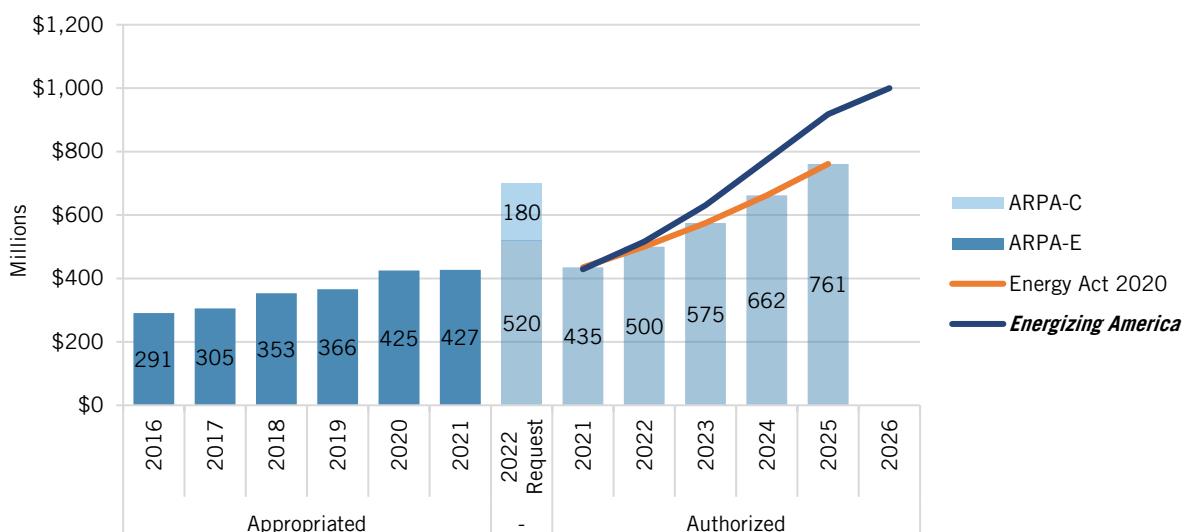


# Federal Energy RD&D: ARPA-E

COLIN CUNLIFF AND LINH NGUYEN | JUNE 2021

Modeled after the highly successful Defense Advanced Research Projects Agency (DARPA), the Advanced Research Projects Agency-Energy (ARPA-E) advances high-potential, high-impact energy technologies that could radically improve U.S. economic prosperity, national security, and environmental well-being, but are too early for private-sector investment. Its grants help fund energy innovators that are developing technologies to solve critical crosscutting, real-world problems in transportation, electricity, building, and other sectors.

**Figure 1: *Energizing America* recommends ramping funding to \$1 billion in FY 2026.<sup>1</sup>**



## What's at Stake

Created by Congress in 2007, and funded for the first time in 2009, ARPA-E is an important new institution that has proven to be a valuable and versatile catalyst of energy innovation.<sup>2</sup> Compared with traditional research, development, and demonstration (RD&D) programs, ARPA-E was designed to focus more on the potential impact of the research that it funds and to fill “white spaces” unexplored by other federal energy RD&D programs. To qualify for ARPA-E funding, each program must explain how its success will change the global energy landscape, identify the key barriers to making such a change, and lay out a set of milestones and metrics for assessing progress.

ARPA-E's high-risk/high-reward ventures are already yielding big returns. As of March 2021, ARPA-E had provided \$2.6 billion in RD&D funding to over 1,000 projects; 177 ARPA-E projects had attracted more than \$4.9 billion in private-sector follow-on funding; 88 ARPA-E project teams had formed new companies to advance their technologies; and 237 ARPA-E projects had partnered with other government agencies for further development. Moreover, ARPA-E projects have generated 4,614 peer-reviewed journal articles, along with 716 new patents.<sup>3</sup> The Bipartisan Policy Center noted that other Department of Energy (DOE) offices have started to adopt ARPA-E's best practices.<sup>4</sup>

ARPA-E has had limited success in ensuring that its awardees are able to scale their inventions from the proof-of-concept stage into commercial-scale products.<sup>5</sup> The Information Technology and Information Foundation (ITIF) has written frequently about the “scale-up gap” in federal innovation policies and the importance of programs that demonstrate and validate technologies at commercial or near-commercial scale under real-world conditions.<sup>6</sup> The average size of an ARPA-E award, on the order of \$3-4 million per project, is typically not enough to address scaling challenges. To remedy this, ARPA-E launched a new Seeding Critical Advances for Leading Energy technologies with Untapped Potential (SCALEUP) program in 2020, in which successful ARPA-E projects can apply for follow-on funding to help them scale and demonstrate their technologies.<sup>7</sup> The awards under SCALEUP are larger than traditional ARPA-E awards, and have ranged from \$2.5–19.9 million.<sup>8</sup> As of January 2021, ARPA-E has awarded \$70 million to ten projects through the SCALEUP program, out of a total semifinalist pool of 22.<sup>9</sup>

Congress has continuously shown bipartisan support for the agency, expanding its budget by 46 percent over the last five years. The Energy Act of 2020 reauthorizes ARPA-E and expands its goals to include emissions reduction, improved energy efficiency, management of radioactive waste and nuclear spent fuel, and improved energy infrastructure. The bill authorizes \$435 million for FY 2021, \$500 million for FY 2022, \$575 million for FY 2023, \$662 million for FY 2024, and \$761 million for FY 2025.

Figure 1 shows historical appropriations for ARPA-E for FY 2016 through FY 2021 and the FY 2022 budget request. The request includes \$200 million for a new ARPA-C program that focuses on climate-related innovations to increase adaptation and resilience.<sup>10</sup> The orange line shows authorized funding levels from the Energy Act of 2020. The blue line shows recommended funding levels from the *Energizing America* report (see box 1).

### Box 1: Recommendations for ARPA-E

The *Energizing America* report coauthored by ITIF and Columbia University’s Center on Global Energy Policy offers several recommendations to maximize ARPA-E’s contribution to energy innovation. Similarly, ITIF’s November 2017 report “ARPA-E: Versatile Catalyst for U.S. Energy Innovation” makes recommendations to DOE and Congress to increase ARPA-E’s effectiveness:

- Congress should increase ARPA-E’s funding to \$1 billion per year in 2025 to fulfill the target set by the 2007 National Academies *Rising Above the Gathering Storm* report.<sup>11</sup>
- ARPA-E’s distinctive operating procedures should be maintained. While collaboration between ARPA-E and the rest of DOE is encouraged, DOE should resist exerting greater control over ARPA-E.<sup>12</sup>
- An ARPA-E trust fund should be established to sustain and stabilize the agency’s budget. A portion of revenues from oil and gas production on federal lands should be allocated to the ARPA-E trust fund.<sup>13</sup>

## ARPA-E RD&D Programs and Projects

ARPA-E funds are not bound by the technology-specific silos of DOE's applied-energy offices. Rather, ARPA-E's programs are developed by technical experts drawn from industry and academia who, during their three- or four-year terms as program managers, engage intensively with communities of researchers and innovators to create targeted, time-limited programs that seek to fill the "white space" of underexplored but potentially great ideas. In addition, ARPA-E holds open competitions every three years to bring to light promising ideas that might otherwise slip through the cracks between energy RD&D programs.

ARPA-E currently funds 393 projects across 42 active programs, which are broadly organized into 4 areas: electricity generation; efficiency and emissions; transportation and storage; and grid and grid storage.<sup>14</sup> These projects provide a sense of ARPA-E's accomplishments:

- **Primus Power**, which sells zinc-bromide flow batteries, was named one of the prestigious 2019 Global Cleantech 100 companies, and had raised almost \$100 million in equity investment as of late 2018. In June 2019, the California Energy Commission awarded Primus a \$4 million grant to increase the company's manufacturing capacity of EnergyPod 2, a long-duration, low-cost zinc bromide flow battery.<sup>15</sup>
- **Rebellion Photonics**, based in Houston, Texas, produced monitoring imagers that detect methane leaks in real time to reduce environmental effects from the gas supply chain. The company continued to make progress in its intelligent monitoring platform, the only of a kind that "visually identifies and quantifies gas releases," and demonstrated rapid growths in revenue before it was acquired by Honeywell in December 2019.<sup>16</sup>
- An ARPA-E-funded research team lead by **Clemson University** in South Carolina is developing resilient sorghum varieties that will be optimized for energy biomass production in the Southeast on land not suitable for food production.<sup>17</sup>
- **Bridger Photonics**, based in Bozeman, Montana, developed and commercialized a Gas Mapping LiDAR (GML) technology to detect and quantify methane leakage throughout the natural gas value chain, and eliminate the need for costly ground-crew site visits. In 2020, DOE awarded a \$4.6 million grant as part of the SCALEUP program to scale and expand GML operations.<sup>18</sup>

## Key Elements of the FY 2022 Budget Proposal<sup>19</sup>

The budget proposal seeks \$500 million for ARPA-E, an 18 percent increase above the FY 2021 level. ARPA-E plans to release fifteen new funding opportunity announcements in areas that are not represented in the current portfolio, including:

- **Materials for carbon-neutral or carbon-negative buildings**, including those derived from feedstocks such as forest and agricultural crop residues, as well as direct use of greenhouse gases such as carbon dioxide and methane.
- **Advanced battery electrodes and conductors** that reduce charging times, increase capacity at lower weights, and utilize easily sourced materials.

- **Advanced fusion approaches and energy applications** focused on fuel options and power conversions that are less scientifically mature than the Deuterium-tritium (D-T) thermonuclear reaction.
- **SCALEUP expansion**, both in scope and in funding level, to push previous early-stage ARPA-E projects to commercialization.

## Further Reading

- Varun Sivaram et al., *Energizing America: A Roadmap to Launch a National Energy Innovation Mission* (ITIF and Columbia University SIPA Center on Global Energy Policy, 2020), <http://www2.itif.org/2020-energizing-america.pdf>.
- David M. Hart and Michael Kearney, “ARPA-E: Versatile Catalyst for U.S. Energy Innovation” (ITIF, November 2017), <http://www2.itif.org/2017-arpae-energy-innovation.pdf>.
- Anna Goldstein et al., “Startups supported by ARPA-E were more innovative than others but an investment gap may remain,” *Nature Energy* 5 (September 2020), 741–742, <https://www.nature.com/articles/s41560-020-00691-8.pdf>.

## Acknowledgments

The authors wish to thank David M. Hart for providing input to this report. Any errors or omissions are the authors' alone.

## About the Authors

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

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

## About ITIF

The Information Technology and Innovation Foundation (ITIF) is an independent, nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized by its peers in the think tank community as the global center of excellence for science and technology policy, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

For more information, visit us at [www.itif.org](http://www.itif.org).

## ENDNOTES

1. Varun Sivaram et al., *Energizing America: A Roadmap to Launch a National Energy Innovation Mission* (ITIF and Columbia University SIPA Center on Global Energy Policy, 2020), 114–115, <https://itif.org/publications/2020/09/15/energizing-america-roadmap-launch-national-energy-innovation-mission>.
2. David M. Hart and Michael Kearney, “ARPA-E: Versatile Catalyst for U.S. Energy Innovation” (Washington, D.C.: ITIF, November 2017), <http://www2.itif.org/2017-arpae-energy-innovation.pdf>.
3. ARPA-E, “ARPA-E Impact,” accessed March 3, 2021, <https://arpa-e.energy.gov/about/our-impact>; see also National Academies of Science, Engineering and Medicine (NASEM), Committee on Evaluation of the Advanced Research Projects Agency-Energy (ARPA-E), Board on Science, Technology, and Economic Policy, “An Assessment of ARPA-E” (Washington, D.C.: National Academies Press, 2017).
4. Erin Smith and Addison Stark, “ARPA-E at 10.” (Bipartisan Policy Center, April 2019), <https://bipartisanpolicy.org/blog/arpa-e-at-10/>.
5. National Academies of Sciences, Engineering, and Medicine (NASEM), *An Assessment of ARPA-E* (The National Academies Press, 2017), <https://doi.org/10.17226/24778>; Anna Goldstein et al., “Patenting and business outcomes for cleantech startups funded by the Advanced Research Projects Agency-Energy” *Nature Energy* 5, September 25, 2020, 803–810, <https://doi.org/10.1038/s41560-020-00683-8>.
6. Robert Rozansky and David M. Hart, “More and Better: Building and Managing a Federal Energy Demonstration Project Portfolio” (ITIF, 2020) <https://itif.org/publications/2020/05/18/more-and-better-building-and-managing-federal-energy-demonstration-project>; David M. Hart, “Across the ‘Second Valley of Death’: Designing Successful Energy Demonstration Projects” (ITIF, 2017), <https://itif.org/publications/2017/07/26/across-%22second-valley-death%22-designing-successful-energy-demonstration>.
7. Advanced Research Projects Agency-Energy (ARPA-E), “SCALEUP—Seeding Critical Advances for Leading Energy technologies with Untapped Potential,” accessed April 5, 2021, <https://arpa-e.energy.gov/scaleup>.
8. Ibid.
9. Advanced Research Projects Agency-Energy (ARPA-E), “SCALEUP Launch Pad, ARPA-E’s Semi-Finalists,” accessed April 5, 2021, <https://arpa-e.energy.gov/technologies/scaleup-launch-pad-2020> accessed April 5, 2021.
10. DOE, “FY 2022 Congressional Budget Justification” Volume 3.2, (DOE Chief Financial Officer DOE/CF-0174, May 2021), 356–363, <https://www.energy.gov/sites/default/files/2021-06/doe-fy2022-budget-volume-3.2-v3.pdf>.
11. Varun Sivaram et al., *Energizing America*, 114–115.
12. David M. Hart and Michael Kearney, “ARPA-E: Versatile Catalyst for U.S. Energy Innovation” (Washington, D.C.: ITIF, November 2017), <http://www2.itif.org/2017-arpae-energy-innovation.pdf>.
13. Ibid.
14. ARPA-E, accessed March 3, 2021, <https://arpa-e.energy.gov/technologies/programs>.
15. California Energy Commission, “Minutes of June 12, 2019, Energy Commission Business Meeting” (California, June 2019), [https://www.energy.ca.gov/sites/default/files/2019-07/2019-06-12\\_Minutes.pdf](https://www.energy.ca.gov/sites/default/files/2019-07/2019-06-12_Minutes.pdf).
16. Honeywell, “Honeywell Acquires Rebellion Photonics, a Leader in Intelligent, Automated, Visual Gas Monitoring Solutions” (Charlotte, NC, December 2019), <https://www.honeywell.com/en-us/newsroom/pressreleases/2019/12/honeywell-acquires-rebellion-photonics-a-leader-in-intelligent-automated-visual-gas-monitoring-solutions>; ARPA-E, “Rebellion Photonics (MONITOR)” (DOE, May

- 2018), <https://arpa-e.energy.gov/?q=impact-sheet/rebellion-photonics-monitor>; Olivia Pulsinelli, “Honeywell Acquires Fast-Growing Houston-Based Energy Tech Co.” (*Houston Business Journal*, December 2019), <https://www.bizjournals.com/houston/news/2019/12/18/honeywell-acquires-fast-growing-houston-based.html>.
17. “ARPA-E Impacts: A Sampling of Project Outcomes, Volume III,” edited by Dr. Yanzhi Ann Xu (ARPA-E, 2018), 41, <https://arpa-e.energy.gov/sites/default/files/documents/files/ARPA-E-Impact-Book-Volume-3-Final-May10.pdf>.
  18. Advanced Research Projects Agency-Energy (ARPA-E), “DOE Announces \$24 Million for Commercial Scaling of Battery and Methane Detection Technologies,” accessed April 6, 2021, <https://arpa-e.energy.gov/news-and-media/press-releases/doe-announces-24-million-commercial-scaling-battery-and-methane>; ARPA-E, “Bridger Photonics,” accessed April 6, 2021, <https://arpa-e.energy.gov/technologies/scaleup-launch-pad-2020/bridger-photonics>.
  19. DOE, “FY 2022 Congressional Budget Justification” Volume 3.2, (DOE Chief Financial Officer DOE/CF-0174, May 2021), 338-353, <https://www.energy.gov/sites/default/files/2021-06/doe-fy2022-budget-volume-3.2-v3.pdf>.