U.S. DEPARTMENT OF ENERGY

ARPA-E Fiscal Year 2023 Annual Report

Report to Congress
August 2025

United States Department of Energy
Washington, DC 20585

Message from the Acting Director

The mission of the Department of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) is to enhance the economic and energy security of the United States (U.S.) through the development of energy technologies and to ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies. To fulfill this mission, ARPA-E maintains a dynamic funding portfolio in which roughly one-third of programs turnover annually. ARPA-E supports project teams whose technologies advance the boundaries of science. The agency helps those teams to both develop and strategically prepare to deploy their technologies.

In fiscal year (FY) 2023, ARPA-E announced a total of 13 funding opportunities for up to $363.0 million in early-stage funding. Of these 13 funding opportunities, six were notices of funding opportunities (NOFOs), which are multi-topic solicitations designed to support high-risk research and development (R&D) leading to the development of potentially disruptive new technologies. The remaining seven were Exploratory Topics, which are intended to explore new areas of technology development that, if successful, could establish new program areas for ARPA-E, or complement the current portfolio of ARPA-E programs.

ARPA-E selected 110 projects in FY 2023 for a total of $300.7 million in funding. Each project ARPA-E selects is managed as part of either a focused program, OPEN program, or Exploratory Topic.

In addition to providing both financial support and technical guidance and project management to high-potential, high-impact R&D, ARPA-E provides commercialization guidance, called Technology-to-Market. ARPA-E tracks key early indicators that help illustrate how the agency's support drives commercial impact. This impact can include private-sector follow-on funding, new company formation, partnership with other government agencies, publications, inventions, and patents.

Many ARPA-E project teams have continued to advance their technologies toward market impact since being selected for agency support. As of September 2023, 150 new companies have been formed by ARPA-E projects, 323 patent licenses for new inventions have been reported from ARPA-E projects, 306 projects have partnered with other government agencies for further development, and 218 project teams have attracted more than $11.8 billion in private-sector follow-on funding to continue to advance the commercialization of their technology.[1] Additionally, ARPA-E has provided financial assistance awards for R&D to 27

[1] The 'Follow-on Funding' value includes any commercial funding committed or received from other sources (e.g., private investors, venture capital) after the effective date of the ARPA-E award to support the ARPA-E-funded project or work that is directly or indirectly related to the ARPA-E funded project.

companies that have either been acquired, merged, or made initial public offerings (IPO)[2] with market valuations worth $21.9 billion total.

As of September 2023, ARPA-E projects have advanced general scientific understanding and technological innovation through 7,047 peer-reviewed journal articles and 1,073 patents issued by the United States Patent and Trademark Office. These indicators demonstrate that ARPA-E's approach to selecting, funding, and actively managing early-stage energy R&D continues to advance state of the art energy, science, and engineering, and define new opportunities for commercialization.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable Mike Lee**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable Martin Heinrich**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Dave McCormick**
  Chair, Subcommittee on Energy
  Senate Committee on Energy and Natural Resources

- **The Honorable Ruben Gallego**
  Ranking Member, Subcommittee on Energy
  Senate Committee on Energy and Natural Resources

- **The Honorable Brett Guthrie**
  Chair, House Committee on Energy and Commerce

- **The Honorable Frank Pallone, Jr.**
  Ranking Member, House Committee on Energy and Commerce

- **The Honorable Brian Babin**
  Chairman, House Committee on Science, Space, and Technology

- **The Honorable Zoe Lofgren**
  Ranking Member, House Committee on Science, Space, and Technology

[2] The total enterprise valuation number for public listing transactions, acquisitions, and company sales is reported separately from the 'follow on funding' number. This 'acquired, merged, and made initial IPO' number includes development capital and equity valuation minus cash on hand.

- **The Honorable Randy Weber**
  Chairman, Subcommittee on Energy
  House Committee on Science, Space, and Technology

- **The Honorable Deborah Ross**
  Ranking Member, Subcommittee on Energy
  House Committee on Science, Space, and Technology

- **The Honorable Susan Collins**
  Chair, Senate Committee on Appropriations

- **The Honorable Patty Murray**
  Vice Chair, Senate Committee on Appropriations

- **The Honorable John Kennedy**
  Chairman, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Patty Murray**
  Ranking Member, Subcommittee on Energy and Water Development
  Senate Committee on Appropriations

- **The Honorable Tom Cole**
  Chairman, House Committee on Appropriations

- **The Honorable Rosa DeLauro**
  Ranking Member, House Committee on Appropriations

- **The Honorable Chuck Fleischmann**
  Chairman, Subcommittee on Energy and Water Development, and Related Agencies
  House Committee on Appropriations

- **The Honorable Marcy Kaptur**
  Ranking Member, Subcommittee on Energy and Water Development, and Related Agencies
  House Committee on Appropriations

If you have any questions or need additional information, please contact me or Ms. Meg Roessing, Deputy Director for External Coordination, Office of Budget, Office of the Chief Financial Officer, at (202) 586-3128 or Mr. Scott Marks, Deputy Assistant Secretary for Senate Affairs or Mr. Michael Inguanta, Deputy Assistant Secretary for House Affairs, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Dr. Daniel Cunningham
Acting Director
Advanced Research Projects Agency-Energy

Executive Summary

The Advanced Research Projects Agency-Energy (ARPA-E) funds high-risk, high-potential energy innovation R&D. The agency's mission is to advance energy innovations that will create a more secure, affordable, and sustainable American energy future.

This report presents a summary of ARPA-E's funding activities during FY 2023 – including both notices of funding opportunities (NOFOs) and project selections. ARPA-E NOFOs are notices of new funding opportunities tied to a specific ARPA-E initiative (e.g., focused programs, OPEN solicitations, Exploratory Topics). Energy innovators with relevant ideas are encouraged to apply to the NOFO. After a comprehensive review process, applicants may be selected to perform R&D work under that funding opportunity. An agreement is negotiated between ARPA-E and the selectee, including specific technical milestones, followed by execution of the award.

ARPA-E focuses on early-stage energy technologies that can be meaningfully advanced with modest funding over a defined time period. ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement provide America's energy innovators with funding, technical assistance, and market awareness. As an aspect of its due diligence, ARPA-E thoroughly reviews all applications and technologies to ensure that funding is provided to topics not likely to be pursued by industry, Federal agencies, or DOE applied R&D programs.

In FY 2023, ARPA-E announced 13 funding opportunities for up to $363.0 million total[3] which cover a broad array of energy technologies:

1. Up to $10.0 million through the **INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL)** Exploratory Topics[4] funding opportunity to develop technology to model the low-carbon intermodal freight transportation system of the future;

2. Up to $10.0 million through the **Creating Revolutionary Energy And Technology Endeavors (CREATE)** Exploratory Topics[4] funding opportunity to help establish potential new areas of technology development and provide ARPA-E with information that could lead to new focused funding programs;

[3] The amount listed is at the time of the funding opportunity was announced. The funding amount for the program is subject to change at the time of project selection or based on award negotiations and ongoing program management.

[4] In 2022, ARPA-E issued the Exploratory Topics funding opportunity, an ongoing funding mechanism to explore high-risk R&D leading to the development of potentially disruptive new technologies across the full spectrum of energy applications.

3. Up to $10.0 million through the **Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS)** Exploratory Topics[4] funding opportunity to develop new technologies and tools to reduce the environmental impact of aviation;

4. Up to $45.0 million to facilitate the development of the marine carbon dioxide removal (mCDR) industry through scalable Measurement, Reporting and Validation (MRV) technologies through **SEA-CO2** *(Sensing Exports of Anthropogenic Carbon Through Ocean Observation);*

5. Up to $48.0 million to support a new program focused on developing power grid technologies that improve control and protection of the domestic power grid through **ULTRAFAST** *(Unlocking Lasting Transformative Resiliency Advances by Faster Actuation of power Semiconductor Technologies);*

6. Up to $40.0 million for a new program dedicated to developing cost-effective, high-speed, and safe undergrounding technologies to strengthen the system reliability for distribution grids by undergrounding electric power lines in urban and suburban areas through **GOPHURRS** *(Grid Overhaul with Proactive, High-speed Undergrounding for Reliability, Resilience, and Security);*

7. Up to $5.0 million through the **Critical Mineral Extraction from Ocean Macroalgal Biomass (Algal Mining)** Exploratory Topics[4] funding opportunity to explore critical mineral extraction from ocean macroalgae;

8. Up to $10.0 million through the **Novel Superconducting Technologies for Conductors** Exploratory Topics[4] funding opportunity to develop novel manufacturing technologies for superconducting tapes;

9. Up to $100.0 million to provide further funding to previous ARPA-E awardees determined to be feasible for widespread commercialization domestically through **SCALEUP 2023** *(Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2023)*;

10. Up to $35.0 million to enable zero-process-emission ironmaking and ultra-low life cycle emissions steelmaking through **ROSIE** *(Revolutionizing Ore to Steel to Impact Emissions);*

11. Up to $30.0 million to develop next-generation, high-energy storage solutions to help accelerate the electrification of the aviation, railroad, and maritime transportation sectors through **PROPEL-1K** *(Pioneering Railroad, Oceanic and Plane ELectrification with 1K energy storage systems);*

12. Up to $10.0 million through **Topic G: Production of Geologic Hydrogen Through Stimulated Mineralogical Processes** Exploratory Topics[5] funding opportunity to seek technologies that stimulate hydrogen production from mineral deposits found in the subsurface; and

13. Up to $10.0 million through **Topic H: Subsurface Engineering for Hydrogen Reservoir Management** Exploratory Topics[5] funding opportunity to focus on technologies relevant to the extraction of geologic hydrogen.

In FY 2023, ARPA-E selected 110 projects across 10 funding opportunities to receive $300.7 million[6] in funding to support early-stage R&D:

1. Twelve projects were selected to receive $38.0 million through **CURIE** *(Converting UNF Radioisotopes Into Energy);*

2. Sixteen projects were selected to receive $39.0 million through **MINER** *(Mining Innovations for Negative Emissions Resources);*

3. Eight projects were selected to receive $100.0 million through **SCALEUP 2021** *(Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2021);*

4. Ten projects were selected to receive $3.7 million through **GO Competition Challenge 3** *(Grid Optimization Competition Challenge 3);*

5. Twelve projects were selected to receive $42.0 million through **EVs4ALL** *(Electric Vehicles for American Low-carbon Living);*

6. Eight projects were selected to receive $10.0 million through the **Low-Energy Nuclear Reactions (LENR)** Exploratory Topics funding opportunity;[7]

7. Eighteen projects were selected to receive $40.0 million through **COOLERCHIPS** *(Cooling Operations Optimized for Leaps in Energy, Reliability, and Carbon Hyperefficiency for Information Processing Systems);*

[5] In 2022, ARPA-E issued the Exploratory Topics funding opportunity, an ongoing funding mechanism to explore high-risk R&D leading to the development of potentially disruptive new technologies across the full spectrum of energy applications.
[6] The amount listed is at the time of the project selections. The funding amount for the program is subject to change based on award negotiations and ongoing program management.
[7] In 2022, ARPA-E issued the Exploratory Topic funding opportunity, an ongoing funding mechanism to explore high-risk R&D leading to the development of potentially disruptive new technologies across the full spectrum of energy applications.

8. Six projects were selected to receive $9.0 million through the **INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL)** Exploratory Topics funding opportunity;[7]

9. Eighteen projects were selected to receive $9.0 million through the **Creating Revolutionary Energy And Technology Endeavors (CREATE)** Exploratory Topics funding opportunity;[7] and

10. Five projects were selected to receive $10.0 million through the **Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS)** Exploratory Topics funding opportunity.[7]

In FY 2023, ARPA-E Program Directors (1) provided awardees with hands-on engagement and technical guidance; and (2) engaged diverse communities to identify gaps where ARPA-E funding could lead to new programs. ARPA-E continued to provide awardees with practical training and critical business information as part of the agency's Technology-to-Market program. This support equips performers with a clear understanding of market needs to guide technical development and help their projects succeed in the marketplace.

ARPA-E Fiscal Year 2023
Annual Report to Congress

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I. Legislative Language

This report is in response to the requirements set forth in the America COMPETES Act, Public Law 110-69, section 5012(g)(1)(2007) as amended, which has been codified as 42 U.S.C. § 16538(h)(1), wherein it is stated:

> *"…the Director shall provide to the relevant authorizing and appropriations committees of Congress a report describing projects supported by ARPA-E during the previous fiscal year."*

The statutory goals of ARPA-E are to:

1. Enhance economic and energy security of the United States through the development of energy technologies that –
    a. reduce imports of energy from foreign sources;
    b. reduce energy-related emissions, including greenhouse gases;
    c. improve the energy efficiency of all economic sectors;
    d. provide transformative solutions to improve the management, clean-up, and disposal of radioactive waste and spent nuclear fuel;
    e. improve the resilience, reliability, and security of infrastructure to produce, deliver, and store energy, and
2. Ensure that the U.S. maintains a technological lead in developing and deploying advanced energy technologies.

ARPA-E focuses on early-stage energy technologies that can be meaningfully advanced with modest funding over a defined time period. ARPA-E's rigorous program design, competitive project selection process, and hands-on engagement provide America's energy innovators with funding, technical assistance, and market awareness. Each year, ARPA-E thoroughly reviews all applications and technologies to ensure that funding is provided to topics not likely to be pursued by industry, Federal agencies, or DOE applied R&D programs.

II. Fiscal Year 2023 Appropriation

The Consolidated Appropriations Act, 2023 included $470 million in FY 2023 funds for ARPA-E.

III. Notice of Funding Opportunity

In FY 2023, ARPA-E announced 13 funding opportunities[8] for up to $363.0 million in R&D funding. The technology programs created by these solicitations provide a unique bridge from

[8] Including Exploratory Topics (Topic B: INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL), Topic C: Creating Revolutionary Energy And Technology Endeavors (CREATE),

basic science to early-stage technology. They draw from the latest scientific discoveries and will help create a viable path to commercial implementation through firm grounding in the economic realities and changing dynamics of the marketplace.

The table below summarizes the funding opportunities announced in FY 2023. The funding amounts detailed below reflect the potential funding amount at the time of the announcement. The funding amounts may change at the time of project selections.

Table 1: Summary of ARPA-E Notices of Funding Opportunities in FY 2023

Program	Notice of Funding Opportunity Date	Funding Opportunity FY	Funding Amount at time of announcement ($ Million)[9]	Project Selection Date	Project Selection FY	Number of Projects[10]	Funding Amount at Time of Project Selection ($ Million)[11]
Exploratory Topics: Topic B (INTERMODAL)[12]	2/8/2023	FY 2023	$10.0	8/10/2023	FY 2023	6	$9.0
SEA-CO2	2/16/2023	FY 2023	$45.0	10/26/2023	FY 2024	11	$36.0
Exploratory Topics: Topic C (CREATE)[13]	2/17/2023	FY 2023	$10.0	8/3/2023	FY 2023	18	$9.0
Exploratory Topics: Topic D (PRE-TRAILS)[14]	2/23/2023	FY 2023	$10.0	8/29/2023	FY 2023	5	$10.0
ULTRAFAST	2/24/2023	FY 2023	$48.0	11/21/2024	FY 2024	15	$42.0
GOPHURRS	3/30/2023	FY 2023	$40.0	1/16/2024	FY 2024	12	$34.0

Topic D: Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS), Topic E: Critical Mineral Extraction from Ocean Macroalgal Biomass (Algal Mining), Topic F: Novel Superconducting Technologies for Conductors (Superconducting Tape), Topic G: Production of Geologic Hydrogen Through Stimulated Mineralogical Processes, and Topic H: Subsurface Engineering for Hydrogen Reservoir Management), SEA-CO2, ULTRAFAST, GOPHURRS, SCALEUP 2023, ROSIE, and PROPEL-1K.

[9] Funding levels shown in this column are the amounts at the time of the notice of funding opportunity. The funding amounts are subject to change at the time of the project selection.

[10] Number of projects in this column are at the time of the project selection. The number of projects is subject to change based on award negotiations and ongoing program management.

[11] Funding levels shown in in this column are as of the date of the project selection. The funding amounts are subject to change based on award negotiations and ongoing program management.

[12] This funding opportunity is also included in Table 2 of Section IV: Project Selections, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.

[13] This funding opportunity is also included in Table 2 of Section IV: Project Selections, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.

[14] This funding opportunity is also included in Table 2 of Section IV: Project Selections, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.

Exploratory Topics: Topic E (Algal Mining)	4/28/2023	FY 2023	$5.0	11/2/2023	FY 2024	3	$5.0
Exploratory Topics: Topic F (Superconducting Tape)	5/30/2023	FY 2023	$10.0	10/5/2023	FY 2024	3	$10.0
SCALEUP 2023	6/8/2023	FY 2023	$100.0	6/25/2024	FY 2024	4	$63.5
ROSIE	6/22/2023	FY 2023	$35.0	4/18/2024	FY 2024	13	$28.0
PROPEL-1K	9/1/2023	FY 2023	$30.0	2/21/2024	FY 2024	13	$15.0
Exploratory Topics: Topic G (Geologic Hydrogen Stimulation)	9/7/2023	FY 2023	$10.0	2/8/2024	FY 2024	11	$10.0
Exploratory Topics: Topic H (Geologic Hydrogen Engineering)	9/7/2023	FY 2023	$10.0	2/8/2024	FY 2024	7	$10.0

Summary of ARPA-E's funding opportunities announced in FY 2023:

From February 8, 2023, through September 7, 2023, ARPA-E announced seven Exploratory Topics under the **Exploratory Topics** funding opportunity**.**

- On February 8, 2023, ARPA-E announced up to $10.0 million in funding for **Topic B,** *INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL)*.

  The INTERMODAL Exploratory Topic seeks to develop the low-carbon intermodal freight transportation system of the future, with the goal of minimizing greenhouse gas emissions and maximizing freight resiliency. Project innovations developed within this Exploratory Topic will support the deployment of energy infrastructure and logistics for moving goods across maritime, rail, and road transportation in the United States.

- On February 17, 2023, ARPA-E announced up to $10.0 million in funding for **Topic C**, *Creating Revolutionary Energy And Technology Endeavors (CREATE).*

  The objective of the CREATE Exploratory Topic is to identify and support disruptive energy-related technologies. Projects funded through CREATE should have the potential for large-scale impact. If successful, projects should create new paradigms in energy technology and have the potential to achieve significant advances in any ARPA-E's Mission Areas.

- On February 23, 2023, ARPA-E announced up to $10.0 million in funding for **Topic D,** *Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS).*

The PRE-TRAILS Exploratory Topic envisions the development of a system to predict aviation contrails that would be capable of informing pilots and ground controllers in real-time whether an airplane is likely to produce persistent aircraft-induced cirrus (AIC). This new system could foster the development of a) avoidance strategies – allowing re-direction of airplanes by ground control to more favorable (non-AIC) flight trajectories – and/or b) on-board mitigation technologies.

- On April 28, 2023, ARPA-E announced up to $5.0 million in funding for **Topic E,** *Critical Mineral Extraction from Ocean Macroalgal Biomass (Algal Mining)*.

  The Algal Mining Exploratory Topic investigates the feasibility of extracting critical minerals, specifically Rare Earth Elements (REEs) critical for the production of electric motors and generators, and high-value Platinum Group Metals (PGMs), from macroalgae cultivated and/or harvested within the U.S. Exclusive Economic Zone (EEZ).

- On May 30, 2023, ARPA-E announced up to $10.0 million in funding for **Topic F,** *Novel Superconducting Technologies for Conductors (Superconducting Tape).*

  The goal of the Superconducting Tape Exploratory Topic is to focus attention to the manufacturing processes of high-performance, rapidly produced superconducting tapes. Widely available low-cost high-temperature superconducting (HTS) tapes would encourage their use into several energy-related applications that could have major implications in the energy transition. The superconductors targeted in this Exploratory Topic are expected to help enable the market growth and proliferation of nuclear fusion, superconducting cables for the electric grid, electric aviation, and superconductor-based electric generators/motors.

- On September 7, 2023, ARPA-E announced up to $10.0 million in funding for **Topic G,** *Production of Geologic Hydrogen Through Stimulated Mineralogical Processes.*

  The goal of the Geologic Hydrogen (H_2) Exploratory Topics is to focus the attention of the scientific and technical community on developing and demonstrating technologies that can lead to the lowest cost and lowest environmental impact production of hydrogen fuel from the subsurface.

  The technologies targeted in Exploratory Topic G pertain to methods for stimulating the generation of hydrogen within the subsurface, such as enhanced serpentinization or other hydrogen generating processes, as well as modeling and characterization methods focused on predicting or monitoring yield of these stimulation methods.

- On September 7, 2023, ARPA-E announced up to $10.0 million in funding for **Topic H,** *Subsurface Engineering for Hydrogen Reservoir Management*.

> The goal of the Geologic Hydrogen (H_2) Exploratory Topics is to focus the attention of the scientific and technical community on developing and demonstrating technologies that can lead to the lowest cost and lowest environmental impact production of hydrogen fuel from the subsurface.
>
> Exploratory Topic H focuses on demonstrating methods for identifying, managing, and monitoring hydrogen reservoirs, as well as assessing the risk of hydrogen reservoir development.

ARPA-E issued the Exploratory Topics funding opportunity in 2022. This announcement is purposely broad in scope and covers a wide range of topics to encourage the submission of the most innovative and unconventional ideas in energy technology. The objective of this solicitation is to support high-risk R&D leading to the development of potentially disruptive new technologies across the full spectrum of energy applications. Topics under this NOFO will explore new areas of technology development that, if successful, could establish new program areas for ARPA-E, or complement the current portfolio of ARPA-E programs.

On February 16, 2023, ARPA-E announced up to $45.0 million in funding for **SEA-CO2** *(Sensing Exports of Anthropogenic Carbon through Ocean Observation).*

The SEA-CO2 program seeks to accelerate the development of the marine carbon dioxide removal (mCDR) carbon capture industry through the advancement of scalable Measurement, Reporting and Validation (MRV) technologies. SEA-CO2 seeks to develop new approaches to chemical oceanographic sensing, modeling, and data characterization by developing:

1. Marine carbon sensor technologies operating across spatial and temporal scales broad enough to sufficiently understand mCDR effects on the ocean carbon cycle, quantify carbon removal efficiency, and reduce or eliminate under-sampling concerns that limit carbon credit quality; and
2. Regional-scale ocean carbon flux models that integrate and estimate additional carbon drawn down in the combined major carbon cycles likely to be impacted by one or more mCDR approaches for selected regions.

On February 24, 2023, ARPA-E announced up to $48.0 million in funding for **ULTRAFAST** *(Unlocking Lasting Transformative Resiliency Advances by Faster Actuation of power Semiconductor Technologies).*

The ULTRAFAST program seeks to develop and demonstrate next-generation ultra-fast power semiconductors for advanced system-level power electronics converters that would bring significant improvements in reliability, resiliency, and control of the power grid. Specifically, ULTRAFAST projects will create faster-switching higher-rated device and power module technologies that enable realization of transformative power management, protection, and control not only for the grid, but also for future green autonomous power distribution systems such as those for electric vehicles, all-electric aviation, and more.

On March 30, 2023, ARPA-E announced up to $40.0 million in funding for **GOPHURRS** *(Grid Overhaul with Proactive, High-Speed Undergrounding for Reliability, Resilience, and Security).*

The GOPHURRS program seeks to simplify the construction of underground medium voltage (MV, 5 – 46 kV) power distribution grids in urban and suburban areas by adopting a concurrent drilling and conduit installation method of construction that reduces the inefficiencies associated with today's horizontal drilling and conduit installation operations. Projects will focus on advancing transformative autonomous utility installation technologies such as automated and rapid subsurface drilling along the terrain and concurrent conduit installation, while also avoiding hidden underground obstacles with advanced look-ahead sensors. GOPHURRS projects could reduce costs, increase speed, and improve the safety of undergrounding operations and the surrounding communities by developing technologies focused on automation, damage prevention, and error elimination.

On June 8, 2023, ARPA-E announced up to $100.0 million in funding for **SCALEUP 2023** *(Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2023).*

The SCALEUP program provides a vital mechanism for the support of innovative energy R&D that complements ARPA-E's primary R&D focus on early-stage transformational energy technologies that still require proof-of-concept. The goal of the program is to help ARPA-E-funded technologies, past and present, transition from proof-of-concept prototypes to commercially scalable and deployable versions of the technology and be well-positioned for investment from the private sector.

On June 22, 2023, ARPA-E announced up to $35.0 million in funding for **ROSIE** *(Revolutionizing Ore to Steel to Impact Emissions).*

The iron and steel industry accounts for around 7% of global greenhouse gas (GHG) emissions and 11% of global carbon dioxide (CO_2) emissions. By 2050, global iron and steel demand is projected to rise as much as 40%. ROSIE aims to develop new technology pathways to enable zero direct process emissions in ironmaking (i.e., zero-process-emission ironmaking) and ultra-low life cycle emissions for steelmaking at scale.

On September 1, 2023, ARPA-E announced up to $30.0 million in funding for **PROPEL-1K** *(Pioneering Railroad, Oceanic and Plane ELectrification with 1K energy storage systems).*

PROPEL-1K aims to develop emission-free, high-energy, and high-power energy storage solutions to electrify domestic aircraft, railroad, and ships. Projects must achieve energy density targets of so-called "1K" technologies that equal or exceed 1,000 watt-hours per kilogram and 1,000 watt-hours per liter at the end of life and at the net energy storage system level. Electrochemical and chemical solutions developed in the PROPEL-1K program must be distinct from traditional energy storage and battery solution strategies to achieve the ambitious high energy density targets.

IV. Project Selections

In FY 2023, ARPA-E selected 110 projects across 10 funding opportunities[15] for a total of $300.7 million in funding.

The CURIE, MINER, SCALEUP 2021, GO Competition Challenge 3, EVs4ALL, COOLERCHIPS, and Exploratory Topics (Topic A) funding opportunities were issued in FY 2022 with projects selected in FY 2023. The Exploratory Topics (Topic B, Topic C, and Topic D) funding opportunities were issued in FY 2023 with projects selected in FY 2023.

The table below summarizes the projects selected in FY 2023.

Table 2: Summary of ARPA-E Projects Selected in FY 2023

Program	Notice of Funding Opportunity Date	Funding Opportunity FY	Funding Amount at time of announcement ($ Million)[16]	Project Selection Date	Project Selection FY	Number of Projects[17]	Funding Amount at Time of Project Selection ($ Million)[18]
CURIE	3/15/2022	FY 2022	$48.0	10/21/2022	FY 2023	12	$38.0
MINER	2/24/2022	FY 2022	$44.0	10/27/2022	FY 2023	16	$39.0
SCALEUP 2021	12/16/2021	FY 2022	$100.0	11/22/2022	FY 2023	8	$100.0
GO Competition Challenge 3	2/16/2022	FY 2022	$4.0	12/8/2022	FY 2023	10	$3.7
EVs4ALL	5/3/2022	FY 2022	$45.0	1/10/2023	FY 2023	12	$42.0
Exploratory Topics: Topic A (LENR)	9/13/2022	FY 2022	$10.0	2/17/2023	FY 2023	8	$10.0
COOLERCHIPS	9/22/2022	FY 2022	$42.0	5/9/2023	FY 2023	15	$40.0
Exploratory Topics: Topic B (INTERMODAL)[19]	2/8/2023	FY 2023	$10.0	8/10/2023	FY 2023	6	$9.0

[15] Including CURIE, MINER, SCALEUP 2021, GO Competition Challenge 3, EVs4ALL, COOLERCHIPS, and four Exploratory Topics (Topic A: Low-Energy Nuclear Reactions (LENR), Topic B: INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL), Topic C: Creating Revolutionary Energy And Technology Endeavors (CREATE), and Topic D: Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS)).

[16] Funding levels shown in this column are the amounts at the time of the notice of funding opportunity. The funding amounts are subject to change at the time of the project selection.

[17] Number of projects in this column are at the time of the project selection. The number of projects is subject to change based on award negotiations and ongoing program management.

[18] Funding levels shown in in this column are as of the date of the project selection. The funding amounts are subject to change based on award negotiations and ongoing program management.

[19] This funding opportunity is also included in Table 1 of Section III: Notice of Funding Opportunity, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.

Exploratory Topics: Topic C (CREATE).[20]	2/17/2023	FY 2023	$10.0	8/3/2023	FY 2023	18	$9.0
Exploratory Topics: Topic D (PRE-TRAILS).[21]	2/23/2023	FY 2023	$10.0	8/29/2023	FY 2023	5	$10.0

Summary and details of projects selected in FY 2023:

On October 21, 2022, ARPA-E selected 12 projects to receive $38.0 million through **CURIE** *(Converting UNF Radioisotopes Into Energy).*

The U.S. has accumulated approximately 86,000 metric tons of used nuclear fuel (UNF) from light-water reactors (LWRs), a value that increases by approximately 2,000 tons per year. This UNF is destined for permanent disposal even though more than 90% of its energy remains. Reprocessing UNF to recover reusable actinides and recycling them into new fuel for advanced reactors (ARs) would improve fuel utilization and drastically reduce the volume of waste requiring permanent disposal.

CURIE seeks to develop innovative separations technologies, material accountancy, and online monitoring technologies, as well as designs for a reprocessing facility that will enable group recovery of actinides for AR feedstocks, incorporate in situ process monitoring, minimize waste volumes, enable a 1¢/kilowatt-hour (kWh) fuel cost for AR fuels, and maintain disposal costs in the range of 0.1¢/kWh.

Example CURIE project: Argonne National Laboratory – "Highly Efficient Electrochemical Oxide Reduction for U/TRU Recovery from LWR Fuel" – Lemont, IL ($4,900,000)

Argonne National Laboratory (ANL) is researching an electrochemical oxide reduction (OR) process that meets CURIE's cost and waste metrics for a pyroprocessing facility. Electrochemical OR is a single-step process that converts used oxide fuels to metal that can be electrorefined to produce uranium/transuranic (U/TRU) alloys suitable for fabrication into advanced reactor fuels. However, current process inefficiencies result in non-uniform and incomplete conversion to metal, long process times, and large waste volumes. ANL is addressing these inefficiencies by researching a highly efficient OR process with 97% conversion of the oxide fuel to metal by incorporating sensors to monitor oxide-to-metal conversion, using stable and efficient next-generation anode materials, and optimizing cell designs to achieve spatially uniform conversion to metal. This optimized OR process could help reduce waste volumes 10X compared with other conversion processes. ANL is also researching an integrated waste disposal plan to economically dispose of pyroprocessing wastes in deep boreholes and an

[20] This funding opportunity is also included in Table 1 of Section III: Notice of Funding Opportunity, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.
[21] This funding opportunity is also included in Table 1 of Section III: Notice of Funding Opportunity, because the funding opportunity was announced in FY 2023 and the project selections occurred in FY 2023.

optimized plan for using the existing LWR UNF supply in a pyroprocessing facility to produce U/TRU alloys suitable for advanced reactor fuel fabrication.

On October 27, 2022, ARPA-E selected 16 projects to receive $39.0 million through **MINER** *(Mining Innovations for Negative Emissions Resources).*

The MINER program seeks to increase the U.S. domestic supplies of copper, nickel, lithium, cobalt, and other rare earth elements. These minerals are critical during the transition to clean sources of energy, such as wind and solar. The MINER program will fund the technology research that increases the mineral yield while decreasing the required energy, and subsequent emissions, to mine and extract these energy-relevant minerals. Specifically, the program will investigate the potential CO_2-reactive ores to unlock net-zero or net-negative emission technologies.

Example MINER project: Colorado School of Mines – "Block Modeling of the Carbonation Potential of Ore Deposits Using Cutting-Edge Core Scanning Technology and Advanced Machine Learning Algorithms" – Golden, CO ($1,159,337)

The Colorado School of Mines (Mines) is developing a novel technological solution and workflow to enable mining companies to quantitatively model the carbonation potential of entire ore deposits using cutting-edge X-ray fluorescence core scanning technology and advanced machine learning techniques. The project is demonstrating how the carbonation potential of a copper-nickel-platinum group element (Cu-Ni-PGE) deposit can be determined involving block modeling of the amount of CO_2 that can be sequestered in situ in an ore body and its surrounding host rocks.

Mines is performing a cost-benefit analysis to show that evaluation of the total carbonation potential of ore deposits should become an integral part of mine feasibility studies. The technology and methodology will allow mine operators to objectively assess the economic benefit of adapting negative emission technologies. Such assessments are not currently possible as existing models estimating the carbonation potential of rock formations are too uncertain and do not take mineralogical heterogeneities into account.

On November 22, 2022, ARPA-E selected eight projects to receive $100.0 million through **SCALEUP 2021** *(Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2021).*

The SCALEUP program provides a vital mechanism for the support of innovative energy R&D that complements ARPA-E's primary R&D focus on early-stage transformational energy technologies that still require proof-of-concept. The goal of the program is to help ARPA-E-funded technologies, past and present, transition from proof-of-concept prototypes to commercially scalable and deployable versions of the technology and be well-positioned for investment from the private sector.

Example SCALEUP 2021 project: Niron Magnetics – "Pilot Production for Commercial Sampling of Rare-Earth-Free Iron Nitride Permanent Magnets" – Minneapolis, MN ($17,500,000)

Niron Magnetics is commercializing the first powerful permanent magnet free of critical materials. Currently, rare earth permanent magnets are expensive. The required rare earth materials are difficult to source because of projected supply shortfalls and geopolitical risk and are environmentally damaging through their extraction and processing. Powerful permanent magnets are essential for clean technologies, including those used by electric vehicle traction motors, wind generators, efficient industrial motors, and more. Niron's Iron Nitride-based Clean Earth Magnet® is made from abundant commodity raw materials, enabling a less expensive, domestically manufacturable solution for the clean economy with minimum supply chain risk and a significantly reduced environmental footprint.

On December 8, 2022, ARPA-E selected 10 projects to receive $3.7 million through **GO Competition Challenge 3** *(Grid Optimization Challenge 3).*

The GO Competition aims to accelerate the development of transformational methods related to the electric power grid. The GO Competition seeks to identify innovative power system optimization and control methods that will accelerate the development and adoption of emerging technologies. Innovative solutions identified by the GO Competition will enable increased grid flexibility, reliability, and resilience. They will also significantly increase energy security, provide greater energy efficiency, and substantially reduce the costs of integrating emerging technologies and resources into the electric power system in the United States.

The GO Competition Challenge 3 focuses on the security-constrained optimal power flow (SCOPF) problem. It is part of a continuing effort that began in GO Competition Challenges 1 and 2, to successfully discover, develop, and test innovative and disruptive software solutions for critical energy challenges and to overcome existing barriers. Challenge 3 will focus on multiperiod dynamic markets including advisory models for extreme weather events, day-ahead markets, and the real-time markets with an extended look-ahead. These problems will include active bid-in demand and topology optimization.

On January 10, 2023, ARPA-E selected 12 projects to receive $42.0 million in funding through **EVs4ALL** *(Electric Vehicles for American Low-carbon Living).*

The EVs4ALL program aims to expand domestic electric vehicle (EV) adoption by developing batteries that last longer, charge faster, perform efficiently in freezing temperatures, and have better overall range retention. Electrifying the transportation sector is critical to rapidly decarbonizing the American economy and eliminating heavy-emitting industries. The transportation sector is responsible for 28% of greenhouse gas emissions in the U.S., with road-based passenger vehicles accounting for 57% of those emissions. The key to EV adoption is a reliable, inexpensive battery that can charge fast and provide improved performance and range retention in cold weather compared to state-of-the-art commercial options. ARPA-E's EVs4ALL

program will increase EV market share by developing next-generation battery technologies to significantly improve EV affordability, convenience, reliability, and safety.

Example EVs4ALL project: South 8 Technologies – "Liquefied Gas Electrolytes for Next-Gen EV Batteries" – San Diego, CA ($3,152,000)

South 8 Technologies is developing high-power lithium-ion battery cells with the capacity to charge rapidly using a novel liquefied gas (LiGas) electrolyte technology. The LiGas electrolyte uses non-toxic and non-corrosive gases, which are already domestically manufactured and widely available, that are liquefied under moderate pressures and can be contained in standard form-factor cylindrical cell cans. The technology has demonstrated excellent performance in conventional graphite/lithium-nickel-manganese-cobalt-oxide cells and offers several opportunities for cost reduction. South 8 Technologies is harnessing the inherent safety, high-power, and low-temperature advantages of the LiGas electrolyte in combination with a high-energy, low-cost, and cobalt-free lithium nickel manganese oxide cathode.

On May 9, 2023, ARPA-E selected 15 projects to receive $40.0 million through **COOLERCHIPS** *(Cooling Operations Optimized for Leaps in Energy, Reliability, and Carbon Hyperefficiency for Information Processing Systems).*

The COOLERCHIPS program will develop transformational, highly efficient, and reliable cooling technologies for data centers. The target for COOLERCHIPS is to reduce total cooling energy expenditure to less than 5% of a typical data center's IT load at any time and any U.S. location for a high-density compute system. A data center's total cooling energy is the energy needed to ensure that all heat generated from its IT and non-IT loads is rejected. Reducing data center cooling energy will reduce the operational CO_2 footprint of data center operations.

COOLERCHIPS technologies will achieve these goals by dramatically reducing the thermal resistance of heat rejection, which will allow for coolants to exist at temperatures much closer to operating temperatures of the latest generation of chips (targeting <10°C difference between chip and coolant). This will result in more efficient heat removal from the facility. The program will develop solutions for high volumetric compute density systems of >80kW/m3, equivalent to about >3kW per server. COOLERCHIPS aims to be commercially competitive with current state-of-the-art solutions by offering a lower total cost of ownership without compromising data center reliability and availability.

Example COOLERCHIPS project: HP – "Embedded Microfluidic Cooling for Nextgen High Power Server Architectures" – Corvallis, OR ($3,250,000)

HP is working with partners to develop an aggressive liquid cooling solution that reduces the need for thermal interface material and the number of thermal interfaces between high-power CPUs/GPUs and the coolant, thereby dramatically lowering the package thermal resistance. The approach leverages HP's inkjet microfluidics platform and relies on first coupling silicon microchannels to a device's surface, and then by embedding microfluidics deeper into the

device as a future step. This design would reject server heat to 40°C and 60% relative humidity external ambient air.

From February 17, 2023, through August 29, 2023, ARPA-E selected 37 Exploratory Topic projects under four **Exploratory Topics** funding opportunities**.**

- On February 17, 2023, ARPA-E selected eight projects to receive $10.0 million through **Topic A**, *Low-Energy Nuclear Reactions (LENR).*

  This Exploratory Topic offered $10 million in funding for eight projects working to determine whether low-energy nuclear reactions (LENR) could be the basis for a potentially transformative carbon-free energy source. The teams selected aim to break the stalemate of research in this space.

  Example LENR Exploratory Topic project: Massachusetts Institute of Technology – "Neutron Emission from Laser-Stimulated Metal Hydrides" – Cambridge, MA ($2,000,000)

  Massachusetts Institute of Technology (MIT) is working on a hypothesis-driven experimental campaign to examine prominent claims of low energy nuclear reactions (LENR) with nuclear and material diagnostics, focusing on unambiguous indicators of nuclear reactions such as emitted neutrons and nuclear ash with unnatural isotopic ratios. The team is developing an experimental platform that thoroughly and reproducibly test claims of nuclear anomalies in gas-loaded metal-hydrogen systems.

- On August 10, 2023, ARPA-E selected six projects to receive $9.0 million through **Topic B**, *INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL).*

  The INTERMODAL Exploratory Topic seeks to develop the low-carbon intermodal freight transportation system of the future, with the goal of minimizing greenhouse gas emissions and maximizing freight resiliency. Project innovations developed within this Exploratory Topic will support the deployment of energy infrastructure and logistics for moving goods across maritime, rail, and road transportation in the United States.

  Example INTERMODAL Exploratory Topic project: University of Tennessee, Knoxville – "A Cognitive Freight Transportation Digital Twin for Resiliency and Emission Control Through Optimizing Intermodal Logistics (RECOIL)" – Knoxville, TN ($1,900,000)

  The University of Tennessee, Knoxville is developing a cognitive digital twin for the U.S. intermodal freight transportation system, including all road, rail, and waterways, to maximize efficiency and resiliency and minimize life cycle greenhouse gas emissions. This digital representation could offer flow planning, scheduling, and optimization of the entire intermodal freight system within 24 hours. Additionally, the technology could

adapt quickly to traffic, weather, and other disruptions by supplying local route rescheduling within one hour.

- On August 3, 2023, ARPA-E selected 18 projects to receive $9.0 million through **Topic C**, *Creating Revolutionary Energy And Technology Endeavors (CREATE).*

  The objective of the CREATE Exploratory Topic is to identify and support disruptive energy-related technologies. Projects funded through CREATE should have the potential for large-scale impact. If successful, projects should create new paradigms in energy technology and have the potential to achieve significant advances in any of ARPA-E's Mission Areas.

  Example CREATE Exploratory Topic project: GaNify – "50-kV/1-A Sub-Microsecond Power Switch for Gyrotron Modulation" – State College, PA ($500,000)

  GaNify is developing a unique power switch for gyrotron modulators in nuclear fusion systems that could switch 50-kV/1-A in less than a microsecond without the need to stack multiple switches in series. Their design significantly reduces the complexity and shorten the modulation voltage rise time, effectively pushing the voltage limit of solid-state power switches toward the high voltage regime.

- On August 29, 2023, ARPA-E selected five projects to receive $10.0 million through **Topic D**, *Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS).*

  The PRE-TRAILS projects will work on new technologies and tools to reduce the environmental impact of aviation and will develop diagnostics and predictive tools needed to enable mitigation of contrail-related climate forcing.

  Condensation trails—commonly known as contrails—occur when aircraft exhaust water mixes with cold, surrounding humid air at high altitude. Under certain specific atmospheric conditions, engine exhaust can cause the formation of long-lived contrails. These can result in persistent clouds known as aircraft-induced cirrus (AIC). Studies indicate AIC likely contribute to changes in the atmosphere at a level that is roughly equivalent to that of the CO_2 emissions from the entire aviation sector, or about 2% of total global CO_2 emissions.

  Example PRE-TRAILS Exploratory Topic project: GE Research – "Engine-informed Prediction of Aviation Induced Cirrus Trails-EPIC-Trails" – Niskayuna, NY ($1,500,000)

  GE Research is developing a real-time, in-flight prediction system for aircraft-induced cirrus formed from contrails for commercial aircraft operators, who typically have little to no information on which flights cause long-lived cirrus clouds. In partnership with Southwest Airlines, GE's system would combine detailed engine operational data, a

hybrid physics and machine learning model, on-airplane data, and real-time satellite observations to predict aviation-induced cirrus that last more than 5 hours.

In 2022, ARPA-E issued the Exploratory Topics funding opportunity. This announcement is purposely broad in scope and covers a wide range of topics to encourage the submission of the most innovative and unconventional ideas in energy technology. The objective of this solicitation is to support high-risk R&D leading to the development of potentially disruptive new technologies across the full spectrum of energy applications. Topics under this NOFO will explore new areas of technology development that, if successful, could establish new program areas for ARPA-E, or complement the current portfolio of ARPA-E programs.

Table 3 summarizes ARPA-E's programs to date (from 2009-2023). A full list of the projects selected during FY 2023 can be found in Appendix I. Additional information related to these projects is on ARPA-E's website: http://arpa-e.energy.gov.

Table 3: ARPA-E Programs to Date (from 2009-2023)

FUNDING YEAR	PROGRAM NAME	NUMBER OF PROJECTS[22]	FUNDING AMOUNT ($ Million)[23]
PRIOR TO FY 2023	OPEN 2009	41	$174.0
	Batteries for Electrical Energy Storage in Transportation (BEEST)	12	$38.0
	Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT)	15	$40.0
	Electrofuels	13	$48.0
	Agile Delivery of Electrical Power Technology (ADEPT)	14	$38.0
	Building Energy Efficiency Through Innovative Thermodevices (BEETIT)	17	$38.0
	Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)	15	$40.0
	Plants Engineered To Replace Oil (PETRO)	10	$56.0
	High Energy Advanced Thermal Storage (HEATS)	15	$37.0
	Rare Earth Alternatives in Critical Technologies (REACT)	14	$39.0
	Green Electricity Network Integration (GENI)	15	$43.0
	Solar Agile Delivery of Electrical Power Technology (Solar ADEPT)	7	$12.0
	Methane Opportunities for Vehicular Energy (MOVE)	13	$42.0

[22] Number of projects listed are at the time of project selection. The final number of projects are subject to change based on contract negotiations and ongoing program management.
[23] Funding amounts listed are at the time of project selection. The final funding amount is subject to change based on contract negotiations and ongoing program management.

Table 3: ARPA-E Programs to Date (from 2009-2023)			
FUNDING YEAR	**PROGRAM NAME**	**NUMBER OF PROJECTS**[22]	**FUNDING AMOUNT ($ Million)**[23]
	Advanced Management and Protection of Energy Storage Devices (AMPED)	15	$34.0
	OPEN 2012	66	$171.0
	Innovative Development in Energy-related Applied Science (IDEAS)	59	$28.0
	Robust Affordable Next Generation Energy Storage Systems (RANGE)	22	$45.0
	Reducing Emissions using Methanotrophic Organisms for Transportation Energy (REMOTE)	16	$48.0
	Modern Electro/Thermochemical Advancements for Light metals Systems (METALS)	19	$45.0
PRIOR TO FY 2023	Full-Spectrum Optimized Conversion and Utilization of Sunlight (FOCUS)	14	$35.0
	Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES) & SBIR/STTR	14	$36.0
	Reliable Electricity Based on Electrochemical Systems (REBELS)	13	$37.0
	Cycling Hardware to Analyze and Ready Grid-Scale Electricity Storage (CHARGES)	2	$6.5
	Delivering Efficient Local Thermal Amenities (DELTA)	11	$32.0
	Methane Observation Networks with Innovative Technology to Obtain Reductions (MONITOR)	12	$39.0
	Accelerating Low-cost Plasma Heating and Assembly (ALPHA)	9	$31.0
	Advanced Research In Dry cooling (ARID)	15	$33.0
	GENerators for Small Electrical and Thermal Systems (GENSETS)	14	$37.0
	Transportation Energy Resources from Renewable Agriculture (TERRA)	6	$38.0
	Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET)	5	$15.0
	Micro-scale Optimized Solar-cell Arrays with Integrated Concentration (MOSAIC)	11	$26.0
	OPEN 2015	39	$124.0
	Network Optimized Distributed Energy Systems (NODES)	12	$35.0
	Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA)	7	$11.0
	Single-Pane Highly Insulating Efficient Lucid Design (SHIELD)	14	$27.0
	Integration and Optimization of Novel Ion-Conducting Solids (IONICS)	16	$37.0

Table 3: ARPA-E Programs to Date (from 2009-2023)			
FUNDING YEAR	**PROGRAM NAME**	**NUMBER OF PROJECTS**[22]	**FUNDING AMOUNT ($ Million)**[23]
	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles (NEXTCAR)	11	$35.0
	Rhizosphere Observations Optimizing Terrestrial Sequestration (ROOTS)	10	$36.0
	Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL)	16	$33.0
	Energy-Efficient Light-Wave Integrated Technology Enabling Networks that Enhance Datacenters (ENLITENED)	9	$25.0
	Power Nitride Doping Innovation Offers Devices Enabling SWITCHES (PNDIODES)	7	$6.9
PRIOR TO FY 2023	Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors (CIRCUITS)	21	$30.0
	Macroalgae Research Inspiring Novel Energy Resources (MARINER)	18	$22.0
	Saving Energy Nationwide in Structures with Occupancy Recognition (SENSOR)	15	$20.0
	Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation (INTEGRATE)	8	$16.0
	Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration (MEITNER)	6	$14.0
	Duration Addition to electricity Storage (DAYS)	10	$28.0
	Building Reliable Electronics to Achieve Kilovolt Effective Ratings Safely (BREAKERS)	8	$21.0
	High Intensity Thermal Exchange through Materials and Manufacturing Processes (HITEMMP)	15	$29.2
	OPEN 2018 (and related OPEN+ cohorts)	77	$202.8
	Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS)	13	$26.0
	Solicitation on Topics Informing New Program Areas (Topics A – K)	67	$69.7
	Grid Optimization (GO) Competition Challenge 1	10	$3.4
	Design Intelligence Fostering Formidable Energy Reduction and Enabling Novel Totally Impactful Advanced Technology Enhancements (DIFFERENTIATE)	23	$15.0
	Environmental Security Technology Certification Program (ESTCP)	4	$3.2
	Performance-based Energy Resource Feedback, Optimization, and Risk Management (PERFORM)	12	$30.5

Table 3: ARPA-E Programs to Date (from 2009-2023)			
FUNDING YEAR	**PROGRAM NAME**	**NUMBER OF PROJECTS**[22]	**FUNDING AMOUNT ($ Million)**[23]
	Generating Electricity Managed by Intelligent Nuclear Assets (GEMINA)	9	$27.0
	Breakthroughs Enabling Thermonuclear-fusion Energy (BETHE)	16	$35.0
	FLExible Carbon Capture and Storage (FLECCS)	12	$11.5
	Aviation-class Synergistically Cooled Electric-motors with iNtegrated Drives (ASCEND)	9	$14.5
	Range Extenders for Electric Aviation with Low Carbon and High Efficiency (REEACH)	9	$20.0
	SCALEUP "Fast Track"	2	$24.0
PRIOR TO FY 2023	Systems for Monitoring and Analytics for Renewable Transportation Fuels from Agricultural Resources and Management (SMARTFARM)	6	$16.5
	Galvanizing Advances in Market-Aligned Fusion for an Overabundance of Watts (GAMOW)	14	$29.0
	Rapid Encapsulation of Pipelines Avoiding Intensive Replacement (REPAIR)	10	$33.0
	Solicitation on Topics Informing New Program Areas (Topics L – R)	29	$31.0
	Submarine Hydrokinetic and Riverine Kilo-megawatt Systems (SHARKS)	11	$35.0
	Ultrahigh Temperature Impervious Materials Advancing Turbine Efficiency (ULTIMATE)	17	$16.0
	Energy and Carbon Optimized Synthesis for the Bioeconomy (ECOSynBio)	15	$35.0
	Seeding Critical Advances for Leading Energy technologies with Untapped Potential (SCALEUP)[24]	7	$47.0
	Solicitation on Topics Informing New Program Areas (Topics S and Topic T)	25	$13.6
	Renewable Energy to Fuels through Utilization of Energy-dense Liquids Integration and Testing (REFUEL + IT)	1	$10.0
	Next-Generation Energy Technologies for Connected and Automated On-Road Vehicles Phase II (NEXTCAR Phase II)	4	$18.0
	OPEN 2021	68	$175.0
	Reducing Emissions of Methane Every Day of the Year (REMEDY)	12	$35.0

[24] This excludes SCALEUP "Fast Track."

Table 3: ARPA-E Programs to Date (from 2009-2023)			
FUNDING YEAR	**PROGRAM NAME**	**NUMBER OF PROJECTS**[22]	**FUNDING AMOUNT ($ Million)**[23]
	Optimizing Nuclear Waste and Advanced Reactor Disposal Systems (ONWARDS)	11	$36.0
	Solicitation on Topics Informing New Program Areas (Topic U)	4	$9.7
FY 2022 NOFO / FY 2023 SELECTION	Converting UNF Radioisotopes Into Energy (CURIE)	12	$38.0
	Mining Innovations for Negative Emissions Resources (MINER)	16	$39.0
	Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2021 (SCALEUP 2021)	8	$100.0
	Grid Optimization Competition Challenge 3 (GO Competition Challenge 3)	10	$3.7
	Electric Vehicles for American Low-carbon Living (EVs4ALL)	12	$42.0
	Exploratory Topics Topic A: Low-Energy Nuclear Reactions (LENR)	8	$10.0
	Cooling Operations Optimized for Leaps in Energy, Reliability, and Carbon Hyperefficiency for Information Processing Systems (COOLERCHIPS)	15	$40.0
FY 2023	Exploratory Topics Topic B: INcreasing Transportation Efficiency and Resiliency through MODeling Assets and Logistics (INTERMODAL)	18	$9.0
	Exploratory Topics Topic C: Creating Revolutionary Energy And Technology Endeavors (CREATE)	6	$9.0
	Exploratory Topics Topic D: Predictive Real-time Emissions Technologies Reducing Aircraft Induced Lines in the Sky (PRE-TRAILS)	5	$10.0
FY 2023 NOFO / FY 2024 SELECTION	Exploratory Topics Topic F: Novel Superconducting Technologies for Conductors (Superconducting Tape)	3	$10.0
	Sensing Exports of Anthropogenic Carbon through Ocean Observation (SEA-CO2)	11	$36.0
	Exploratory Topics Topic E: Critical Mineral Extraction from Ocean Macroalgal Biomass (Algal Mining)	3	$5.0
	Grid Overhaul with Proactive, High-Speed Undergrounding for Reliability, Resilience, and Security (GOPHURRS)	12	$34.0
	Exploratory Topics Topic G: Production of Geologic Hydrogen Through Stimulated Mineralogical Processes	11	$10.0
	Exploratory Topics Topic H: Subsurface Engineering for Hydrogen Reservoir Management	7	$10.0
	Pioneering Railroad, Oceanic and Plane ELectrification with 1K energy storage systems (PROPEL-1K)	13	$15.0

Table 3: ARPA-E Programs to Date (from 2009-2023)			
FUNDING YEAR	**PROGRAM NAME**	**NUMBER OF PROJECTS**[22]	**FUNDING AMOUNT ($ Million)**[23]
	Revolutionizing Ore to Steel to Impact Emissions (ROSIE)	13	$28.0
	Seeding Critical Advances for Leading Energy technologies with Untapped Potential 2023 (SCALEUP 2023)	4	$63.5
	Unlocking Lasting Transformative Resiliency Advances by Faster Actuation of power Semiconductor Technologies (ULTRAFAST)	15	$42.0
	TOTAL	**1,465**	**$3,508.2**

V. ARPA-E Energy Innovation Summit

ARPA-E held its 13th ARPA-E Energy Innovation Summit from March 22-24, 2023, at the Gaylord National Convention Center, outside of Washington, D.C.

The ARPA-E Energy Innovation Summit is the premier energy innovation conference and technology showcase that brings together experts from different technical disciplines and professional communities to think about America's energy challenges in new and innovative ways. The Summit offers a unique, three-day program aimed at highlighting the boldest, most audacious ideas that could have the biggest impact on our energy future.

Summit attendees had the opportunity to hear from thought leaders on the Summit's Main Stage, engage in dynamic breakout panels, participate in focused networking opportunities, and explore the Technology Showcase. The Summit's Technology Showcase featured presentations, displays, prototypes, and demonstrations from ARPA-E performers and a highly select group of other companies, stakeholders, and research organizations.

2023 ARPA-E Energy Innovation Summit Highlights:

- More than 2,700 registered attendees from 49 states and 27 countries.
- More than 400 exhibitor booths displaying transformational technologies from ARPA-E awardees and other innovative companies.
- More than 100 speakers and keynote addresses, including Cabinet Secretaries, Chief Executive Officers, and entrepreneurs working to design the energy systems and technologies of the future.
- Thirty-five government agencies including representatives from the Department of Defense, DOE, and other civilian, state, and international agencies.
- Over 50 registered students from 26 universities across 18 states and D.C.

VI. Conclusion

In FY 2023, ARPA-E announced 13 funding opportunities for up to $363.0 million[25] in funding which covered a broad array of energy technologies:

1. **INTERMODAL Exploratory Topic:** Developing technology to model the low-carbon intermodal freight transportation system of the future;

2. **CREATE Exploratory Topic:** Helping to establish potential new areas of technology development;

3. **PRE-TRAILS Exploratory Topic:** Developing new technologies and tools to reduce the environmental impact of aviation;

4. **SEA-CO2:** Facilitating the development of the marine carbon dioxide removal (mCDR) industry through scalable Measurement, Reporting and Validation (MRV) technologies;

5. **ULTRAFAST:** Developing power grid technologies that improve control and protection of the domestic power grid;

6. **GOPHURRS:** Developing cost-effective, high-speed, and safe undergrounding technologies to strengthen the system reliability for distribution grids;

7. **Algal Mining Exploratory Topic:** Exploring critical mineral extraction from ocean macroalgae;

8. **Superconducting Tape Exploratory Topic:** Developing develop novel manufacturing technologies for superconducting tapes;

9. **SCALEUP 2023:** Scaling up promising energy technologies to the pre-pilot stage of the path to market and ultimately realizing commercial impact;

10. **ROSIE:** Enabling zero-process-emission ironmaking and ultra-low life cycle emissions steelmaking;

11. **PROPEL-1K:** Developing next-generation, high-energy storage solutions to accelerate the electrification of the aviation, railroad, and maritime transportation sectors;

[25] The amount listed is at the time of the funding opportunity was announced. The funding amount for the program is subject to change at the time of project selection or based on award negotiations and ongoing program management.

12. **Geologic Hydrogen Stimulation Exploratory Topic:** Stimulating hydrogen production from mineral deposits found in the subsurface; and

13. **Geologic Hydrogen Engineering Exploratory Topic:** Focusing on technologies relevant to the extraction of geologic hydrogen.

In FY 2023, ARPA-E selected **110** projects across 10 funding opportunities for a total of $300.7 million in funding:

1. **CURIE:** Developing technologies to advance used nuclear fuel (UNF) recycling, reduce the volume of high-level waste requiring permanent disposal, and provide safe domestic advanced reactor fuel stocks;

2. **MINER:** Developing commercially scalable technologies that will enable greater domestic supplies of copper, nickel, lithium, cobalt, rare earth elements, and other critical elements;

3. **SCALEUP 2021:** Scaling up innovative energy technologies that are determined to have a viable road to market;

4. **GO Competition Challenge 3:** Developing software management solutions to address challenging power grid problems;

5. **EVs4ALL:** Developing next-generation battery technologies to significantly improve EV affordability, convenience, reliability, and safety;

6. **LENR Exploratory Topic:** Determining whether LENR could be the basis for a potentially transformative carbon-free energy source;

7. **COOLERCHIPS:** Developing high-performance, energy efficient cooling solutions for data centers;

8. **INTERMODAL Exploratory Topic:** Exploring infrastructure and logistics for moving goods across, maritime, rail, and road transportation;

9. **CREATE Exploratory Topic:** Establishing potential new areas of technology development; and

10. **PRE-TRAILS Exploratory Topic:** Developing technologies and tools to reduce the environmental impact of aviation.

ARPA-E will continue to catalyze and accelerate the development of transformational energy technologies that could enable a more secure and affordable energy future in America and achieve ARPA-E's statutory goals. ARPA-E will maintain the use of its successful model to select

projects through focused programs, OPEN solicitations, and Exploratory Topics, quickly and effectively leveraging new scientific discoveries and market developments. In addition, ARPA-E will track and evaluate the success of awardee technologies after their participation in a funding program to assess the transformative effects of ARPA-E's funding.

VII. Appendix I: Projects Selected in FY 2023

Additional information on these projects is available on the ARPA-E website: http://arpa-e.energy.gov.

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
CURIE	University of Alabama at Birmingham	Group Hexavalent Actinide Separation: A Single-Step, Proliferation-Resistant Approach to Nuclear Fuel Reprocessing	Birmingham, AL	$1,844,998
CURIE	University of Colorado, Boulder	Achieving 1% Assay of Special Nuclear Materials in 2 Minutes with Microcalorimeter-Array Gamma-Ray Spectroscopy	Boulder, CO	$1,994,663
CURIE	Curio	Closing the Cycle with NuCycle™	Washington, D.C.	$5,000,000
CURIE	Mainstream Engineering	Improved Volatile and Semi-volatile Radionuclide Off-Gas Management	Rockledge, FL	$1,580,774
CURIE	Idaho National Laboratory	Development of Robust Anode Materials for the Electrochemical Recovery of Actinide Elements from Used Nuclear Fuel	Idaho Falls, ID	$2,659,677
CURIE	Argonne National Laboratory	Radioisotope Capture Intensification Using Rotating Packed Bed Contactors	Lemont, IL	$1,520,000
CURIE	Argonne National Laboratory	Highly Efficient Electrochemical Oxide Reduction for U/TRU Recovery from LWR Fuel	Lemont, IL	$4,900,000
CURIE	NuVision Engineering	Modular Power Fluidics and Online Optical Spectroscopy for Reprocessing Plant Control and Accountancy	Mooresville, NC	$4,715,163
CURIE	EPRI	Establishing an Advanced Reactor Fuel Cycle Enterprise	Charlotte, NC	$2,796,545
CURIE	GE Research	Monochromatic Assays Yielding Enhanced Reliability (MAYER)	Niskayuna, NY	$6,449,997

[26] Organizations selected and funding amounts listed are at the time of project selection. The final funding amounts, organizations selected, project titles, and location are subject to change based on award negotiations and ongoing program management.

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
CURIE	University of North Texas	Self-Powered Wireless Hybrid Density-Level Sensing with Differential Pressure Sensors for Safeguarding and Monitoring of Electrochemical Processing of Nuclear Spent Fuel	Denton, TX	$2,711,342
CURIE	University of Utah	Pyrochemical Dissolution of LWR Spent Fuel with Actinide Recovery for Advanced Reactors	Salt Lake City, UT	$1,454,074
MINER	Travertine Technologies	Ex Situ Tailings Leaching and Lateritization with Electrolytic Acid Recycling for Critical Metal Concentration and Mineral Carbon Sequestration	Boulder, CO	$2,000,000
MINER	Colorado School of Mines	Block Modeling of the Carbonation Potential of Ore Deposits Using Cutting-Edge Core Scanning Technology and Advanced Machine Learning Algorithms	Golden, CO	$1,159,337
MINER	Idaho National Laboratory	Integrated Electro-Hydraulic Fracturing and Real-Time Monitoring for Carbon Negative In-Situ Mining	Idaho Falls, ID	$3,143,000
MINER	University of Kentucky Research Foundation	Development of a Carbon-Negative Process for Comminution Energy Reduction and Energy-Relevant Mineral Extraction through Carbon Mineralization and Biological Carbon Fixation	Lexington, KY	$3,500,000
MINER	Harvard University	Developing Advanced NMR Techniques to Predict And Monitor CO_2 Storage and Mineralization for Enhanced Mining Exploration and Operation	Cambridge, MA	$1,889,308
MINER	Phoenix Tailings	CO_2 GONE – CO_2 Gasification of Ore for Nickel Extraction	Woburn, MA	$1,275,000
MINER	Johns Hopkins University	Carbon-Negative Mining from Gangue Minerals Enabled by Energy-Efficient Electrosynthesis of Acid and Base	Baltimore, MD	$2,000,000
MINER	Michigan Technological University	Energy Reduction and Improved Critical Mineral Recovery from Low-Grade Disseminated Sulphide Deposits and Mine Tailings	Houghton, MI	$2,467,817

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
MINER	Missouri University of Science and Technology	Reduce Comminution Energy and Improve Energy Relevant Mineral Yield using Carbon-Negative Oxalatization Reactions	Rolla, MO	$2,045,715
MINER	University of Nevada, Reno	Accelerated Reactive Carbonation Process (ARCP) for Energy Efficient Separation of Rare Earth Minerals	Reno, NV	$3,300,000
MINER	Columbia University	Hydrometallurgical Production of Domestic Metals for Energy Transition	New York, NY	$2,949,395
MINER	Columbia University	Innovative Stirred Media Mill Reactor with Integrated Carbon Mineralization and Electrochemical Separation of Critical Metals (critical SMM-e)	New York, NY	$2,500,000
MINER	University of Texas at Arlington	RECLAIM: Electrochemical Lithium and Nickel Extraction with Concurrent Carbon Dioxide Mineralization	Arlington, TX	$2,999,997
MINER	The University of Texas at Austin	Carbon Negative Reaction-Driven Cracking for Enhanced Mineral Recovery: In-Situ Test at a Ni-Co-PGE Deposit	Austin, TX	$4,997,015
MINER	Virginia Polytechnic Institute and State University	Energy-Relevant Elements Recovery from CO_2-Reactive Minerals During Carbon Mineralization	Blacksburg, VA	$2,200,000
MINER	Pacific Northwest National Laboratory	Re-Mining Red Mud Waste for CO_2 Capture and Storage and Critical Element Recovery (RMCCS-CER)	Richland, WA	$1,000,000
SCALEUP 2021	Ampaire	Hybrid Electric Aircraft Technology Platform	Hawthorne, CA	$9,000,000
SCALEUP 2021	Via Separations	DISPLACER: Deploying Industrial Separation Processes Leading to Accelerated Climate Emissions Reduction	Watertown, MA	$9,750,000
SCALEUP 2021	InventWood	Carbon Sequestration and Climate Resiliency via Super Wood	College Park, MD	$20,000,000
SCALEUP 2021	Niron Magnetics	Pilot Production for Commercial Sampling of Rare-Earth-Free Iron Nitride Permanent Magnets	Minneapolis, MN	$17,500,000

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
SCALEUP 2021	CorePower Magnetics	Scaled In-Line Processing Facility for Permeability Engineered Nanocrystalline Magnetics	Pittsburgh, PA	$5,000,000
SCALEUP 2021	Kent Houston Offshore Engineering	Passively Controlled Floating Wind Platforms for Low-cost Energy	Houston, TX	$17,500,000
SCALEUP 2021	Quidnet Energy	Catalyzing Commercialization of Geomechanical Pumped Storage	Houston, TX	$10,000,000
SCALEUP 2021	Imagen Energy	CHARGED: Commercialization of Highlight Accelerated Reliable Grid-Networked Energy Delivery	Wauwatosa, WI	$12,000,000
GO Competition Challenge 3	University of Tennessee	Scalable Unit Commitment with Security Constrained AC Power Flow via ADMM and Hybrid Modeling Strategies	Knoxville, TN	$400,000
GO Competition Challenge 3	University of Pittsburgh	Tightest Mixed-integer Programming Formulations for Quadratic SCUC Optimization	Pittsburgh, PA	$400,000
GO Competition Challenge 3	Massachusetts Institute of Technology	Alternating Direction Decomposition with Strong Bounding and Convexification (ADD-SBC) for Solving Security Constrained AC Unit Commitment Problems	Cambridge, MA	$399,902
GO Competition Challenge 3	University of Texas, Austin	Fast and Robust Strategies for Large-scale Mixed-integer SCOPF	Austin, TX	$400,000
GO Competition Challenge 3	Columbia University	Solving Multiperiod SCOPF Problems Via Nonlinear Optimization	New York, NY	$400,000
GO Competition Challenge 3	Global Optimal Technology Inc	Robust and High-Performance Nonlinear Security-constrained Multi-Period Resource Commitment and Optimal Power Flow	Ithaca, NY	$276,480
GO Competition Challenge 3	University of Florida	Computational Algorithms for Unit Commitment with AC Power Flows	Gainesville, FL	$279,047
GO Competition Challenge 3	Mississippi State University	Intelligent Partitioning based Fully Parallel AC Security-Constrained Optimal Power Flow (pSCOPF)	Mississippi State, MS	$367,345
GO Competition Challenge 3	IncSys	Cognitive Grid Optimization	Bellevue, WA	$400,000
GO Competition Challenge 3	Lawrence Livermore National Laboratory	LLGoMax: Enhancing Industry-Standard Tools for AC Optimal Unit Commitment	Livermore, CA	$400,000

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
EVs4ALL	Ampcera	Thermally Modulated Solid-State Batteries for Ultra-Safe Fast-Charging Electric Vehicles	Tucson, AZ	$2,120,120
EVs4ALL	Project K	Optimizing a Potassium-ion Electrolyte for Revolutionary Automotive Batteries	Palo Alto, CA	$2,587,618
EVs4ALL	Tyfast Energy	High SYmmetric PowER (HYPER) Battery	San Diego, CA	$2,823,199
EVs4ALL	South 8 Technologies	Liquefied Gas Electrolytes for Next-Gen EV Batteries	San Diego, CA	$3,152,000
EVs4ALL	Solid Power Operating	High Energy Fast Charging All-Solid-State Batteries	Thornton, CO	$5,600,000
EVs4ALL	National Renewable Energy Laboratory	Evaluating the Safety of Next-generation Energy Storage Cells	Golden, CO	$3,425,000
EVs4ALL	24M Technologies	Low-Cost, High Areal Capacity, Anode-Free Sodium-Metal Batteries Enabled by Solid Electrolytes	Cambridge, MA	$3,198,085
EVs4ALL	University of Maryland	Fast-Charge, High-Energy-Density, Solid-State Battery	College Park, MD	$4,852,733
EVs4ALL	Sandia National Laboratories	Framework for Safety Evaluation of EVs4ALL Batteries	Albuquerque, NM	$3,700,000
EVs4ALL	The Ohio State University	Extreme Fast Charging Batteries with Extended Cycle Life for EVs	Columbus, OH	$3,876,363
EVs4ALL	Zeta Energy	Enabling Fast Charging Batteries with 3D Lithium Metal Architectures and Sulfurized Carbon Cathodes	Houston, TX	$4,000,000
EVs4ALL	Virginia Polytechnic Institute and State University	Fast-Charging, Wide-Temperature, Low-Cost, Durable Batteries Enabled by Cobalt- and Nickel-Free Cathodes and Cell Engineering	Blacksburg, VA	$2,945,000
COOLERCHIPS	University of California, Davis	Holistic Modular Energy-efficient Directed Cooling Solutions (HoMEDiCS) for Edge Computing	Davis, CA	$3,586,473
COOLERCHIPS	NVIDIA Corporation	Green Refrigerant Compact Hybrid System for Ultra-Efficient and Sustainable HPC Cooling	Santa Clara, CA	$5,000,000
COOLERCHIPS	HRL Laboratories	Aligned Graphite Microchannel Cooling (AGMC) System with Additively Manufactured Manifolds	Malibu, CA	$2,000,000
COOLERCHIPS	National Renewable Energy Laboratory	COOLERCHIPS Technical Evaluation Team	Golden, CO	$1,463,319

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
COOLERCHIPS	Raytheon Technologies Research Center	EXTRACT: Extra Efficient Data Centers Using Avionics Cooling Technology	East Hartford, CT	$2,504,024
COOLERCHIPS	University of Florida	Hyperefficient Data Centers for Deep Decarbonization of Large-scale Computing	Gainesville, FL	$3,042,417
COOLERCHIPS	University of Illinois at Urbana-Champaign	Holistic Rack-to-Processor Power and Thermal Co-Design for Future Servers	Champaign, IL	$2,500,000
COOLERCHIPS	Purdue University	Confined Direct Two-phase Jet Impingement Cooling with Topology Optimized Surface Engineering and Phase Separation using Additive Manufacturing	West Lafayette, IN	$1,881,315
COOLERCHIPS	JetCool Technologies	Sub-One PUE through Silicon Cooling Efficiency	Littleton, MA	$1,265,747
COOLERCHIPS	University of Maryland	Multi-Objective Optimization Software for COOLERCHIPS	College Park, MD	$3,484,484
COOLERCHIPS	Flexnode	Prefab Modular Liquid-cooled Micro Data Center	Bethesda, MD	$3,500,000
COOLERCHIPS	University of Missouri	Dual-mode hybrid Two-phase Loop for Data Center Cooling	Columbia, MO	$1,649,290
COOLERCHIPS	HP	Embedded Microfluidic Cooling for Nextgen High Power Server Architectures	Corvallis, OR	$3,250,000
COOLERCHIPS	University of Texas at Arlington	Holistic Co-Design of Novel Hybrid Cooling Technology for the Data Center of the Future	Arlington, TX	$2,843,223
COOLERCHIPS	Intel Federal	Enabling Two-Phase Immersion Cooling to Support High TDP	Austin, TX	$1,711,416
Exploratory Topics Topic A: LENR	Lawrence Berkeley National Laboratory	Quantifying Nuclear Reactions in Metal Hydrides at Low Energies	Berkeley, CA	$1,500,000
Exploratory Topics Topic A: LENR	Stanford University	Nuclear Product Detection from Deuterated Nanoparticles under Phonon Stimulation	Redwood City, CA	$1,500,000
Exploratory Topics Topic A: LENR	Massachusetts Institute of Technology	Neutron emission from laser-stimulated metal hydrides	Cambridge, MA	$2,000,000
Exploratory Topics Topic A: LENR	Energetics Technology Center	CATHODE (CATHode scintillatOr Detector for Electrochemistry)	Indian Head, MD	$1,500,000
Exploratory Topics Topic A: LENR	University of Michigan	Ionizing Radiation Detection for Exploratory Experiments in Low-Energy Nuclear Reactions	Ann Arbor, MI	$902,213

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
Exploratory Topics Topic A: LENR	University of Michigan	Systematic evaluation of Claims of Excess Heat Generation From Deuteration of Palladium-Nickel Nanocomposites	Ann Arbor, MI	$1,108,412
Exploratory Topics Topic A: LENR	Amphionic	Nanostructured PD-ANF Composites for Controlled LENR Exploitation	Dexter, MI	$295,924
Exploratory Topics Topic A: LENR	Texas Tech University	Advanced Materials Characterization and Nuclear Product Detection for LENR	Lubbock, TX	$1,150,000
Exploratory Topics Topic B: INTERMODAL	National Renewable Energy Laboratory	Intermodal Freight Optimization for a Resilient Mobility Energy Systems (INFORMES)	Golden, CO	$2,200,000
Exploratory Topics Topic B: INTERMODAL	University of Tennessee: Knoxville	A Cognitive Freight Transportation Digital Twin for Resiliency and Emission Control Through Optimizing Intermodal Logistics (RECOIL)	Knoxville, TN	$1,900,000
Exploratory Topics Topic B: INTERMODAL	Michigan Technological University	A decarbonized and Resilient Intermodal Freight Transportation (DRIFT) Modeling Platform for Intermodal Logistical Decisions under Uncertainty	Houghton, MI	$1,200,000
Exploratory Topics Topic B: INTERMODAL	Pacific Northwest National Laboratory	Optimal Global Platform for Transportation (Opt-GPT): Optimal net-zero technology deployment and route planning Co-Design in intermodal freight transportation for multi-objective-system-level efficiency and climate change mitigation	Richland, WA	$1,500,000
Exploratory Topics Topic B: INTERMODAL	University of Illinois at Urbana-Champaign	Integrated Intermodal Freight Models and Tools for Efficiency and Resiliency	Urbana, IL	$1,500,000
Exploratory Topics Topic B: INTERMODAL	Oliver Wyman	Intermodal Routing and Environmental Impact Analysis Tool	Princeton, NJ	$500,000
Exploratory Topic Topic C: CREATE	Calion Technologies, Inc.	Zero-GWP Air Source Heat Pump Steam Generation Using Ionocalorics	Danville, CA	$500,000
Exploratory Topic Topic C: CREATE	Marathon Fusion	Advanced Metal Foil Pumps and Integrated Test Environment for the Fusion Fuel Cycle	San Francisco, CA	$449,387
Exploratory Topic Topic C: CREATE	Deep Isolation	Sequential Advancement of Technology for Deep Borehole Disposal (SAVANT)	Berkeley, CA	$441,674

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
Exploratory Topic Topic C: CREATE	C-Crete Technologies	High Performance Nanocomposite Kraft Papers to Improve Insulation and Lifetime of Large Power Transformers	San Leandro, CA	$500,000
Exploratory Topic Topic C: CREATE	University of Notre Dame	GaN Core-Shell Nanofin Vertical Transistor (CoNVerT): a New Direction for Power Electronics	Notre Dame, IN	$334,319
Exploratory Topic Topic C: CREATE	Northeastern University	Accelerating Electrocatalyst Innovation: High-Throughput Automated Microkinetic, multiscale, and techno-economic modeling	Boston, MA	$500,000
Exploratory Topic Topic C: CREATE	NK Labs LLC	Active-target Muon Source for Muon-catalyzed Fusion	Cambridge, MA	$500,000
Exploratory Topic Topic C: CREATE	Foundation Alloy Technology Explorations	Enabling Resilient and Secure Domestic Supply Chains for Critical Reactor Components with Novel Materials and Additive Manufacturing	Cambridge, MA	$449,100
Exploratory Topic Topic C: CREATE	Eva Technology	Nanoprotonic Devices for >240x Performance Analog AI Hardware	Boston, MA	$500,000
Exploratory Topic Topic C: CREATE	WH-Power, Inc.	Low Cost All Temperature Zinc-pulp Battery for Stationary Storage	College Park, MD	$500,000
Exploratory Topic Topic C: CREATE	Johns Hopkins University	High-Entropy Glass-Ceramics for Nuclear Waste Immobilization	Baltimore, MD	$500,000
Exploratory Topic Topic C: CREATE	Johns Hopkins University	Enantioselective-Selective Electrosynthesis of Amino Acids	Baltimore, MD	$500,000
Exploratory Topic Topic C: CREATE	Pacific Industrial Development Corporation	Biomimetic CO_2 to Fuel Enabled by Scalable Catalyst Development and Synthetic Electrochemistry	Ann Arbor, MI	$500,000
Exploratory Topic Topic C: CREATE	North Carolina State University	HVPE Grown GaN Conductive Substrates for Power Electronics	Raleigh, NC	$476,190
Exploratory Topic Topic C: CREATE	Princeton University	Highly Efficient Charged Particle Beam Injection into Magnetically Confined Plasmas	Princeton, NJ	$499,866
Exploratory Topic Topic C: CREATE	GaNify LLC	50-kV/1-A Sub-Microsecond Power Switch for Gyrotron Modulation	State College, PA	$500,000
Exploratory Topic Topic C: CREATE	Perseus Materials, Inc.	Variable Cross-sectional Casting: New Composite Fabrication Process for Wind Turbine Blades	Knoxville, TN	$498,767

Appendix 1: Projects Selected in FY 2023 [26]				
Program	**Lead Organization**	**Project Title**	**Location**	**ARPA-E Funding**
Exploratory Topic Topic C: CREATE	Texas Tech University	Development of Cubic Boron Nitride (c-BN) Ultrawide Bandgap Semiconductors	Lubbock, TX	$500,000
Exploratory Topic Topic D: PRE-TRAILS	GE Research	Engine-informed Prediction of Aviation Induced Cirrus Trails-EPIC-Trails	Niskayuna, NY	$1,500,000
Exploratory Topic Topic D: PRE-TRAILS	RTX Technologies Research Center	CONFIRMMS: CONtrail Forecasting through In-situ Reliable Multisourced Modeling and Sensing	East Hartford, CT	$2,500,000
Exploratory Topic Topic D: PRE-TRAILS	The Boeing Company	Contrail INformation for Collaborative Operations (CINCO)	Everett, WA	$2,497,451
Exploratory Topic Topic D: PRE-TRAILS	Universities Space Research Association	Physics & Machine Learning Based Aviation Contrails Prediction and Observation System	Mountain View, CA	$1,000,000
Exploratory Topic Topic D: PRE-TRAILS	Northrop Grumman Systems Corporation	Contrail Avoidance System	Redondo Beach, CA	$2,490,000