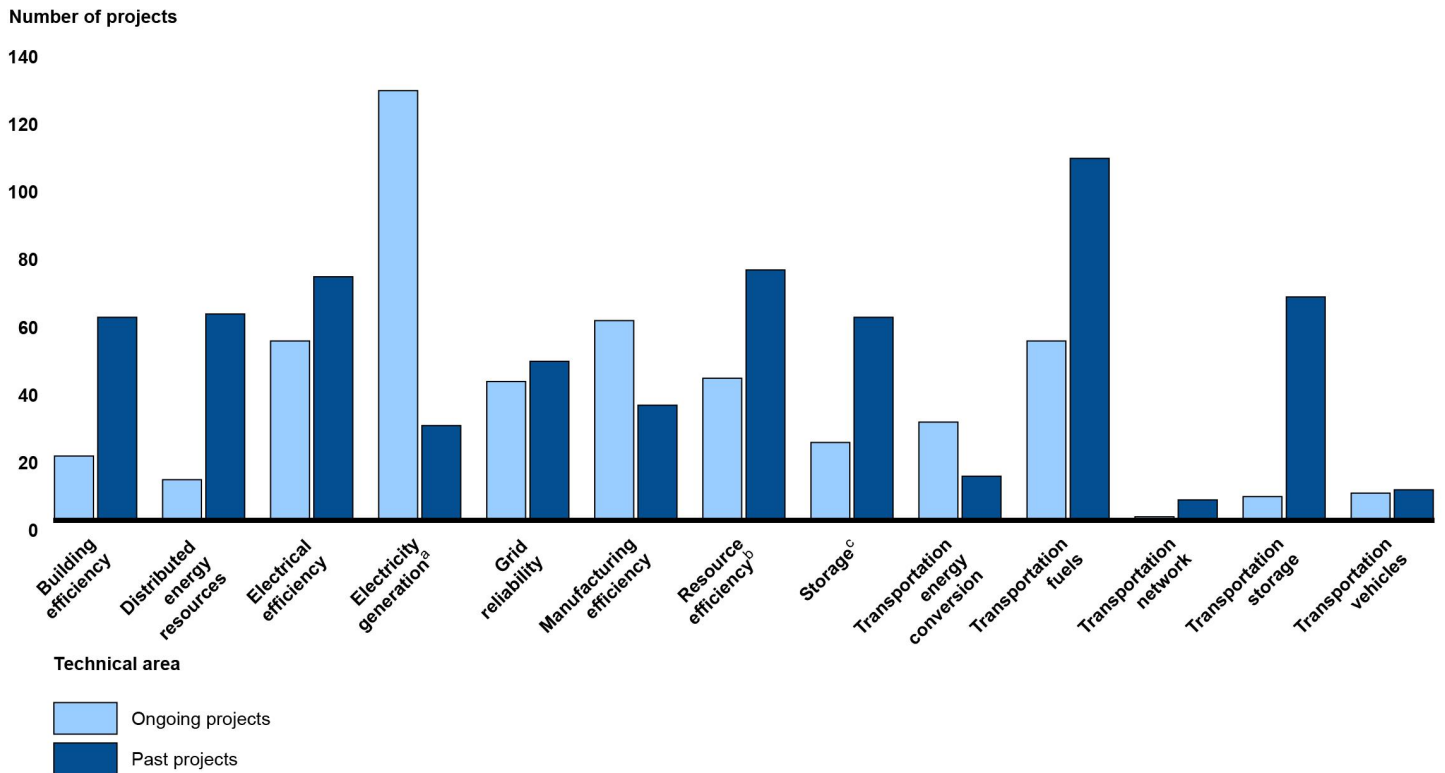
ARPA-E's focus on transformational energy projects allows the agency to provide funding and technical assistance to U.S. energy researchers that may otherwise be unavailable because other research organizations in the public and private sector are unwilling to invest in high-risk energy-related research initiatives, even though such initiatives might produce high rewards. Since 2009, ARPA-E has provided more than \$2.6 billion in research funds for more than 1,000 projects and the U.S Patent and Trademark Office has issued hundreds of patents associated with ARPA-E projects. In addition, the private sector has invested more than \$4.9 billion towards projects that build on projects funded by ARPA-E.

ARPA-E's energy-related research primarily focuses on 13 technical areas, such as building energy efficiency and transportation fuels. To date, ARPA-E has supported more than 60 programs across these

⁶Committee on Prospering in the Global Economy of the 21st Century, and Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, D.C.: The National Academies Press, 2007).

technical areas, which could include some degree of overlap.⁷ Programs can range from research focused on microalgae to be used as transportation fuel to floating wind turbines intended to lower the development costs of renewable energy production. Each program may include multiple projects. Figure 1 identifies the number of ongoing and past projects that ARPA-E has funded within each of the 13 technical areas.

Figure 1: Advanced Research Projects Agency-Energy: Number of Projects by Technical Area, as of September 2021



Source: GAO analysis of Advanced Research Projects Agency-Energy information. | GAO-22-104775

⁷GAO defines overlap as multiple agencies or programs having similar goals, engaging in similar activities or strategies to achieve them, or targeting similar beneficiaries. GAO defines duplication as two or more agencies or programs engaging in the same activities or providing the same services to the same beneficiaries. GAO, *2021 Annual Report: Additional Opportunities to Reduce Fragmentation, Overlap, and Duplication and Achieve Billions in Financial Benefits*, [GAO-21-455SP](#) (Washington, D.C.: May 12, 2021).

Accessible Data for Figure 1: Advanced Research Projects Agency-Energy: Number of Projects by Technical Area, as of September 2021

Category	Ongoing projects	Past projects
Building efficiency	19	60
Distributed energy resources	12	61
Electrical efficiency	53	72
Electricity generation	127	28
Grid reliability	41	47
Manufacturing efficiency	59	34
Resource efficiency	42	74
Storage	23	60
Transportation energy conversion	29	13
Transportation fuels	53	107
Transportation network	1	6
Transportation storage	7	66
Transportation vehicles	8	9

^aElectricity generation refers to nuclear, wind, thermal, solar, and other electricity generation sources.

^bResource efficiency projects aim to improve the efficiency of a system or reduce the demand of a resource.

^cStorage refers to novel storage systems for stationary applications; thermal, electrical, and chemical storage systems.

ARPA-E has 16 program directors to manage these research efforts. The program directors typically serve for a 3-year appointment. According to DOE, the limited terms help promote fresh thinking and new perspectives. Program directors are involved with the development and ongoing management of ARPA-E programs, as well as the projects that support each program. Program directors have multiple responsibilities, including evaluating program performance from a technical, cost, and schedule perspective. Program directors also recommend which projects to fund, which projects to terminate because they are not performing as intended, and which projects to provide with additional funding or extended timeframes.

The applied science offices within DOE's Office of the Undersecretary for Science and Energy coordinate with ARPA-E on proposed and ongoing energy-related research and development efforts. These applied science offices are the Office of Electricity (OE), Office of Science, Office of

Energy Efficiency and Renewable Energy (EERE), and the Office of Fossil Energy and Carbon Management (FECM). Each of these offices conduct energy-related research across technical areas similar to those focused on by ARPA-E.⁸

- **DOE Office of Electricity.** OE's mission is to ensure that the nation's energy delivery system is secure, resilient, and reliable. OE's projects support development of new technologies to improve infrastructure that brings electricity to homes, offices, and factories. According to OE officials, ARPA-E and OE both conduct research related to electrical energy storage.
- **DOE Office of Science.** The Office of Science is the nation's largest supporter of basic research in the physical sciences, which includes energy-related research and development. The office is the steward of 10 national laboratories that provide support to DOE's science programs. It is also the lead federal agency supporting fundamental research for energy production and security. According to Office of Science officials, both the Office of Science and ARPA-E conduct research related to energy sciences.
- **DOE Office of Energy Efficiency and Renewable Energy.** EERE's mission is to accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition the U.S. to net-zero greenhouse gas emissions economy-wide by no later than 2050, and ensure that the clean energy economy benefits all Americans. According to EERE officials, ARPA-E and EERE both conduct research related to bio-mining of critical minerals, semiconductors, and marine energy.
- **DOE Office of Fossil Energy and Carbon Management.** FECM is responsible for federal research, development, and demonstration efforts on advancing technologies to meet climate goals and minimize the environmental impacts of fossil fuel use, including low carbon power generation and low carbon supply chains; carbon capture and storage technologies; methane emissions reductions; critical mineral productions; and carbon dioxide removal. According to FECM officials, ARPA-E and FECM both conduct research in the areas of carbon capture and storage and energy storage, among other areas.

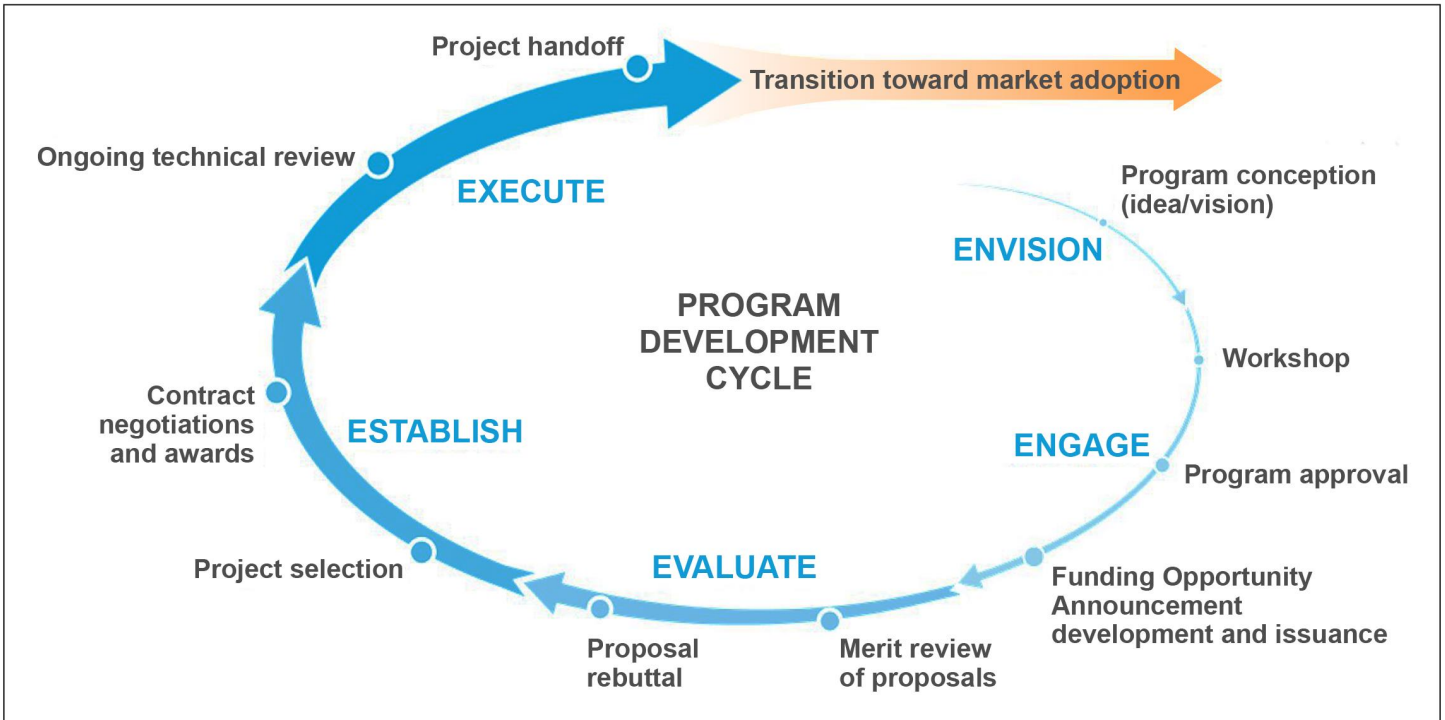
⁸The Office of Science conducts basic research across fundamental science areas that are related to the technical areas pursued by ARPA-E. As such, the Office of Science is not an "applied science" office. However, for the purposes of this report, we refer collectively to OE, the Office of Science, EERE, and FECM as "applied science offices."

In addition, other DOE stakeholders support energy-related research initiatives. For example, the National Energy Technology Laboratory (NETL), which works with FECM on DOE's fossil energy program, conducts research as part of DOE's national laboratory system to support the department's mission to advance the energy security of the U.S. Specifically, NETL has expertise in coal, natural gas, and oil technologies, among other areas. Other DOE stakeholders outside of the applied science offices also support energy-related research initiatives. For example, DOE's Office of Economic Impact and Diversity, the National Nuclear Security Administration, and the Intragovernmental and External Affairs Office participate in working groups with ARPA-E to (1) discuss DOE's efforts to ensure the equity and security of its research initiatives, and (2) strengthen nation-to-nation coordination with tribes.

ARPA-E Has Practices to Manage Overlap and Potential Duplication During Its Program Development Cycle

ARPA-E uses collaborative practices in the early steps of the program development cycle that help program directors identify gaps in research and avoid potentially inefficient duplication of research efforts with DOE's applied science offices. ARPA-E uses a five-stage program development cycle to scope and execute its research programs, a process which includes soliciting, reviewing, and selecting the projects it will fund within the new program (see fig. 2).

Figure 2: Advanced Research Projects Agency-Energy’s Five-Stage Cycle for the Development of New Research Programs, including Project Selection



Source: Advanced Research Projects Agency-Energy. | GAO-22-104775

Program directors have the primary responsibility for ensuring each new program follows the steps in the cycle. Steps that help the program directors identify gaps and avoid duplication include a scoping workshop and a review of individual project proposals, which are shown in the first half of the cycle in figure 2. During the workshop and review of proposals, ARPA-E program directors have invited officials from other DOE applied science offices to provide input on proposed research programs and projects. This practice is consistent with our leading collaboration practice to include relevant participants with the appropriate skills and knowledge.⁹ Participating in these workshops and serving as reviewers allows officials from DOE applied science offices to help ARPA-E better understand related DOE research efforts, identify potential duplication, and identify gaps where ARPA-E can focus on new research.

⁹GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: Sept. 27, 2012).

Specifically, the steps in the program development cycle that help ARPA-E identify gaps and potential duplication in research occur primarily during the stages called “envision,” “engage,” and “evaluate,” described in the following sections.

Envision. During this first stage, an ARPA-E program director develops an idea for a new research program and defines a scope for the program. ARPA-E provides its program directors with a number of tools they can use to improve their understanding of the current state of knowledge of the proposed program area and to identify key stakeholders to engage in the development process.

ARPA-E Research Program: Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT)

The IMPACCT program aimed to address the numerous challenges that remained surrounding carbon capture technology despite the past decade of intensive research and development. Chief among these challenges has been the high cost of capture. Creating new materials developed specifically for capturing carbon dioxide while developing more cost-effective and energy-efficient processes would enable widespread implementation of carbon capture systems. The goal of the IMPACCT program was to minimize the cost of removing carbon dioxide from coal-fired power plant exhaust by developing materials and processes that have never before been considered for this application.

Source: Advanced Research Projects Agency-Energy (ARPA-E). | GAO-22-104775

For example, one tool that a program director can use to better define the scope of a potential program is a Request for Information. These requests are published to ARPA-E’s online application portal and generally describe a research topic, program, or area of interest. They ask the public to submit data, comments, or other information relevant to that topic. In addition, program directors can use an ARPA-E data management, analysis, and visualization tool, which provides a literature search capability, to identify gaps in research and relevant subject matter experts to consult.

For example, during the initial scoping for the Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT) program, ARPA-E reviewed other DOE carbon capture and sequestration research efforts. It determined that there was an opportunity for ARPA-E

to develop a program that would complement, but not duplicate, the existing research at DOE's NETL. Specifically, ARPA-E determined that it could have a significant effect by embracing higher-risk concepts and could use NETL as a partner for transitioning new technology.

Engage. After gathering initial information, a program director will assemble technical peers from within ARPA-E for a presentation on the idea to gather constructive feedback on the initial idea and help focus future development. In order to proceed with the program idea, the program director has to address questions such as

- What is new in this approach?
- What is the value added?
- Does the proposed new program complement research and development efforts in other DOE programs, federal agencies, and the private sector?

Following this internal engagement effort, program directors assemble a scoping workshop, to which—according to program documentation—they may invite between 50 and 70 experts from relevant external technical communities. According to ARPA-E officials and officials from DOE's applied science offices, experts from these other DOE offices have attended these workshops.

ARPA-E Research Program: Ultrahigh - Temperature Impervious Materials Advancing Turbine Efficiency (ULTIMATE)

The ULTIMATE program aims to develop ultrahigh temperature materials for gas turbines, enabling them to operate continuously at 1300 degrees Celsius (2372 degrees Fahrenheit) or higher. Gas turbine efficiency largely depends on the temperature of the gas at the inlet, and the higher the temperature, the higher the efficiency. Improving turbines' efficiency is important for reducing energy usage and carbon emissions, as well as improving the economics of aviation, power generation, and other industrial sectors.

Source: Advanced Research Projects Agency-Energy (ARPA-E). | GAO-22-104775

Program directors may incorporate any feedback they receive at the workshop into their final pitch to ARPA-E peers, which, if successful, results in permission to develop a Funding Opportunity Announcement to create a new research program. For example, an ARPA-E program director collected input from Department of Defense's (DOD) Air Force

Research Lab when scoping the Ultrahigh Temperature Impervious Materials Advancing Turbine Efficiency (ULTIMATE) program. The Air Force Research lab reported that the proposed ARPA-E program would fill a major gap in research aimed at developing new high-temperature structural materials.

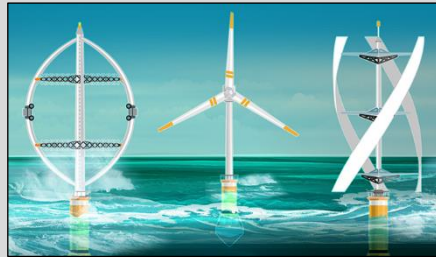
Evaluate. During this stage, ARPA-E solicits, reviews, and evaluates project proposals from the public under a Funding Opportunity Announcement. According to ARPA-E officials, the process for Funding Opportunity Announcement release and review is consistent with DOE's Merit Review Guide for Financial Assistance.¹⁰ This guidance establishes a two-part competitive proposal review process. The first part is an initial compliance review. Under the initial compliance review, ARPA-E may deem proposals to be nonresponsive to the criteria in the funding announcement and not considered for funding. This may happen if, among other considerations, the submission is not different in scientific approach or objective when compared to activities currently supported by or actively under consideration for funding by any other office within DOE.

According to DOE guidance, proposals that have passed the initial compliance review then go through a merit review. Program directors are responsible for nominating reviewers, who may be federal employees, contractors, or experts from academic institutions and industry. Officials from DOE's applied science offices routinely serve as proposal reviewers, according to agency officials, and we found this was the case for several of the programs we reviewed. For each of the proposed projects, the reviewers evaluate, among other things, novelty and scientific and technical merit. They also provide numerical scores and comments about the strengths and weaknesses of the proposal.

¹⁰Department of Energy, Office of Procurement and Assistance Policy, Office of Acquisition Management, *Merit Review Guide for Financial Assistance* (Oct. 1, 2020). This guidance applies to all financial assistance, grants, or agreements within the DOE.

ARPA-E Research Program: Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS)

The ATLANTIS program aims to develop new and potentially disruptive innovations in floating offshore wind turbine technology to enable a greater market share of offshore wind energy, ultimately strengthening and diversifying the array of domestic energy sources available to Americans. These turbines are currently designed to be large and heavy to replicate more familiar onshore wind turbine dynamics, maintain stability, and survive storms. ATLANTIS will pursue radically new design concepts that minimize mass and maximize productive rotor area to provide economical offshore wind power.



Source: Advanced Research Projects Agency-Energy (ARPA-E). | GAO-22-104775

For example, ARPA-E assembled a team of reviewers, including a representative from EERE, to review proposals for the Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS) program. During the merit review, the reviewers evaluated 25 proposals and found potential overlap with other research efforts in three of the proposals. The review board noted that part of one proposal included research on a technology that was funded elsewhere in DOE, and this part of the proposal should be removed from the scope. By doing so, the program would instead focus on novel approaches. Of the three applications with potential overlap, one was not recommended for funding, and the other two were recommended on the condition that the projects scope out areas of potential overlap.

In addition, ARPA-E officials may consider program policy factors during the selection process, which, according to DOE’s Merit Review Guide for Financial Assistance, are non-technical factors that ensure proposed projects maximize the effectiveness of available federal funding and align

with DOE program objectives. Specifically, the program policy factors in ARPA-E's merit reviews include that (1) the proposed project avoids duplication and overlap with other publicly or privately funded projects, and (2) high technical or financial uncertainty of the proposal means that there are no other public, private, or internal funding resources available to support that project.

ARPA-E Research Program: Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors (CIRCUITS)

The CIRCUITS program seeks to accelerate the development and deployment of a new class of efficient, lightweight, and reliable power converters, based on wide-bandgap semiconductors. Power electronic devices condition, control, and convert electrical power in order to optimize the transmission, distribution, and consumption of electricity. Most of today's power electronics are silicon-based with inherent physical limitations to their performance, temperature resilience, and size. In contrast, emerging wide-bandgap materials (e.g., silicon carbide or gallium nitride) and associated devices present opportunities to dramatically improve power converter performance while reducing size and weight.

Source: Advanced Research Projects Agency-Energy (ARPA-E). | GAO-22-104775

In some of the programs we reviewed, reviewers had noted potential duplication as a weakness of a proposal and recommended that the proposal be revised or not funded. For example, the merit review for the Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors (CIRCUITS) research program found one proposal that did not meet several program policy factors, including that the project did not avoid duplication and overlap with other publicly or privately funded projects. The proposed project was subsequently not recommended for funding. The application proposal reviewers included an official from EERE and an official from DOE's National Renewable Energy Laboratory.

According to an ARPA-E overview of the selection process, it is the responsibility of the program director to consider each of the submitted comments and scores when making recommendations for selection to the merit review board, which consists of other ARPA-E program directors. According to DOE's Merit Review Guide for Financial Assistance, the merit review board will discuss the strengths and weaknesses of each proposal, and it may consider the input of the independent reviewers before making a final consensus recommendation to select or not select the proposal for funding.

ARPA-E Takes Actions Outside of Its Program Development Cycle to Coordinate with DOE and Other Stakeholders

ARPA-E coordinates with DOE and other stakeholders by publishing a Strategic Vision that communicates its plans to DOE agencies and by issuing open funding announcements that solicit ideas for innovative research from the public. ARPA-E also participates in departmental working groups on energy-related research initiatives. These actions help ARPA-E and its stakeholders to keep apprised of each other's research priorities and avoid duplicating and overlapping research efforts.

ARPA-E Uses Its Publications to Help Coordination with Stakeholders

ARPA-E uses its Strategic Vision, required by statute, to make its research plans available to the DOE stakeholders with which it coordinates its research.¹¹ ARPA-E's last Strategic Vision was published in 2013. An updated Strategic Vision was required by October 1, 2021.¹² According to ARPA-E officials, the agency has been coordinating within DOE to update the Strategic Vision and plans to release it in February 2022. Congress intends for the Strategic Vision to be used by ARPA-E, in part, to help guide its research investments over the next 4 fiscal years.

Federal agencies can use strategic plans as tools to drive collaboration with other agencies and other partners and establish complementary goals and strategies for achieving results. We have found that agencies that create a means to monitor, evaluate, and report the results of collaborative efforts can better identify areas for improvement.¹³ Further, if agencies are unable to respond to requests or mandates to engage in strategic planning and conduct performance evaluations or if the

¹¹The America Competes Act required the publication of ARPA-E's first Strategic Vision in 2008. America Competes Act § 5012. Amendments to the act also required updated Strategic Visions to be published in 2010 and 2013. America Competes Reauthorization Act of 2010, Pub. L. No. 111-358, § 904, 124 Stat. 3982, 4045 (2011).

¹²42 U.S.C. § 16538(h)(2).

¹³GAO, Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies, [GAO-06-15](#) (Oct. 21, 2005).

information they provide is limited, congressional decision makers could consider, for example, appropriating funds only to those programs that demonstrate their effectiveness and efficiency.¹⁴ Officials in DOE applied science offices told us that an up-to-date Strategic Vision from ARPA-E would help them in planning their own research. More specifically, by knowing more about the technical areas of research ARPA-E plans to undertake, the DOE program offices can better ensure that they appropriately coordinate with ARPA-E on relevant research efforts and undertake research that does not duplicate research being supported by ARPA-E.

ARPA-E coordinates with industry stakeholders on research by publishing an open funding opportunity announcement every 3 years, most recently in April 2021. ARPA-E's open funding announcements serve as a public invitation to stakeholders throughout the energy research and development community to submit proposals—through concept papers—to the agency for consideration of funding. Submissions provide ARPA-E with ideas for new and emerging opportunities to fund transformative energy research and help ARPA-E ensure that the agency does not miss opportunities to support innovative energy research and development opportunities that fall outside the scope of ARPA-E's existing research programs.¹⁵ These announcements also present opportunities for the other DOE applied science offices, which assist ARPA-E in reviewing the concept papers, to gain insights about the research and development opportunities proposed by industry stakeholders.

ARPA-E takes steps to ensure that the proposals it approves for funding avoid duplication and overlap with publicly and privately funded projects, including projects funded by other DOE offices. Specifically, ARPA-E considers applicants' efforts to collaborate across the public and private sectors when determining which proposals to encourage to submit a full application and which full applications to select for award. Open funding announcements are a productive tool for the agency; approximately one-third of the projects ARPA-E considered to be "most successful" resulted from open funding announcements. According to ARPA-E, the agency

¹⁴[GAO-15-49SP](#).

¹⁵In 2015, ARPA-E invested \$125 million into 44 projects across 10 technical areas as a result of its open funding announcement. ARPA-E's 2018 open funding announcement resulted in 77 projects receiving nearly \$200 million across 13 technical areas.

plans to award \$100 million through its 2021 open funding announcement.

ARPA-E Participates in DOE-Led Working Groups

ARPA-E officials participate with multiple DOE offices, including the applied science offices, in intra-agency working groups that serve to inform the participants about each other's research priorities and activities. In addition to the workshops and other coordination that occurs as part of ARPA-E's program management cycle, DOE offices lead multiple working groups related to energy research and development; these working groups facilitate department-wide coordination on research. ARPA-E participates on these working groups to, in part, ensure the agency is coordinating on research topics that may be relevant to other DOE offices.

For example, according to officials from FECM, ARPA-E and FECM coordinated through DOE's carbon capture working group on research related to carbon capture technologies. ARPA-E's Innovative Materials & Processes for Advanced Carbon Capture Technologies (IMPACCT) program is focused on technologies intended to minimize the cost of removing carbon dioxide from coal-fired power plant exhausts, and it is, therefore, relevant to FECM's mission. ARPA-E funded 15 projects under the IMPACCT program. These projects were focused on technologies that were unlikely to be funded by other research institutions due to technical uncertainties and, therefore, had not been supported by FECM's own carbon capture program. According to ARPA-E officials, due in part to the strategic coordination efforts resulting from the working group, the FECM carbon capture program supported the advancement of six projects beyond the laboratory scale following their completion from the ARPA-E IMPACCT program. FECM subsequently supported these technologies through a pilot phase and is now conducting studies for commercial application. See appendix II for additional examples of ARPA-E's ongoing coordination efforts with DOE stakeholders, among others.

ARPA-E's participation in department-wide strategic coordination efforts has been partly aided by its inclusion in DOE's Science and Energy Tech Teams (SETT) working group framework. SETT and its predecessor, the Research and Technology Investment Committee (RTIC), were created by DOE in response to congressional requirements to collaborate and

coordinate between and among DOE's research activities.¹⁶ ARPA-E has been an active participant in DOE's research efforts under these working groups. For example, ARPA-E participated in the RTIC working group on critical minerals and is currently participating in the SETT working group for energy storage research. According to FECM officials, there has been better coordination and communication between DOE's research efforts, including ARPA-E, since DOE began the working groups.

Agency Comments

We provided a draft of this report to DOE for review and comment. DOE provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committee, the Secretary of Energy, and other interested parties. In addition, the report will be available at no charge on the GAO Web site at <http://www.gao.gov>.

¹⁶The Department of Energy Research and Innovation Act of 2018 requires collaboration and coordination between and among DOE's research activities. Specifically, the act requires DOE to identify strategic opportunities for collaborative research, development, demonstration, and commercial application of innovative science and technologies; coordination and consolidation of DOE's existing activities and programs; and prioritization of activities that use domestic resources. Pub. L. No. 115-246, § 203, 132 Stat. 3130, 3135 (2018) (codified at 42 U.S.C. § 18631). In addition, the act added elements to an existing requirement to periodically review all of the science and technology activities of DOE in a strategic framework. In response to these requirements, DOE reported that they established the DOE RTIC. According to DOE officials, as of 2021, the department has discontinued the RTIC effort and renamed the department's working groups SETT.

If you or your staffs 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 major contributions to this report are listed in appendix IV.

A handwritten signature in black ink that reads "Frank Rusco". The signature is written in a cursive style with a long, sweeping horizontal line extending to the right from the end of the name.

Frank Rusco
Director, Natural Resources and Environment

Appendix I: Scope and Methodology

You asked us to review Advanced Research Projects Agency-Energy's (ARPA-E) efforts to coordinate its research with other Department of Energy (DOE) offices. This report examines (1) the practices ARPA-E uses to manage overlap and duplication of its energy research with DOE's other research efforts, and (2) the actions ARPA-E takes to coordinate with DOE stakeholders in conducting its energy research and development activities.

To examine ARPA-E's practices for managing overlap and avoiding duplication of research, we reviewed DOE and ARPA-E guidance, such as guidance on new program development and project selection and templates used by ARPA-E's program directors. We also interviewed ARPA-E officials and officials from DOE's applied science offices about the steps ARPA-E takes to implement this guidance, including the steps intended to help identify potential instances of duplication. DOE's applied science offices include the (1) Office of Electricity, (2) Office of Energy Efficiency and Renewable Energy, (3) Office of Science, and (4) Office of Fossil Energy and Carbon Management.

We also reviewed supporting documentation from six examples of ARPA-E research programs to understand how ARPA-E has applied these practices to existing programs. We selected the six programs by identifying programs that appear to be, or could potentially be, duplicative because they involve research in the same or similar technological area (e.g., wind power technology). The six programs do not represent a generalizable sample of ARPA-E programs; instead, we used these programs to (1) illustrate some of the controls ARPA-E has in place to prevent inefficiencies or ineffectiveness as a result of duplication or overlap with DOE's other energy-related research and development activities, and (2) provide contextual sophistication for ARPA-E's funding decisions.

We reviewed ARPA-E program guidance documents, such as merit review reports and stakeholder briefings that identify the stages of ARPA-E's program management cycle, including the steps identified in the guidance that are to be taken to coordinate with key stakeholders, such as DOE's applied science offices. We compared ARPA-E's coordination

practices identified in its program guidance documents to standards for internal controls. *Standards for Internal Control in the Federal Government* provide the overall framework for establishing and maintaining an effective internal control system stating that management should establish an organizational structure, assign responsibility, and delegate authority to achieve the entity's objectives.¹

To examine the actions ARPA-E takes to coordinate with other DOE stakeholders, we assessed the extent to which ARPA-E was coordinating with DOE's applied science offices, consistent with applicable laws and best practices. These included the America COMPETES Act and the Department of Energy Research and Innovation Act,^{2,3} as well as standards for best practices for coordination.⁴ Specifically, we assessed the extent to which ARPA-E was coordinating with DOE's applied science offices consistent with applicable laws and best practices. We interviewed officials from DOE's applied science offices and ARPA-E to discuss their coordination and collaboration efforts related to energy research and development. We asked questions about the purpose, scope, and extent of ongoing coordination between the DOE offices, including in which DOE-led coordination efforts in which they participate. We requested and reviewed additional documentation from ARPA-E that illustrated the agency's collaborative practices—such as ARPA-E's Strategic Vision, examples of open funding announcements published in the *Federal Register*, and agency presentations—to determine the extent to which ARPA-E coordinates with DOE stakeholders outside of its program development cycle. In addition, we reviewed ARPA-E program guidance, examples of funding announcement opportunities, and other ARPA-E documentation to determine the extent ARPA-E coordinates with other DOE offices on energy-related research across energy-related research and development technical areas.

We conducted this performance audit from February 2021 to February 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to

¹[GAO-14-704G](#), p. 27.

²America COMPETES Act, Pub. L. No. 110-69, 121 Stat. 572 (2007).

³Department of Energy Research and Innovation Act, Pub. L. No. 115-246, 132 Stat. 3130 (2018).

⁴*Fragmentation, Overlap, and Duplication: An Evaluation and Management Guide*, [GAO-15-49SP](#) (Washington, D.C.: April 14, 2015).

obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Examples of Activities through Which Advanced Research Projects Agency-Energy Coordinates with Department of Energy and Other Stakeholders

ARPA-E coordinates on research and development with other DOE stakeholders through various efforts, including intra-agency working groups. In addition, ARPA-E participates in coordination efforts led by other federal government agencies. According to ARPA-E officials, these efforts help enhance ARPA-E's knowledge of industry stakeholders' energy-related research and development efforts. See table 1 for examples of ARPA-E's ongoing coordination efforts related to energy research and development.

Appendix II: Examples of Activities through Which Advanced Research Projects Agency-Energy Coordinates with Department of Energy and Other Stakeholders

Table 1: Examples of Advanced Research Projects Agency-Energy (ARPA-E) Ongoing Coordination Activities

Coordination activity	Name of coordination activity	Lead organization	Description of coordination activity
Working group	Executive Order (EO) 13985 on Equity – Research and Development	Department of Energy (DOE) Office of Economic Impact & Diversity	Working group to discuss equity in multiple aspects of DOE’s research activities.
Working group	Earthshot Steering Committee	DOE Office of Undersecretary for Science and Energy	Working group as part of a White House directive serving as a gatekeeper to various DOE Earthshot groups, including Hydrogen, Battery Storage, and Carbon Dioxide Removal.
Working group	Carbon Dioxide Removal Task Force	DOE Office of Fossil Energy and Carbon Management (FECM)	ARPA-E’s involvement is mainly to assist in literature review.
Working group	Tribal Energy Steering Committee	DOE Intergovernmental and External Affairs Office	Coordinating across the agency to respond to the President’s Memorandum on Tribal Consultation and Strengthening Nation-to-Nation Relationships.
Working group	Research Security and Integrity Policy Working Group	DOE Office of Energy Efficiency and Renewable Energy (EERE); Office of Science; National Nuclear Security Administration (NNSA)	DOE intra-agency working group responsible for developing policies to address security issues in financial assistance (e.g., grants, cooperative agreements).
Working group	Exploring opportunities for interagency coordination on compact-fusion research and development	DOE ARPA-E	An aerospace corporation hosted a virtual workshop on April 28, 2021, on compact fusion. Follow-up working groups are meeting to explore potential next steps for interagency coordination in compact-fusion development.
Working group	Ammonia Team	DOE EERE, Hydrogen and Fuel Cell Technologies Office	Planning for ammonia-related program activities in EERE.
Working group	Thermal energy storage	DOE EERE, Solar Energy Technologies Office (SETO)	Meetings to discuss various thermal energy storage projects.
Working group	Fed Field Validation	U.S. Army, General Services Administration	Informal coordination group that discusses various building technology demonstration efforts.
Working group	Justice40 Community of Practice	DOE Office of Economic Impact and Diversity (ED)	Led by ED, this forum was created to collaborate, share tips and best practices, ask questions and provide support in the advancement of Justice40 initiatives within the Department.
Working group	EO 13985 on Equity - Demo	DOE ED	Working group discussing equity in multiple aspects of DOE’s research activities. This working group focuses on demonstrations.
Working group	Federal Consortium for Advanced Batteries	DOE EERE, Vehicle Technologies Office	Multi-agency effort to build a domestic supply chain for lithium-based batteries.

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Coordination activity	Name of coordination activity	Lead organization	Description of coordination activity
Working group	Interagency Advanced Power Group	Varies	This is a long-standing multi-agency group to exchange ideas and information on power and energy programs.
Working group	Propulsion and Power System Alliance	Varies	Interagency group primarily focused on systems for aircraft, such as turbines.
Working group	Power Africa	U.S. Agency for International Development	This is the coordination group for Power Africa.
Working group	DOD Energy and Power Technologies Community of Interest	DOD Research and Engineering Enterprise	Coordinates energy and power science and technology research among the various elements of DOD.
Working group	Critical Minerals Crosscut	DOE: FECM, EERE, Office of Science, Office of International Affairs	Interoffice communication of projects progress, review of pending funding opportunity announcements, and background preparation for trilateral commission on critical mineral sourcing.
Working group	Long-Duration Storage Shot	DOE Office of Electricity	Coordinating on DOE strategy to develop long-duration energy storage technology development, as well as technology transfer, valuation and policy, workforce development, and manufacturing.
Working group	Hydrogen Shot	EERE Hydrogen and Fuel Cells Technologies Office	Coordinating on DOE strategy to reduce the cost and carbon intensity of hydrogen
Working group	EERE hydrogen and fuel cells working group	Hydrogen and Fuel Cell Technologies Office	Monthly meeting to coordinate among several DOE offices regarding ongoing and potential new funding opportunities.
Working group	Advanced reactor catalyst meeting	DOE Office of Nuclear Energy	Working group to advance nuclear reactor needs across the DOE.
Working group	Supercritical CO2 Tech Team crosscut meeting	DOE EERE, SETO	Working group to discuss equity in multiple aspects of DOE's research activities in the area of supercritical carbon dioxide technologies.
Working group	Supercritical Carbon Dioxide Technology Team	DOE Office of Undersecretary for Science and Energy	Providing scientific/engineering input and strategic guidance on super-critical carbon dioxide removal research efforts and technical targets.
Working group	Carbon Management Science and Energy Technical Team (SETT)	DOE Office of Undersecretary for Science and Energy	Providing scientific/engineering input and strategic guidance on potential research efforts for carbon neutral fuel production pathways and technical pathway targets.
Working group	Biomass Research and Development Initiative (BRDI)	DOE EERE; U.S. Department of Agriculture Office of the Chief Scientist	Serving on BRDI Operations Committee and working to align inter-agency bioeconomy research efforts and offering strategic guidance on technical direction for ongoing and new collaborative efforts.
Working group	Carbon Cycle Interagency Working Group	Global Change Research Program	Participating in technical review of and development of the carbon cycle and carbon dioxide removal chapters for the National Climate Assessment.

Appendix II: Examples of Activities through Which Advanced Research Projects Agency-Energy Coordinates with Department of Energy and Other Stakeholders

Coordination activity	Name of coordination activity	Lead organization	Description of coordination activity
Working group	Offshore wind coordination meeting	DOE Wind Energy Technologies Office, EERE	A monthly meeting to offer offshore wind related updates across many DOE agencies for the purposes of coordinating efforts.
Working group	Investment Performance Tracking	DOE Office of Policy	Working group focused on developing performance metrics for the bipartisan infrastructure bill and reconciliation package deployment funds across the DOE.
"Work Stream 5"	Office of Clean Energy Demonstrations	DOE ARPA-E, Office of the Chief Financial Officer	Co-leading work stream group developing key performance metrics for the DOE's OCED.
Interagency Policy Committee	Manufacturing Scale Up	Executive Office of the President, Council of Economic Advisors	Panel of internal and external experts exploring policy options to scale manufacturing in the U.S.
Review panel	DARPA Reefense Program Review Committee	DOD Defense Advanced Research Projects Agency	ARPA-E serving as a proposal reviewer for the development of environmentally sound, ecologically friendly coastal stabilization projects to mitigate severe storm damage and erosion.
Review panel	Small Business Technology Transfer on power electronics, electromagnetism, and controls	DOD Office of Naval Research	Selection to peer reviews over the course of the program.
Review panel	Advanced Thermal Management of Power Converters	DOD Office of Naval Research	Selection to peer reviews over the course of the program.
Ongoing dialogue	Carbon Sequestration via Sinking Kelp	National Oceanic and Atmospheric Administration (NOAA)	Ongoing coordination with NOAA on carbon sequestration via sinking kelp.
Ongoing dialogue	Demo Partnership	DOE ARPA-E	ARPA-E program to demonstrate ARPA-E technology at DOD installations.
Ongoing dialogue	Zero-emission iron & steel production coordination	DOE Advanced Manufacturing Office & ARPA-E	Coordinating regarding scope, technologies, overlap, and potential follow-on funding for potential program for iron and steel decarbonation.
Ongoing dialogue	Zero-emission iron & steel production coordination	DOE Vehicle Technologies Office & ARPA-E	Coordinating regarding scope, technologies, overlap, and potential follow-on funding for potential program on iron and steel decarbonation.
Ongoing dialogue	Beyond Lithium-Ion Battery Technologies	Office of the Director of National Intelligence, Intelligence Advanced Research Projects Activity and DARPA	Discuss beyond lithium-ion battery technologies.
Ongoing dialogue	Maritime decarbonization	Federal Inter-agency working group	Monthly information-sharing seminar.
Ongoing dialogue	Ocean Energy	DOE Water Power Technologies Office	Coordinating regarding scope, technologies, and overlap for potential program on marine energy and blue economy.

Appendix II: Examples of Activities through Which Advanced Research Projects Agency-Energy Coordinates with Department of Energy and Other Stakeholders

Coordination activity	Name of coordination activity	Lead organization	Description of coordination activity
Ongoing dialogue	Pipeline mapping and rehabilitation	DOE FECM, Department of Transportation Pipeline and Hazardous Materials Safety Administration	Coordination on pipeline mapping and rehabilitation programs.
Ongoing dialogue	De-carbonization of Rail Freight	DOE Vehicle Technologies Office	Discussions on coordinating with ARPA-E's Lowering CO2: Models to Optimize Train Infrastructure, Vehicles, and Energy Storage program.

Source: GAO analysis of ARPA-E information. GAO-21-104775

Note: ARPA-E officials provided information about these coordination efforts. We did not independently verify ARPA-E's participation in each of these efforts.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco at 202-512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, Karla Springer (Assistant Director), R. Denton Herring (Analyst-In-Charge), Mark Braza, Antoinette Capaccio, Gwendolyn Kirby, Dan Royer, Tind Shepper Ryen, Sarah Veale, and Daniel Will made key contributions to this report.

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