FINANCIAL ASSISTANCE
NOTICE OF FUNDING OPPORTUNITY

ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

REALIZE ENERGY-RICH COMPOUND OPPORTUNITIES VALORIZING EXTRACTION FROM REFUSE WATERS SBIR/STTR (RECOVER SBIR/STTR)

Announcement Type: Initial Announcement
Notice of Funding Opportunity No. DE-FOA-0003511
Assistance Listing Number 81.135

Mod. No.	Date	Description of Modifications*
01	12/9/24	• Clarified the selectivity definition in Section I.F Technical Performance Metrics.

*All modifications to the Notice of Funding Opportunity (NOFO) are highlighted in yellow in the body of the NOFO.

NOFOs are posted on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/), Grants.gov (http://www.grants.gov/), and FedConnect (https://www.fedconnect.net/FedConnect/). Any modifications to the NOFO are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this NOFO. It is recommended that you register as soon as possible after release of the NOFO to ensure that you receive timely notice of any modifications or other announcements.

Questions about this NOFO? Check the Frequently Asked Questions available at https://arpa-e.energy.gov/faqs. For questions that have not already been answered, email ARPA-E-CO@hq.doe.gov (with NOFO name and number in subject line). Problems with ARPA-E eXCHANGE? Email ExchangeHelp@hq.doe.gov (with NOFO name and number in subject line).

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BASIC INFORMATION

KEY DATES:	
Notice of Funding Opportunity (NOFO) Issue Date:	November 21, 2024
Deadline for Concept Paper Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, December 20, 2024
Submission Deadline for Concept Papers:	9:30 AM ET, December 31, 2024
Anticipated Date for Encourage/Discourage Notifications:	5 PM ET, February 2025
Deadline for Full Application Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Expected Reviewer Comment Release Date:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Anticipated Timeframe for Selection Notifications:	June 2025
Anticipated Timeframe for Award:	September 2025
Anticipated Period of Performance:	September 2025 – September 2028

BASIC INFORMATION:	
Total Amount to Be Awarded	Approximately $36 million, subject to the availability of appropriated funds to be shared between NOFOs DE-FOA-0003510 and DE-FOA-0003511.
Anticipated Number and Value of Awards	ARPA-E anticipates making approximately 10-16 awards between NOFOs DE-FOA-0003510 and DE-FOA-0003511. ARPA-E may issue one, multiple, or no awards under this NOFO. The Federal share of awards under this NOFO may vary between $1.5 million and $4 million.
Agency Contact Information	• Questions and answers (Q&As) about ARPA-E and this specific NOFO: http://arpa-e.energy.gov/faq. • Send other questions about the NOFO to: ARPA-E-CO@hq.doe.gov. • Send questions about use of ARPA-E eXCHANGE to: ExchangeHelp@hq.doe.gov. Upon the issuance of a NOFO, only the Grants Officer via ARPA-E-CO@hq.doe.gov may communicate with Applicants. This "quiet period" remains in effect until ARPA-E's public announcement of project selections. Emails sent to other email addresses will be disregarded.

The Realize Energy-rich Compound Opportunities Valorizing Extraction from Refuse waters (RECOVER) program seeks to develop technologies to concentrate and recover high value energy materials from aqueous waste streams. Priority high value energy materials for the program are ammonia and metals considered critical to energy and diversifying the U.S. supply chain. Ammonia is produced using the Haber-Bosch process with a high energy and greenhouse gas penalty, and much of this ammonia ends up in municipal and animal waste streams where it is destroyed without recovery. Critical metals are obtained from ore mining and processing and are almost entirely sourced from overseas; their use in infrastructure and military technologies makes their supply a matter of national concern. Produced water and mining waste streams have sufficient amounts of key critical metals to displace all or most of U.S. imports.

The RECOVER program will enable: i) the replacement of 50% of conventional ammonia supplies, and all or partial critical metals imports, ii) the valorization of multiple high value energy materials from an

aqueous waste stream, iii) the reduction of energy demands and CO_2-equivalent (CO_2eq) emissions for ammonia and critical metals procurement, and iv) the recovery of market-valuable products at competitive prices. Recovery of market-valuable products will create new revenue sources for aqueous waste stream processors, thereby reducing net costs and contributing to improved water treatment outcomes.

Relevant waste stream targets are municipal or animal feedlot waste streams, produced water waste streams, and mining waste streams. New technology development efforts under the RECOVER program include three technical categories: 1) new materials, 2) process development and derisking, and 3) process integration. Capable technologies will be energy efficient, highly selective, and durable over extended use. Processes will involve limited sequential steps, be scalable, and be adaptable to existing or new wastewater facilities.

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), as further amended by the Energy Act of 2020 (P.L. 116-260):

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that—
(i) reduce imports of energy from foreign sources;
(ii) reduce energy-related emissions, including greenhouse gases;
(iii) improve the energy efficiency of all economic sectors;
(iv) provide transformative solutions to improve the management, clean-up, and disposal of radioactive waste and spent nuclear fuel; and
(v) improve the resilience, reliability, and security of infrastructure to produce, deliver, and store energy; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Notice of Funding Opportunity (NOFO) under its authorizing statute codified at 42 U.S.C. § 16538. The NOFO and any cooperative agreements or grants made under this NOFO are subject to 2 C.F.R. Part 200 as supplemented by 2 C.F.R. Part 910.

ARPA-E funds research on, and the development of, transformative science and technology solutions to address the energy and environmental missions of the Department. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

ARPA-E funds transformational research. Existing energy technologies generally progress on established "learning curves" where refinements to a technology and the economies of scale that accrue as manufacturing and distribution develop drive improvements to the cost/performance metric in a gradual fashion. This continual improvement of a technology is important to its increased commercial deployment and is appropriately the focus of the private sector or the applied technology offices within DOE. In contrast, ARPA-E supports transformative research that has the potential to create fundamentally new learning curves. ARPA-E technology projects typically start with cost/performance estimates well above the level of an incumbent technology. Given the high risk inherent in these projects, many will fail to progress, but some may succeed in generating a new learning curve with a projected cost/performance metric that is significantly better than that of the incumbent technology. ARPA-E will provide support at the highest funding level only for submissions with significant

technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

ARPA-E funds applied research and development (R&D). The Office of Management and Budget defines "applied research" as an "original investigation undertaken in order to acquire new knowledge…directed primarily towards a specific practical aim or objective" and defines "experimental development" as "creative and systematic work, drawing on knowledge gained from research and practical experience, which is directed at producing new products or processes or improving existing products or processes."[1] Applicants interested in receiving financial assistance for basic research (defined by the Office of Management and Budget as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts")[1] should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E Applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on early-stage R&D for the improvement of technology along defined roadmaps may be more appropriate for support through the DOE applied energy offices including: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy and Carbon Management (https://www.energy.gov/fecm/office-fossil-energy-and-carbon-management), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity (https://www.energy.gov/oe/office-electricity).

ARPA-E encourages submissions stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists. Submissions can propose a project with the end deliverable being an extremely creative, but partial solution.

[1] OMB Circular A-11 (https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf), Section 84, pg. 3.

B. SBIR/STTR PROGRAM OVERVIEW

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are Government-wide programs authorized under Section 9 of the Small Business Act (15 U.S.C. § 638). The objectives of the SBIR program are to (1) stimulate technological innovation in the private sector, (2) strengthen the role of Small Business Concerns in meeting Federal R&D needs, (3) increase private sector commercialization of innovations derived from Federal R&D activities, (4) foster and encourage participation by socially and economically disadvantaged and women-owned Small Business Concerns, and (5) improve the return on investment from Federally funded research and economic benefits to the Nation. The objective of the STTR program is to stimulate cooperative partnerships of ideas and technologies between Small Business Concerns and partnering Research Institutions through Federally funded R&D activities.[2]

ARPA-E administers a joint SBIR/STTR program in accordance with the Small Business Act and the SBIR and STTR Policy Directive issued by the U.S. Small Business Administration (SBA).[3] ARPA-E provides SBIR/STTR funding in three phases (Phase I, Phase II, and Phase IIS).

Applicants must apply for a Combined Phase I/II Award or a Combined Phase I/II/IIS Award. Combined Phase I/II and I/II/IIS Awards are intended to develop transformational technologies with disruptive commercial potential. Such commercial potential may be evidenced by (1) the likelihood of follow-on funding by private or non-SBIR/STTR sources if the project is successful, or (2) the Small Business Concern's record of successfully commercializing technologies developed under prior SBIR/STTR awards. Phase IIS awards are a "sequential" (i.e., additional) Phase II award, intended to allow the continued development of promising energy technologies. Combined Phase I/II/IIS awards may be funded up to $4,505,859. Funding amounts will be consistent with the Phase I and Phase II limits posted on SBIR.gov website.[4]

ARPA-E reserves the right to select all or part of a proposed project (i.e., only Phase I, or only Phase I and Phase II). In the event that ARPA-E selects Phase I only or Phase I/II only, then the maximum award amount for a Phase I award is $314,363 and the maximum amount for a Phase I/II award is $2,410,111.

[2] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[3] See 88 Fed. Reg. 19704 (May 3, 2023) or SBIR.gov file at SBIR and STTR Policy Directive - May 2023.

[4] For current SBIR and STTR Phase I and Phase II funding amounts, see https://legacy.www.sbir.gov/about. Phase IIS funding amounts are equal to Phase II funding amounts for both SBIR and STTR awards.

C. PROGRAM OVERVIEW

The Realize Energy-rich Compound Opportunities Valorizing Extraction from Refuse waters (RECOVER) program seeks to develop technologies to concentrate and recover high value energy materials (ammonia and critical metals) from aqueous waste streams. The RECOVER program will enable the U.S. to fully replace imports of these high value energy materials with domestic sources, thereby enhancing energy security. The RECOVER program will also enable a 30% reduction in energy demand and a 70% reduction in greenhouse gas (GHG) emissions as compared to conventional production of high value energy materials. This will be achieved by eliminating energy demand for creating or mining high value energy materials, electrifying new recovery technologies, and preventing nitrous oxide (N_2O) emissions from wasted ammonia.

1. BACKGROUND AND MOTIVATION

The RECOVER program defines the aqueous waste stream as any unwanted aqueous byproduct of anthropogenic activities, and includes:

- Municipal wastewater;
- Animal feedlot retention basins/waste ponds;
- Oil and gas flowback, and produced water; and
- Mining drainage, discharge, and tailing ponds.

High value energy materials under consideration include:

- Ammonia, defined as both ammonia (NH_3) and ammonium (NH_4^+) unless otherwise specified;
- Phosphorus (P) when captured in addition to ammonia;
- 13 metals considered critical or near critical to energy and diversifying the U.S. metals supply chain (see Figure 1); and
- All additional rare earth elements (REEs) (see Figure 1).[5]

Other high value energy materials can be targeted for recovery if their importance to ARPA-E's statutory goals as described in Section I.A and ability to meet RECOVER program objectives. By improving recovery technologies, ARPA-E aims to support the creation of new revenue sources for aqueous waste stream processors, thereby reducing net costs for water treatment.

[5] U.S. DOE, "Notice of Final Determination on 2023 DOE Critical Materials Lists" (Federal Register, 2023), *88*, 51792–51798. energy.gov/sites/default/files/2023-07/doe-critical-material-assessment_07312023.pdf .

RECOVER High Energy-Value Materials Targets	
Ammonia (NH_3/NH_4^+)	Magnesium (Mg)
Cerium (Ce)	Neodymium (Nd)
Cobalt (Co)	Nickel (Ni)
Copper (Cu)	Phosphorus (P) (with
Dysprosium (Dy)	Ammonia)
Erbium (Er)	Platinum (Pt)
Europium (Eu)	Praseodymium (Pr)
Gallium (Ga)	Samarium (Sm)
Holmium (Ho)	Terbium (Tb)
Iridium (Ir)	Thulium (Tm)
Lanthanum (La)	Uranium (U)
Lithium (Li)	Ytterbium (Yb)
Luteium (Lu)	Yttrium (Y)

Figure 1. DOE list of the most important critical materials with respect to energy and supply chain risk, and a list of high value energy materials preferred for this NOFO.[6]

Ammonia

Total domestic consumption of anhydrous ammonia is approximately 15 million tonnes (Mt), with greater than 2 Mt of this amount imported at a cost of $1.35 billion in 2023.[7,8] Food production agriculture comprises 88% of this demand.[9] Total worldwide ammonia production is predicted to increase 40% from 2020 to 2050. This growth is mainly driven by economic and population growth in developing countries.[10]

The Haber-Bosch (HB) process is the dominant reaction to manufacture ammonia from nitrogen and natural gas. Ammonia production accounts for approximately 2% of global energy consumption and 1.3% of carbon dioxide (CO_2) emissions; domestic energy and CO_2 impacts are

[6] Figure adapted from U.S. DOE, "Notice of Final Determination on 2023 DOE Critical Materials Lists" (Federal Register, 2023), *88*, 51792–51798. https://www.energy.gov/sites/default/files/2023-07/doe-critical-material-assessment_07312023.pdf.
[7] U.S. Environmental Protection Agency (EPA), "Anhydrous Ammonia Supply Chain – Full Profile," EPA.gov, 2022, https://www.epa.gov/waterutilityresponse/water-treatment-chemical-supply-chain-profiles.
[8] World Integrated Trade Solutions, "United States Anhydrous Ammonia Imports by Country in 2019," 2024, https://wits.worldbank.org/trade/comtrade/en/country/USA/year/2019/tradeflow/Imports/partner/ALL/product/281410#.
[9] U.S. Geological Survey (USGS). "Commodity Statistics and Information," usgs.gov., 2024, https://www.usgs.gov/periodicals/mcs2022/mcs2022-nitrogen.pdf.
[10] International Energy Agency, "Ammonia Technology Roadmap," iea.org, 2021, https://www.iea.org/reports/ammonia-technology-roadmap.

expected to be similar or greater because U.S. ammonia production facilities are older than the global mean.[11] Domestic ammonia production drives a $28 billion domestic fertilizer market.[12]

More than 50% of the ammonia used each year in the U.S. is collected in municipal wastewaters and animal feedlot retention basins, where it is destroyed.[13, 14, 15] Replacement of destroyed ammonia via HB requires approximately 0.4 quads of energy per year (quads/yr) and results in annual GHG emissions of greater than 60 Mt of CO_2eq.[16, 17] Approximately one-third of these GHGs are from direct CO_2 emissions due to energy consumption by HB, while the remainder is associated with N_2O emissions during the destruction of ammonia and its reaction products in treatment facilities or the environment.[18, 19, 20]

The nitrate (NO_3^-) produced and discharged from wastewater treatment plants and animal feedlot basins is a major environmental contaminant that results in eutrophication and hypoxia in surface waters and extensive groundwater contamination.[21, 22]

Critical Metals

The overwhelming majority of nonferrous critical metals are mined and processed outside the U.S. This is especially true for the targeted critical metals listed in Figure 1, as greater than 95% of iridium (Ir), cobalt (Co), magnesium (Mg), and REEs are mined and processed abroad.[23] The

[11] International Energy Agency, "Ammonia Technology Roadmap," iea.org, 2021, https://www.iea.org/reports/ammonia-technology-roadmap.
[12] Mordor Intelligence, "United States Fertilizers Market Size and Share Analysis - Growth Trends and Forecasts up to 2030," https://www.mordorintelligence.com/industry-reports/united-states-fertilizers-market.
[13] U.S. EPA, "Sources and Solutions: Wastewater," EPA.gov, 2023, https://www.epa.gov/nutrientpollution/sources-and-solutions-wastewater.
[14] Metcalf & Eddy. "Wastewater Engineering: Treatment and Resource Recovery," New York: McGraw-Hill, 2014.
[15] U.S. EPA, "Estimated Animal Agriculture Nitrogen and Phosphorus from Manure," EPA.gov, 2023, https://www.epa.gov/nutrientpollution/estimated-animal-agriculture-nitrogen-and-phosphorus-manure.
[16] International Energy Agency, "Ammonia Technology Roadmap," iea.org, 2021, https://www.iea.org/reports/ammonia-technology-roadmap.
[17] U.S. EPA. "Draft of Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024, EPA 430-D-24-001. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022.
[18] U.S. EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021," 2023, EPA-430-R-23-002. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021.
[19] Ewelina Pluciennik-Koropczuk and Sylwia Myszograj, "Significance of Wastewater Treatment to Nitrous Oxide Emission," *Civil and Environmental Engineering Reports* 31, no. 4 (2021): 237–248. https://doi.org/10.2478/ceer-2021-0059.
[20] Patricia M. Gilbert, "From Hogs to HABs: Impacts of Industrial Farming in the US on Nitrogen and Phosphorus and Greenhouse Gas Pollution," *Biogeochemistry* 150, (2020): 139–180. https://doi.org/10.1007/s10533-020-00691-6.
[21] Michal Preisner, Elena Neverova-Dziopak, and Zbigniew Kowalewski, "Analysis of Eutrophication Potential of Municipal Wastewater," *Water Science & Technology* 81, no. 9 (2020): 1994–2003. https://doi.org/10.2166/wst.2020.254.
[22] Karen R. Burrow, et al., "Nitrate in groundwater of the United States, 1991–2003," *Environmental Science & Technology* 44, no. 13 (2010): 4988–4997. https://doi.org/10.1021/es100546y.
[23] U.S. Geological Survey (USGS). "Commodity Statistics and Information," usgs.gov., 2024, https://www.usgs.gov/periodicals/mcs2022/mcs2022-nitrogen.pdf.

lack of domestic mining and processing is often attributed to long permitting times and associated expenses for new facilities due to environmental and social concerns. For example, the average time to obtain a new mining permit is 18 years.[24]

The critical metals listed in Figure 1 are key components in electronics and decarbonization technologies such as computers, electric vehicles, and wind turbines. The use of critical metals in the U.S. for consumer products, infrastructure, and military technologies makes metal procurement a matter of national concern. Demand for critical metals is growing with a projected four times volume increase by 2040 and as much as a six times increase under a "Net-Zero by 2050" scenario (Figure 2).[25] Benchmark Mineral Intelligence estimates that 384 new mines will be needed to meet domestic critical metal demand by 2035.[26] Given the long permitting times for mines, the U.S. is unlikely to meet demand by domestic production alone unless new sources and methods to recover critical metals are discovered.

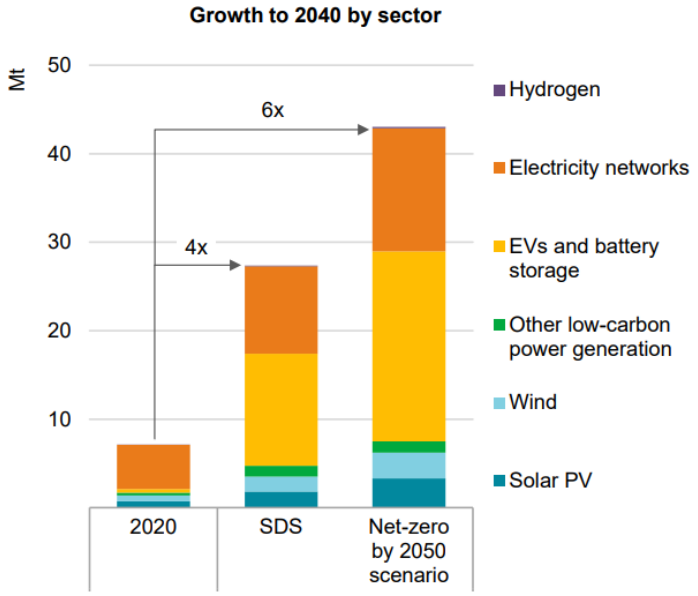

Figure 2. Projected demand of critical materials by sector. Projections show a four times increase under a Sustainable Development Scenario (SDS) by 2040, or a six times increase under the net-zero by 2050 scenario.[27]

[24] Paul Manalo, "Average Lead Time Almost 18 Years for Mines Started in 2020–2023,: S&P Global, S&P Global Market Intelligence, April 10, 2024, https://www.spglobal.com/marketintelligence/en/news-insights/research/average-lead-time-almost-18-years-for-mines-started-in-2020-23.

[25] International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," iea.org., 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions.

[26] Benchmark Mineral Intelligence, "More than 300 new mines required to meet battery demand by 2035", Benchmark Source, 6th Sept. 2022. https://source.benchmarkminerals.com/article/more-than-300-new-mines-required-to-meet-battery-demand-by-2035.

[27] Reproduced with permission from U.S. EPA. "Draft of Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022," 2024, EPA 430-D-24-001. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022.

Large amounts of critical metals can be found in industrial and mining waste streams. Based on median values from the U.S. Geological Survey database, produced waters from conventional hydrocarbon, shale gas, and tight oil wells contain sufficient lithium (Li) to supply all present U.S. needs (i.e., approximately 3,000 tonnes in 2022).[28, 29] Waste streams from 1,100 coal mining sites in Appalachia contain sufficient yttrium (Y) to meet 100% of U.S. demand, and enough praseodymium (Pr), cerium (Ce), and neodymium (Nd) to meet 50% of U.S. demand.[30] However, these metals are often at single digit or lower milligrams per liter (mg/L) levels. Thus, new methods are needed to competitively recover these critical metals.

The energy demand and CO_2eq emissions for conventional mining and processing of critical metals vary widely and depend on ore quality, processing steps, transportation needs, and final purity based on estimates for 63 metals.[31] For the metals targeted in this NOFO (Figure 1), the energy demand and CO_2eq emissions vary greatly by metal type, with the lowest values for Li (125 megajoule equivalents per kilogram (MJeq/kg) and 7.1 kilogram CO_2eq per kilogram (kg CO_2eq/kg)) and the highest for Pt (243,000 MJeq/kg and 12,500 kg CO_2eq/kg). On an annual basis, the domestic demand for Li (3000 t/yr) versus Pt (42 t/yr) brings the yearly energy demand and CO_2eq emissions amounts closer (i.e., Li at 3.6×10^{-4} quads/yr and 21,300 tCO_2eq/yr versus Pt at $9.7x10^{-3}$ quads/yr and 525,000 tCO_2eq/yr). In the same study, relative energy demands for ore mining, beneficiation, and acid leaching were calculated and compared to totals, where totals include all subsequent processing steps such as sequential precipitation and acid dissolution, solvent extractions, and electrowinning.[32] Relative energy demands for ore mining, beneficiation, and acid leaching range from a few percent for Li to approximately 12% for Y with relative CO_2eq emissions closely matching these values.

Overlap between Ammonia and Critical Metals

The challenges of ammonia and critical metals recovery overlap. Both ammonia and critical metals are present as cations, so new cation-selective adsorbents and membranes developed for one may benefit the other. Both ammonia and critical metals are often present at low concentrations such that common pre-concentration steps may be used to facilitate recovery. Technologies to recover either ammonia or critical metals are also subject to deactivation from common organic and inorganic foulants, so similar strategies to prevent or reverse fouling may

[28] U.S. Geological Survey (USGS). "Commodity Statistics and Information," usgs.gov., 2024, https://www.usgs.gov/periodicals/mcs2022/mcs2022-nitrogen.pdf.

[29] Carleton R. Bern, Justin E. Birdwell, and Aaron M. Jubb, "Water–Rock Interaction and the Concentrations of Major, Trace, and Rare Earth Elements in Hydrocarbon-associated Produced Waters of the United States," *Environmental Science: Processes & Impacts* 23, no. 8 (2020): 1198–1219. https://pubmed.ncbi.nlm.nih.gov/34308467/.

[30] Christopher R. Vass, Aaron Noble, and Paul F. Ziemkiewicz, "The Occurrence and Concentration of Rare Earth Elements in Acid Mine Drainage and Treatment By-products: Part 1—Initial Survey of the Northern Appalachian Coal Basin," M*ining, Metallurgy, & Exploration* 36, (2019): 903–916. https://doi.org/10.1007/s42461-019-0097-z.

[31] Phillip Nuss, and Matthew J. Eckelman, "Life Cycle Assessment of Metals: A Scientific Synthesis," *PLOS ONE* 9, no 7 (2014): e101298. https://doi.org/10.1371/journal.pone.0101298.

[32] Phillip Nuss, and Matthew J. Eckelman, "Life Cycle Assessment of Metals: A Scientific Synthesis," *PLOS ONE* 9, no 7 (2014): e101298. https://doi.org/10.1371/journal.pone.0101298.

apply. Further, ammonia and critical metals are present together in some aqueous waste streams, such as produced waters in the Permian Basin.[33, 34] Lastly, the U.S. government has boosted investment for critical metals discovery and production, spurring interest in private sector investment for sourcing domestic critical metals.[35] Private sector investment in new technologies for critical metals will benefit ammonia recovery, reducing reliance on HB ammonia produced using fossil fuels.

2. CURRENT TECHNOLOGY

State-of-the-Art for Municipal Wastewater and Animal Feedlot Retention Basin Treatment and Ammonia Recovery

The state-of-the-art (SoA) technologies for treating aqueous ammonia-containing waste streams at wastewater treatment facilities rely on either ammonia destruction or discharge to the environment. For example, at municipal wastewater plants (Figure 3), activated sludge treatment uses aeration to promote biological oxidation of organic carbon to biomass and CO_2, and ammonia oxidation to NO_3^- (i.e., nitrification).[36] At select municipal wastewater plants, a separate anaerobic reactor is placed before or after the activated sludge process to promote NO_3^- reduction to dinitrogen gas, N_2 (i.e., denitrification). However, most facilities discharge NO_3^- in the effluent to surface water.[37] Biomass, produced in activated sludge processes, is gravity separated and often anaerobically digested to produce methane (i.e., biogas).[38] Anaerobic digestion creates a concentrated ammonia and P stream (i.e., digestate) that is mixed back with the influent wastewater for nitrification in the activated sludge process.[39, 40] In some cases, struvite ($NH_4MgPO_4 \cdot 6H_2O$) is precipitated from the digestate to recover P and an equal molar amount of ammonia before mixing this stream back with the influent

[33] Haiqing Chang, et al., "Consideration of Potential Technologies for Ammonia Removal and Recovery from Produced Water," *Environmental Science & Technology* 56, no. 6 (2022): 3305–3308. https://doi.org/10.1021/acs.est.1c08517.

[34] Lei Hu, et al., "Toxicological Characterization of Produced Water from the Permian Basin," *Science of the Total Environment* 815, (2022): 152943. https://doi.org/10.1016/j.scitotenv.2022.152943.

[35] "Treasury Releases Guidance to Drive Investment in Critical Minerals & Battery Supply Chains in America" (White House Press Release, 2023). https://www.whitehouse.gov/cleanenergy/clean-energy-updates/2023/03/31/treasury-releases-guidance-to-drive-investment-in-critical-minerals-battery-supply-chains-in-america/.

[36] Modified from Siti Baizura Mahat, et al, "Dynamic Membrane Applications in Anaerobic and Aerobic Digestion for Industrial Wastewater: A Mini Review," *Food and Bioproducts Processing* 112, (2018) 150–168. https://doi.org/10.1016/j.fbp.2018.09.008.

[37] George Tchobanoglous, Franklin L. Burton, and H. David Stensel, *Wastewater Engineering: Treatment and Reuse* (New Yorks, NY: McGraw-Hill Education, 2003).

[38] Matthieu Girard, et al., "Biodegradation in Animal Manure Management," in *Biodegradation - Engineering and Technology*, ed. Rolando Chamy, (InTech, 2013), Chapter 10.

[39] Nigel Key, et al., "Trends and Developments in Hog Manure Management: 1998–2009", (USDA Economic Information Bulletin 81, 2011). https://www.ers.usda.gov/webdocs/publications/44579/6018_eib81_1_.pdf?v=0.

[40] Jonathan Rea. *Kinetic Modeling and Experimentation of Anaerobic Digestion* [Undergraduate Thesis, Massachusetts Institute of Technology. DSpace@MIT. http://hdl.handle.net/1721.1/92070.

wastewater.[41] However, the molar ratio of N to P in wastewater is approximately 5:1, so the majority of ammonia remains in wastewater and is destroyed. The entire energy demand for wastewater treatment in the U.S. is on the order of 0.1 quads/yr.[42] Aeration is the most energy intensive step in the treatment process, contributing to greater than 65% of the total energy demand.[43]

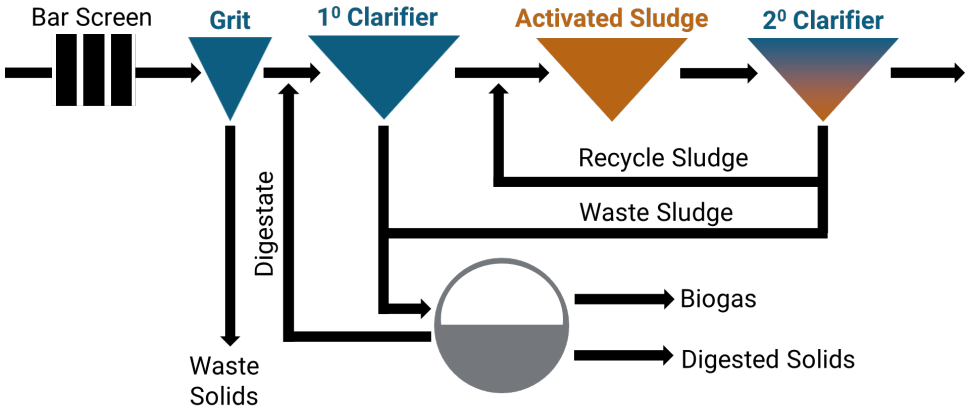

Figure 3. Illustration of major processes at a wastewater treatment plant.

At animal feedlots, retention basins collect urine, rain, wash water, and manure runoff. These waters are held for months to settle and to promote biological decay of organic carbon and possibly ammonia. After suspended solids settle, the overlying water is used to irrigate agricultural fields. Both ammonia and NO_3^- are contained in the overlying water and act as nutrients. The amounts of ammonia and NO_3^- in the water depend on several factors, such as oxygen levels in the detention basin and atmospheric losses of volatile N-containing compounds. Manure is also collected separately from urine and spread onto agricultural fields as a nutrient source. In a few cases, anaerobic digestion is used to treat manure and wash water. This process creates biogas as a side product.[44] As in municipal wastewater treatment, digestion creates a concentrated ammonia stream.

Ammonia has been recovered from high concentration streams, such as anaerobic digestate, via gas-phase column stripping.[45] While functional, a recently published technoeconomic

[41] Shayok Ghosh, Sergey Lobanov, and Victor K. Lo, "An Overview of Technologies to Recover Phosphorus as Struvite from Wastewater: Advantages and Shortcomings," *Environmental Science and Pollution Research* 26, (2019): 19063–19077. https://doi.org/10.1007/s11356-019-05378-6.

[42] Steve Tarallo, *Utilities of the Future* (IWA Publishing, 2014) ISBN: 978-1-78040-680-0/1-78040-680-0.

[43] Alexandra Siatou, Anthoula Manali, and Petros Gikas, "Energy Consumption and Internal Distribution in Activated Sludge Wastewater Treatment Plants of Greece," *Water* 12, no. 4(2020): 1204. https://doi.org/10.3390/w12041204.

[44] Bella, K., Polisetty Venkateswara Rao, "Anaerobic Digestion of Dairy Wastewater: Effect of Different Parameters and Co-Digestion Options – a Review," *Biomass Conversion and Biorefinery* 13, (2023): 2527–2552. https://doi.org/10.1007/s13399-020-01247-2.

[45] Saurajyoti Kar, et al., "Life Cycle Assessment and Techno-economic Analysis of Nitrogen Recovery by Ammonia Air-Stripping from Wastewater Treatment," *Science of the Total Environment* 857, no. 3 (2023): 159499. https://doi.org/10.1016/j.scitotenv.2022.159499.

assessment (TEA) indicates operating costs alone for gas-phase column stripping are several times greater than the cost of NH_3 from HB.[46]

Ammonia recovery from municipal wastewater treatment plants would decrease aeration requirements of activated sludge treatment by eliminating the need for nitrification and could allow either expanded treatment capacity or conversion of the activated sludge process to anaerobic treatment. Recovery from animal feedlot retention basins would remove ammonia from retention basin water, thereby alleviating groundwater contamination concerns, and would remove ammonia toxicity that can hinder anaerobic digestion.

SoA Treatment for Produced Water and Mining Discharge and Critical Metals Recovery

The SoA for produced water treatment typically involves removal of suspended solids and oil droplets prior to disposal into deep injection wells or reuse as a hydraulic fracturing fluid.[47] This treatment does not separate critical metals from produced water, so high value energy materials are generally returned to the subsurface. In a few cases, produced water is treated for desalination (e.g., distillation, reverse osmosis), which creates both a concentrate and freshwater stream.[48] The concentrate is then disposed either downwell or in a landfill after drying without recovery of high value energy materials.

Mining waste stream compositions depend on factors such as mining content, mining processes, water sources, water collection method, and local hydrogeology.[49, 50] Treatment systems depend on waste stream composition, regulations, and local ecological concerns. These treatment systems remove suspended solids as with produced water treatment, and can also include finer filtration approaches (e.g., nanofiltration, reverse osmosis) for total dissolved solids and heavy metals removal. As with produced water, precipitates and concentrate solutions are generally disposed of without recovery of high value energy materials.

The SoA for critical metals recovery and purification from aqueous concentrates includes sequential precipitation and dissolution, sequential organic solvent extractions, cation

[46] Anna Kogler, et al., "Long-Term Robustness and Failure Mechanisms of Electrochemical Stripping for Wastewater Ammonia Recovery," *ACS Environmental Au* 4, no. 2 (2024): 89–105. https://doi.org/10.1021/acsenvironau.3c00058.

[47] Stella I. Eyitayo, et al., "Produced Water Treatment: Review of Technological Advancement in Hydrocarbon Recovery Processes, Well Stimulation, and Permanent Disposal Wells," *SPE Production and Operations* 38, no. 1 (2023): 51–62. https://doi.org/10.2118/212275-PA.

[48] Stella I. Eyitayo, et al., "Produced Water Treatment: Review of Technological Advancement in Hydrocarbon Recovery Processes, Well Stimulation, and Permanent Disposal Wells," *SPE Production and Operations* 38, no. 1 (2023): 51–62. https://doi.org/10.2118/212275-PA.

[49] Funeka Matebese, et al., "Mining Wastewater Treatment Technologies and Resource Recovery Techniques: A Review," *Heliyon* 10, no. 3 (2024): e24730. https://doi.org/10.1016/j.heliyon.2024.e24730.

[50] Ahmet Celebi and Saim Özdemir, "Mining Wastewater Management and its Effects on Groundwater and Ecosystems," *Water Science & Technology* 70, no. 9 (2014): 1481–1487. https://doi.org/10.2166/wst.2014.393.

exchange resins, and electrowinning.[51] Selected metals can be preferentially precipitated over others based on the relative solubility of metal salts, and precipitates can be redissolved in acid for subsequent processing. Selected metals can also be extracted from water into an organic phase, usually using organic ligands (e.g., organophosphorus and carbonic acids). These ligands preferentially bind certain metals and then partition to either water or the organic solvent.[52] Precipitation/dissolution and organic solvent extractions are effective but remain inefficient and environmentally damaging. For example, at a recent pilot facility, REEs and uranium (U) were each purified at 99%, but that process required 150 solvent extraction steps.[53] Also, for every ton of REE purified using conventional extraction methods, approximately 75 tons of acidic wastewater is produced.[54]

Cation exchange resins separate cationic metals by immobilizing metals on a solid support and then releasing them due to a change in environment (e.g., pH adjustment).[55] For example, commercially available resins exhibit adsorption selectivity values (i.e., ratio of adsorption coefficients) among REE pairs in control studies ranging from less than 2 to orders of magnitude higher.[56] Electrowinning takes advantages of differences in metal redox potentials, and allows reduction of one or more metal cations. However, non-target waste stream species can interfere with reduction or bind to zero valent precipitates, resulting in impurities. Also, metals with similar redox potentials (e.g., REEs) can co-precipitate, so preprocessing is needed.

3. TECHNICAL NEEDS

New materials and processes are needed to economically recover ammonia and critical metals from aqueous waste streams to reduce energy demands and GHG emissions that occur with conventional production methods (e.g., HB and hard-rock mining) and to reduce imports of these high value energy materials. Specifically, materials are needed to selectively bind or react target ions over similarly sized and charged cations in solutions with high ionic strength, natural organic matter, and/or divalent cations. Additionally, processes are needed to continuously recover ammonia and critical metals over time without loss in technology performance and scale up with wastewater treatment needs.

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[51] Deniz Talan and Qingqing Huang, "A Review of Environmental Aspects of Rare Earth Element Extraction Processes and Solution Purification Techniques," *Minerals Engineering* 179, (2022): 107430. https://doi.org/10.1016/j.mineng.2022.107430.

[52] Sergei I. Stepanov, et al., "Separation of Rare-earth Elements from Nitrate Solutions by Solvent Extraction Using Mixtures of Methyltri-n-octylammonium Nitrate and Tri-n-butyl phosphate," *Molecules* 27, (2022): 557. https://doi.org/10.3390/molecules27020557.

[53] Deniz Talan and Qingqing Huang, "A Review of Environmental Aspects of Rare Earth Element Extraction Processes and Solution Purification Techniques," *Minerals Engineering* 179, (2022): 107430. https://doi.org/10.1016/j.mineng.2022.107430.

[54] Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?, Institute for the Analysis of Global Security, March 2010. http://www.iags.org/rareearth0310hurst.pdf.

[55] Deniz Talan and Qingqing Huang, "A Review of Environmental Aspects of Rare Earth Element Extraction Processes and Solution Purification Techniques," *Minerals Engineering* 179, (2022): 107430. https://doi.org/10.1016/j.mineng.2022.107430.

[56] "Ln Series Resins Cartridge," Eichrom Technologies Inc., https://www.eichrom.com/products/ln-resins/.

Selectivity among REEs is especially challenging due to similar size, charge, and redox potential (e.g., achieving Li^+ selectivity over elevated concentrations of Mg^{2+}). For example, adsorption selectivity factors greater than three and concentration increases greater than 1,000 times per separation step may be necessary to recover one cation over another at similar concentrations in a dilute waste stream, and to produce a high metal weight percent concentrate solution in one or two steps. Achieving adequate selectivity for low concentration cationic species over non-target high concentration cationic species is also difficult.[57] Several approaches may address these challenges:

- New chemistries (e.g., ligands, catalysts) or biomolecules that selectively bind or react with target species; and
- New functional materials (e.g. adsorbents, membranes, and electrodes) that incorporate new chemistries or biomolecules and are directly used as part of an integrated process.

New chemistries include crown ether and hydroxylamine ligands that preferentially bind one REE over another, and an emerging biomolecule is a lanmodulin protein that binds with high specificity to REEs over other cations.[58, 59, 60, 61] New functional materials include:

- Porous aromatic frameworks incorporated into adsorbents and membranes with high affinities for ammonia and selected metal cations;[62, 63]
- Lanmodulin immobilized without loss of selectivity on various beads and particles to facilitate critical metals separations;[64, 65] and

[57] Ying Sun, et al., "Recent Advances in Magnesium/Lithium Separation and Lithium Extraction Technologies from Salt Lake Brine," *Separation and Purification Technology* 256, (2021): 117807. https://doi.org/10.1016/j.seppur.2020.117807.
[58] Yu Liu, Bao-Hang Han, and Yun-Ti Chen, "The Complexation Thermodynamics of Light Lanthanides by Crown Ethers," *Coordination Chemistry Reviews* 200–202, (2000): 53–73. https://doi.org/10.1016/S0010-8545(99)00239-8.
[59] Robert F. Higgins, et al. "Coordination Chemistry-Driven Approaches to Rare Earth Element Separations," *Accounts of Chemical Research* 55, no. 18 (2022): 2616–2627. https://doi.org/10.1021/acs.accounts.2c00312.
[60] Mark P. Jensen, et al. "Solvent Extraction Separation of Trivalent Americium from Curium and the Lanthanides," *Solvent Extraction and Ion Exchange* 33, no. 4 (2015): 329–345. https://doi.org/10.1080/07366299.2015.1046292.
[61] Gauthier J.-P. Deblonde, "Selective and Efficient Biomacromolecular Extraction of Rare-Earth Elements using Lanmodulin," *Inorganic Chemistry* 59, no. 17 (2020): 11855–11867. https://pubmed.ncbi.nlm.nih.gov/32686425/.
[62] Adam A. Uliana, et al., "Removal of Chromium and Arsenic from Water Using Polyol-Functionalized Porous Aromatic Frameworks," *Journal of the American Chemical Society* 146, (2024): 23831–23841. https://doi.org/10.1021/jacs.4c05728.
[63] Yuyang Tian, and Guangshan Zhu, "Porous Aromatic Frameworks (PAFs)," *Chemical Reviews* 120, no. 16 (2020): 8934–8986. https://doi.org/10.1021/acs.chemrev.9b00687.
[64] Quanhui Ye, et al. "Lanmodulin-Functionalized Magnetic Nanoparticles as a Highly Selective Biosorbent for Recovery of Rare Earth Elements," *Environmental Science & Technology* 57, no. 10 (2023): 4276–4285. https://doi.org/10.1021/acs.est.2c08971.
[65] Lianna Johnson, et al., "Electrospun Membranes Modified with Lanmodulin-Derived Peptides for Lanthanide Adsorption," *ACS Applied Engineering Materials*, (2024). https://doi.org/10.1021/acsaenm.4c00510.

- Prussian blue analogues incorporated into adsorbents and electrodes with preferential binding of selected cations.[66, 67, 68]

Functional materials have mainly been evaluated only in relatively clean water matrices, and/or under a relatively narrow set of operating conditions. Further work is needed to derisk these materials for separations in real aqueous waste stream matrices where inorganic scaling, natural organic matter fouling, and high salinities decrease selectivity. High recovery efficiencies of a market-valuable product over repeated cycles are needed for economic viability. Key risks are that functional materials lose both binding affinity or selectivity over long-term use and mechanical integrity when subject to cleaning to reverse fouling. Functional materials also easily foul with natural organic matter.

Some reports show derisked functional materials being integrated into process flow systems to allow for continuous recovery of a market-valuable form of ammonia and/or a critical metal. In one example, repeated fouling and replacement of membranes and electrodes during electrochemical ammonia separation proved cost prohibitive.[69] Integrated processes require high recovery efficiencies of each energy material using as few steps as possible while minimizing pretreatment and integrating fouling mitigation or fouling reversal strategies. Examples of fouling mitigation/reversal strategies include:

- Turbulence promoters to disrupt laminar flow boundary layers at membrane surfaces;[70, 71]
- Creating electrically conducting membranes to alter surface charge or local pH, or oxidize organic foulants;[72]

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[66] Margeret A. Lumley, Do-Hwan Nam, and Kyoung-Shin Choi, "Elucidating Structure–Composition–Property Relationships of Ni-Based Prussian Blue Analogues for Electrochemical Seawater Desalination," *ACS Applied Materials & Interfaces* 12, no. 32 (2020): 36014–36025. https://doi.org/10.1021/acsami.0c08084.

[67] Elia Sebti, et al. "Removal of Na^+ and Ca^{2+} with Prussian Blue Analogue Electrodes for Brackish Water Desalination," *Desalination* 487, (2020): 114479. https://doi.org/10.1016/j.desal.2020.114479.

[68] Yeisy C. López, Greter A. Ortega, and Edilso Reguera, "Microporous Prussian Blue Analogs and Their Application for Environmental Remediation: A Deeper Look from the Structure-Property-Functionality Perspective," *Microporous and Mesoporous Materials* 333, (2022): 111755. https://doi.org/10.1016/j.micromeso.2022.111755.

[69] Anna Kogler, et al., "Long-Term Robustness and Failure Mechanisms of Electrochemical Stripping for Wastewater Ammonia Recovery," *ACS Environmental Au* 4, no. 2 (2024): 89–105. https://doi.org/10.1021/acsenvironau.3c00058.

[70] Qiao Wang, et al., "Patterned Membranes for Improving Hydrodynamic Properties and Mitigating Membrane Fouling in Water Treatment: A Review," *Water Research* 236, (2023): 119943. https://doi.org/10.1016/j.watres.2023.119943.

[71] Wenjuan Zhang, et al., "Modeling and Simulation of Mitigating Membrane Fouling under a Baffle-filled Turbulent Flow with Permeate Boundary," *Separation and Purification Technology* 179, (2017): 13–24. https://doi.org/10.1016/j.seppur.2017.01.022.

[72] Xiaobo Zhu and David Jassby, "Electroactive Membranes for Water Treatment: Enhanced Treatment Functionalities, Energy Considerations, and Future Challenges," *Accounts of Chemical Research* 52, no. 5 (2019): 1177–1186. https://doi.org/10.1021/acs.accounts.8b00558.

- Modifying membrane surface functional groups;[73] and
- Using various chemical treatment approaches.[74]

Integrated process flow recovery systems must be scalable for economical treatment of realistic waste stream flow rates and be compatible with existing waste stream treatment systems.

D. PROGRAM OBJECTIVES

The RECOVER program seeks disruptive technologies to source high value energy materials from aqueous waste streams. Specific program objectives are the following:

- Enable replacement of 50% of conventional ammonia supplies, and full replacement of key critical metal supplies;
- Recover and valorize multiple high value energy materials from an aqueous waste stream;
- Reduce energy demand by 30% and CO_2eq emissions by 70% for ammonia and critical metals obtained through aqueous waste stream recovery relative to conventional production methods (e.g., HB, hard-rock mining); and
- Recover market-valuable products at a competitive price.

Market-valuable products are those that can be bought and sold on today's market. Ammonia-based products include commercially sold fertilizers, as well as high purity ammonia, nitrogen-based specialty chemicals, and hydrogen. Critical metals include metal-enriched precipitates purchased by metal recycling companies, as well as high purity metals and precipitates sold as commodities. Cost estimation guidelines for metal-enriched precipitates have been proposed.[75]

Capable technologies will be energy efficient, highly selective, and durable over extended use. Processes will involve few sequential steps and will be automated, scalable, and adaptable to existing or new wastewater facilities. The RECOVER program supports ARPA-E's statutory goals to enhance the economic and energy security of the U.S. through the development of technologies that:

- **Decrease energy-related imports:** Eliminate imports of ammonia and selected critical metals found in aqueous waste streams;
- **Improve energy efficiency:** Improve the energy efficiency of procuring market-valuable forms of ammonia and critical metals by eliminating the energy needs for mining,

[73] Dipak Rana and Takeshi Matsuura, "Surface Modifications for Antifouling Membranes," *Chemical Reviews* 110, no. 4 (2010): 2448–2471. https://doi.org/10.1021/cr800208y.

[74] Dongsheng Zhao and Shuili Yu, "A Review of Recent Advance in Fouling Mitigation of NF/RO Membranes in Water Treatment: Pretreatment, Membrane Modification, and Chemical Cleaning," *Desalination and Water Treatment* 55, no. 4 (2015) 870–891. https://doi.org/10.1080/19443994.2014.928804.

[75] Alison Fritz, Thomas J. Tarka, and Meagan S. Mauter, "Assessing the Economic Viability of Unconventional Rare Earth Element Feedstocks," *Nature Sustainability* 6, (2023): 1103–1112. https://doi.org/10.1038/s41893-023-01145-1.

beneficiation, and ore leaching, as well as by eliminating the energy needs of high temperature chemical reactions in HB;

- **Reduce emissions:** Reduce CO_2eq emissions through energy efficiency measures mentioned above, reduction of N_2O emissions for recovered ammonia, and electrification of recovery technologies; and
- **Improve resilience, reliability, and security:** Onshore the production of critical metals to ensure that metals needed to reach net-zero targets are produced and available at high quality and at prices that are competitive with imports.

E. TECHNICAL CATEGORIES OF INTEREST

ARPA-E seeks applications to the RECOVER program from interdisciplinary teams comprised of individuals with project-relevant expertise in areas such as: environmental, chemical, mechanical, electrical, materials, biological, systems, and/or process engineering, organic and inorganic chemistry, microbiology, biology, material science, wastewater treatment, intensive animal farming, metals mining and processing, oil and gas production, fertilizer production and distribution, and/or technoeconomic assessment.

1. TECHNICAL CATEGORIES

This NOFO solicits responses to the three technical categories below.

Category 1. New Materials
Category 1 applicants will propose promising new chemistries or biomolecules that require further development. Selected projects will:

- Develop, characterize, and/or identify new ligands, chelators, catalysts, biomolecules, or other chemistries that selectively bind or react with target species (Figure 1);
- Integrate new chemistries or biomolecules into functional materials such as adsorbents, membranes, and/or electrodes;
- Ensure adsorption or reaction selectivities are maintained at relevant pH and ionic strength values over repeated cycles of use; and
- Project functional material synthesis and technology integration at scale with extrapolated performance and costs using TEA.

Category 2. Process Development and Derisking
Category 2 applicants will propose one or more functional materials for separations or reactions that have shown promise for selective separations or reactions but have not been adequately derisked for full process integration. Selected projects will:

- Determine the effects of inorganic scaling or natural organic matter fouling on functional material performance (e.g., adsorption capacity and rate, reaction rate, selectivity) and develop anti-fouling or fouling mitigation approaches;

- Ensure functional material adsorption or reaction selectivities in synthetic and real waste streams over repeated cycles of treatment;
- Show high recovery of market-valuable products; and
- Project functional material synthesis and technology integration at scale with extrapolated performance and costs using TEA.

Category 3. Process Integration
Category 3 applicants will propose one or more functional materials for separations or reactions that have already been evaluated over a range of aqueous waste stream conditions and are ready for process integration. Selected projects will:

- Design and build a continuous-flow and process recovery technology that is scalable to anticipated waste stream flow rates and can be integrated into a waste stream treatment system;
- Integrate anti-fouling or fouling reversal methods into process flow operations;
- Continuously recover at least two high value, energy market-valuable products over at least one week of operation in synthetic and real waste streams; and
- Determine breakeven recovered product costs based on projected at-scale capital and operating costs, as well as any cost benefits to waste stream treatment, using TEA.

Applicants may address up to two technical categories with proposed budgets commensurate to the scale of work. Applicants must select one of the three waste stream types listed below for recovery and must target at least two high value energy materials for recovery from those listed in Figure 1. Other high value energy materials that advance the ARPA-E mission and address program goals may also be justified. The three waste stream types are:

- **Municipal/animal feedlot waste stream:** High total organic carbon (TOC), low salinity, recoverable ammonia, Mg, and P;
- **Produced water waste stream:** Low TOC, moderate to high salinity, recoverable critical metals possibly including REEs; and
- **Mining waste stream:** Low TOC, low to moderate salinity, recoverable critical metals including REEs.

Representative example compositions of the three waste stream types are provided in a supplementary resource available to download from the RECOVER posting on ARPA-E eXCHANGE[76]. Applicants focusing on Technical Category 1 will work with a representative synthetic waste stream. Applicants in Categories 2 and 3 will initially work with a representative synthetic waste stream, and then with a real waste stream that they must source by the end of the first year. Chosen synthetic and real waste streams will need to be approved by ARPA-E.

Genetic modification is within the scope of Categories 1 and 2. Should a new genetically

[76] Advanced Research Project Agency – Energy, "Funding Opportunity Exchange," https://arpa-e-foa.energy.gov/.

modified material arise from the performance of an award, it must be reported in iEdison,[77] the government-wide portal for reporting new inventions. If you make a new invention that involves genetic modification and you believe that patenting is not appropriate, you should report the invention in iEdison and contact ARPA-E to discuss an appropriate course of action.

2. PROGRAM TECHNICAL SCOPE

Applicants can address up to two technical categories.

For example, an Applicant may have already developed one or more highly promising ligands that selectively bind to a preferred cation over others and tethered this to a resin bead for use as an adsorbent. However, the Applicant may still need to characterize the selectivity of the ligand or adsorbent at relevant ionic strength and pH values, or derisk the adsorbent for repeated use subject to fouling in real aqueous waste stream matrices. Therefore, this Applicant's scope could include part or all of Category 1 and all of Category 2.

Similarly, an Applicant may have partially derisked a functional material, but some questions may remain regarding performance under repeated cycles of treatment. This Applicant's scope could include part or all of Category 2 and all of Category 3. Applicants addressing part or all of any category will need to satisfy all relevant technical performance metrics for their proposed scope.

Applicants are encouraged to include personnel in their team with the following expertise:

- Category 1: Chemistry and/or microbiology, material science and engineering, computational chemistry, wastewater characterization and treatment, and/or engineering cost estimation.
- Category 2: Material science and engineering or microbiology, process treatment engineering, wastewater characterization and treatment, and/or engineering cost estimation.
- Category 3: Process treatment engineering, material science and engineering, wastewater characterization and treatment, and technoeconomic assessment.

F. TECHNICAL PERFORMANCE TARGETS

Performance metrics for each of the three technical categories are detailed in Tables 1–3 below. Applications must include a table of metrics (included in the submission template) with expected performance against the targets, as well as information supporting how each target is achievable. The following definitions are used to describe performance metrics:

- Selectivity (α): Ratio of binding or adsorption constants, ratio~~s~~ of flux (normalized by

[77] National Institute of Standards and Technology, "iEdison,"2022, https://www.nist.gov/iedison.

concentration ratio) through a membrane, or ratio of reaction rates constants of two species.

- Step concentration increase (δ): Ratio of target species concentration in solution after and before one binding, adsorption, filtration, or reaction step.
- Recovery efficiency (η): Mass percent of ammonia, P, or critical metal recovered from a waste stream.
- Recovery steps (n): Number of steps required to obtain a market-valuable product for one species from the starting waste stream (e.g., number of adsorption-desorption cycles, number of passes through a membrane, number of reaction chambers).

Table 1. Category 1: New Materials Metrics.

ID	Metrics	Target	Approach
M1a	Chemistry/ biomolecule performance	For each high energy value material: $\alpha > 3*[C_2/C_1]$ per step¥ $\delta > 100$ per step $\eta > 90\%$	Evaluate with key ion pairs at concentrations found in a selected waste stream, and then in synthetic waste streams with increasing complexity until all ion types and amounts in the selected waste stream are matched
M1b	Functional material performance	Same as M1a Target Metrics	Integrate chemistry or biomolecule into a functional material and evaluate performance in synthetic waste streams per M1a description
M1c	Functional material performance durability	Same as M1a Target Metrics for greater than 10 cycles of recovery	Evaluate performance in synthetic waste streams per M1a description
M1d	Technology market viability	Breakeven recovered product cost less than market cost	Project reasonable technology definition at scale with extrapolated performance and cost

¥ $[C_1]$ is a species concentration of interest, $[C_2]$ is any other species concentration in solution.

Table 2. Category 2: Process Development and Derisking Metrics.

ID	Metrics	Target	Approach
M2a	Functional material performance	For each market-valuable product: $\alpha > 3*[C_2/C_1]$ per step $\delta > 100$ per step $\eta > 90\%$	Evaluate in a synthetic waste stream with all ion types and amounts in a selected real waste stream, and then in the real waste stream
M2b	Functional material performance durability	Same as M2a Target Metrics for greater than 10 cycles of sequential recovery	Evaluate in the above mentioned synthetic and then real waste stream; develop anti-fouling and/or fouling mitigation approaches
M2c	Technology market viability	Breakeven recovered product cost less than market cost	Project reasonable technology definition at scale with extrapolated performance and cost

Table 3. Category 3: Process Integration Metrics.

ID	Metric	Target	Approach
M3a	Continuous flow and scalable process recovery technology	Recovers each high value energy material Scalable to flow rates of real waste stream that are expected in practice	Design and build technology; establish scalability using process modeling or dimensionless number analysis (e.g., constant Reynolds and Damkohler numbers)
M3b	Technology performance and durability	For each market-valuable product: $\alpha > 3*[C_2/C_1]$ per step $\delta > 100$ per step $\eta > 90\%$	Evaluate in a synthetic waste stream with all ion types and amounts in a selected real waste stream, and then in the real waste stream; initially evaluate for short periods, and then continuously for greater than 7 days to evaluate resistance to fouling and performance degradation
M3c	Technology energy demands and CO_2eq emissions	Energy demand less than 70% and CO_2eq emissions less than 30% of SoA processes	Evaluate in real waste stream; calculate direct energy consumption; estimate potential CO_2eq emissions
M3d	Technology market viability	Breakeven recovered product cost less than market cost	Use TEA to assess primary capital and operating costs at scale, and breakeven commercial grade product prices

Applicants must also answer the questions in Table 4 in a one-page Appendix to the Concept Paper (see Section III.B). Answers should provide sufficient granular technical information to enable ARPA-E to make informed selection decisions.

Table 4. Required short answer questions to be submitted as an Appendix to the Concept Paper.

Question	Applicant Response
Q1. How does your new chemistry, functional material, and/or technology work?	
Q2. How does your new chemistry, functional material, and/or technology compare to alternative, established, or emerging approaches?	
Q3. What is (are) your core innovation(s)?	
Q4. What waste stream and associated ions are you targeting, and what is the potential to displace conventional sources?	
Q5. What are your anticipated products and purity?	
Q6. Who is the anticipated customer?	
Q7. What preliminary results do you have that support your approach?	
Q8. How will each team member contribute to achieving your performance metrics?	

Required milestones at the end of year one and at the end of the Period of Performance of this program are shown in Table 5 below for each technical category. Required deliverables at the end of year one represent go/no-go points.

Table 5. Required Milestones.

Time	Category 1. New Materials	Category 2. Process Development and Derisking	Category 3 Process Integration
1 yr Go/No-go	• Achieve target α values for at least two high value energy materials using new chemistries or biomolecule	• Achieve target α values for at least two high value energy materials using functional material(s) in representative synthetic waste stream • Source a real waste stream for testing	• Design and build scalable recovery technology • Source a real waste stream for testing • Present technology-to-market plan indicating technology and economic potential
End of Project	• Achieve performance metrics (i.e., α, η, δ) using functional materials at relevant pH and ionic strength values, over multiple recovery cycles • Present technology-to-market plan indicating technology and economic potential • Identify funding opportunities/ investors/commercial partners for further commercialization	• Achieve performance metrics (i.e., α, η, δ) over multiple recovery cycles in a real waste stream • Present technology-to-market plan indicating technology and economic potential • Identify funding opportunities/investors/commercial partners for further commercialization	• Achieve performance metrics (i.e., α, η, δ) over 7 days in real waste stream • Achieve target energy and CO_{2eq} emissions reductions • Present updated technology-to-market plan indicating technology and economic potential • Identify funding opportunities/ investors/ commercial partners for further commercialization

G. TECHNOLOGY-TO-MARKET

ARPA-E awardees will be required to construct and execute a commercialization plan that is unique to their material or technology. The preparation of this plan will include conducting market analyses, developing and refining a business model, formulating an intellectual property strategy, and preparing the appropriate cost or technoeconomic models to validate value propositions to the customer. For example, performers will extrapolate functional material and associated technology needs at scale, estimate performance, cost, energy demands, and CO_2eq emissions, and compare these metrics with competing approaches either available in practice or reported in the literature. Awardees will also identify customers for recovered products, a business model for technology integration into aqueous waste stream treatment systems, and potential funding partners for the further commercialization. Costs, energy consumed, and CO_2eq emissions should be normalized by mass of species recovered and compared to values for conventionally sourced materials.

H. STATEMENT OF SUBSTANTIAL INVOLVEMENT

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[78] Accordingly, ARPA-E is substantially involved in the direction of projects from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- ARPA-E may, at its sole discretion, modify or terminate projects that fail to achieve predetermined Go/No Go decision points or technical milestones and deliverables.
- During award negotiations, ARPA-E Program Directors and Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Grants Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.339 – 200.343.
- ARPA-E may provide guidance and/or assistance to the Recipient to accelerate the commercialization of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits[79] to provide mentoring and networking opportunities for Recipients. ARPA-E may also organize and sponsor events to educate Recipients about key barriers to the commercialization of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and commercialization of ARPA-E-funded technologies.

[78] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

[79] "Nonprofits" or "nonprofit organizations" has the meaning set forth at 2 C.F.R. § 200.70.

I. FUNDING RESTRICTIONS

1. ALLOWABLE COSTS

All expenditures must be allowable, allocable, and reasonable in accordance with the applicable Federal cost principles. Pursuant to 2 C.F.R. § 910.352, the cost principles in the Federal Acquisition Regulations (48 C.F.R. Part 31.2) apply to for-profit entities. The cost principles contained in 2 C.F.R. Part 200; Subpart E apply to all entities other than for-profits.

2. PRE-AWARD COSTS

ARPA-E will not reimburse any pre-award costs incurred by Applicants before they are selected for award negotiations. Please refer to Section VI.A of the NOFO for guidance on award notices.

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 2 C.F.R. Part 200, as modified by 2 C.F.R. Part 910, and other Federal laws and regulations. All submitted budgets are subject to change and are typically reworked during award negotiations. ARPA-E is under no obligation to reimburse pre-award costs if, for any reason, the Applicant does not receive an award or the award is made for a lesser amount than the Applicant expected, or if the costs incurred are not allowable, allocable, or reasonable.

3. PATENT COSTS

For Subject Inventions disclosed to DOE under an award, ARPA-E will reimburse the Recipient – in addition to allowable costs associated with Subject Invention disclosures - up to $30,000 of expenditures for filing and prosecution of United States patent applications, including international applications (PCT application) submitted to the United States Patent and Trademark Office (USPTO).

The Recipient may request a waiver of the $30,000 cap. Note that patent costs are considered to be Technology Transfer & Outreach (TT&O) costs (see Section I.I.8 of the NOFO below) and should be requested as such.

4. CONSTRUCTION

ARPA-E generally does not fund projects that involve major construction. Recipients are required to obtain written authorization from the Grants Officer before incurring any major construction costs.

5. FOREIGN TRAVEL

ARPA-E generally does not fund projects that involve foreign travel. Recipients are required to obtain written authorization from the ARPA-E Program Director before incurring any foreign travel costs and provide trip reports with their reimbursement requests.

6. PERFORMANCE OF WORK IN THE UNITED STATES

ARPA-E requires all work under ARPA-E funding agreements to be performed in the United States. However, Applicants may request a waiver of this requirement where their project would materially benefit from, or otherwise requires, certain work to be performed overseas.

Applicants seeking this waiver must include an explicit request in the Business Assurances & Disclosures Form. Such waivers are granted where ARPA-E determines there is a demonstrated need.

7. PURCHASE OF NEW EQUIPMENT

All equipment purchased under ARPA-E funding agreements must be made or manufactured in the United States, to the maximum extent practicable. This requirement does not apply to used or leased equipment. The Recipients are required to notify the ARPA-E Grants Officer reasonably in advance of purchasing any equipment that is not made or manufactured in the United States with a total acquisition cost of $250,000 or more. Purchases of foreign equipment with a total acquisition cost of $1,000,000 or more require the approval of the Head of Contracting Activity (HCA). The ARPA-E Grants Officer will provide consent to purchase or reject within 30 calendar days of receipt of the Recipient's notification.

8. TECHNOLOGY TRANSFER AND OUTREACH

ARPA-E is required to contribute a percentage of appropriated funds to Technology Transfer and Outreach (TT&O) activities. In order to meet this mandate, every Project Team must spend at least 5% of the Federal funding provided by ARPA-E on TT&O activities to promote and further the development and eventual deployment of ARPA-E-funded technologies. Project Teams must seek a waiver from ARPA-E, located in the Business Assurances & Disclosures Form, to spend less than the minimum 5% TT&O expenditure requirement.

All TT&O expenditures are subject to the applicable Federal cost principles (i.e., 2 C.F.R. 200 Subpart E and 48 C.F.R. Subpart 31). Examples of TT&O expenditures are as follows:

- Documented travel and registration for the ARPA-E Energy Innovation Summit and other energy-related conferences and events;
- Documented travel to meet with potential suppliers, partners, or customers;

- Documented work by salaried or contract personnel to develop technology-to-market models or plans;
- Documented costs of acquiring industry-accepted market research reports; and
- Approved patent costs.

9. LOBBYING

Recipients and Subrecipients may not use any Federal funds, directly or indirectly, to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. § 1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

Recipients and Subrecipients are required to complete and submit SF-LLL, "Disclosure of Lobbying Activities" (https://www.gsa.gov/forms-library/disclosure-lobbying-activities) if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence any of the following in connection with your application:

- An officer or employee of any Federal agency,
- A Member of Congress,
- An officer or employee of Congress, or
- An employee of a Member of Congress.

10. CONFERENCE SPENDING

Recipients and Subrecipients may not use any Federal funds to:

- Defray the cost to the United States Government of a conference held by any Executive branch department, agency, board, commission, or office which is not directly and programmatically related to the purpose for which their ARPA-E award is made and for which the cost to the United States Government is more than $20,000; or
- To circumvent the required notification by the head of any such Executive Branch department, agency, board, commission, or office to the Inspector General (or senior ethics official for any entity without an Inspector General), of the date, location, and number of employees attending such a conference.

11. INDEPENDENT RESEARCH AND DEVELOPMENT COSTS

ARPA-E does not fund Independent Research and Development (IR&D) as part of an indirect cost rate under its Grants and Cooperative Agreements. IR&D, as defined at FAR 31.205-18(a), includes cost of effort that is not sponsored by an assistance agreement or required in performance of a contract, and that consists of projects falling within the four following areas:

(i) basic research, (ii) applied research, (iii) development, and (iv) systems and other concept formulation studies.

ARPA-E's goals are to enhance the economic and energy security of the United States through the development of energy technologies and ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies. ARPA-E accomplishes these goals by providing financial assistance for energy technology projects and has well recognized and established procedures for supporting research through competitive financial assistance awards based on merit review of proposed projects. Reimbursement for independent research and development costs through the indirect cost mechanism could circumvent this competitive process.

To ensure that all projects receive similar and equal consideration, eligible organizations may compete for direct funding of independent research projects they consider worthy of support by submitting proposals for those projects to ARPA-E. Since proposals for these projects may be submitted for direct funding, costs for independent research and development projects are not allowable as indirect costs under ARPA-E awards. IR&D costs, however, would still be included in the direct cost base that is used to calculate the indirect rate so as to ensure an appropriate allocation of indirect costs to the organization's direct cost centers.

12. BUY AMERICA REQUIREMENT FOR PUBLIC INFRASTRUCTURE PROJECTS

Projects funded through this NOFO that are for, or contain, construction, alteration, maintenance, or repair of public infrastructure in the United States undertaken by applicable recipient types, require that:

- All iron, steel, and manufactured products used in the infrastructure project are produced in the United States; and
- All construction materials used in the infrastructure project are manufactured in the United States.

However, ARPA-E does not anticipate soliciting for or selecting projects that propose project tasks that are for, or contain, construction, alteration, maintenance, or repair of public infrastructure. If a project selected for award negotiations includes project tasks that may be subject to the Buy America Requirement, those project tasks will be removed from the project before any award is issued – i.e., no federal funding will be available for covered project tasks.

This "Buy America" requirement does not apply to an award where the Recipient is a for-profit entity.

13. REQUIREMENT FOR FINANCIAL PERSONNEL

ARPA-E requires Small Business or Nonprofit applicants to identify a finance/budget professional (employee or contracted support) with an understanding of Federal contracting and/or financial assistance and cost accounting (including indirect costs, invoicing, and financial management systems) that will support the team in complying with all applicable requirements.

14. PARTICIPANTS, COLLABORATING ORGANIZATIONS, AND CURRENT AND PENDING SUPPORT

If selected for award negotiations the selected applicant must submit, before the award is issued, an updated list of Covered Individuals[80] who are proposed to work on the project, both at the Recipient and subrecipient level, and a list of all participating[81] organizations. Further, the selectee must submit 1) current and pending support disclosures and resumes for any new Covered Individuals, and 2) updated disclosures if there have been any changes to the current and pending support submitted with the application.

Throughout the life of the award, recipients have an ongoing responsibility to notify DOE of changes to the Covered Individuals and collaborating organizations, within 30 days of such change, and to submit 1) current and pending support disclosure statements and resumes for any Covered Individuals; and 2) updated disclosures if there are changes to the current and pending support previously submitted to ARPA-E. Recipients must certify on an annual basis that no such changes have occurred since their most recent certification.

Note that foreign participation is treated separately and may require a Foreign Entity Waiver, per Section II.D.

15. PAYMENT OF FEE OR PROFIT

ARPA-E will pay a fee or profit to Recipients in an amount not to exceed 7% of total project cost under any agreement resulting from this NOFO, subject to negotiations. Any fee or profit paid by Recipients to their subrecipients (but not commercial suppliers, vendors, or contractors) must be paid from fee or profit paid to Recipients by ARPA-E. Any fee or profit must be included in the budget submitted with Recipients' Full Applications and will be payable to Recipients upon: (i) completion of all work required by the agreement, (ii) submission and acceptance of all for-profit audit reports and resolution of all findings (if any) identified in the reports, (iii) submission and acceptance by the Government of all closeout documentation required by Attachment 4 to the agreement (refer to ARPA-E's Model Cooperative Agreement found at https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements), and (iv) submission of an acceptable invoice.

[80] See Section IX, Glossary, for the definition of Covered Individual.
[81] For a definition of "participation" please see footnote 92.

II. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. SBIR ELIGIBILITY

SBA rules and guidelines govern eligibility to apply to this NOFO. For information on program eligibility, please refer to the SBIR/STTR website, available at https://www.sbir.gov, and to the "Eligibility" section for SBIR/STTR programs at https://www.sbir.gov/apply.

A Small Business Concern[82] may apply as a Standalone Applicant[83] or as the lead organization for a Project Team.[84] If applying as the lead organization, the Small Business Concern must perform at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and Phase IIS, as measured by the Total Project Cost.[85]

2. STTR ELIGIBILITY

SBA rules and guidelines govern eligibility to apply to this NOFO. For information on STTR program eligibility, please refer to the websites in section II.A.1.

Only a Small Business Concern may apply as the lead organization for a Project Team under STTR. The Small Business Concern must perform at least 40% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project Cost. A single Research Institution must perform at least 30% of the work in Phase I, Phase II, and/or Phase IIS, as measured by the Total Project Cost. Please refer to Section II.B.1 of the NOFO for guidance on Research Institutions' participation in STTR projects.

3. JOINT SBIR AND STTR ELIGIBILITY

An Applicant that meets both the SBIR and STTR eligibility criteria above may request both SBIR and STTR funding if:

- The Small Business Concern is partnered with a Research Institution;
- The Small Business Concern performs at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost;

[82] A Small Business Concern is defined by the SBA. Please see SBA.gov for guidelines, including Does Your Small Business Qualify? | U.S. Small Business Administration (sba.gov).
[83] A "Standalone Applicant" is an Applicant that applies for funding on its own, not as part of a Project Team.
[84] A Project Team consists of the Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.
[85] The Total Project Cost is the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.

- The partnering Research Institution performs 30-33.3% of the work in Phase I and 30-50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost; and
- The Principal Investigator (PI) is employed by the Small Business Concern. If the PI is employed by the Research Institution, submissions will be considered only under the STTR program.

B. ELIGIBLE SUBRECIPIENTS

1. RESEARCH INSTITUTIONS

A Research Institution[86] may apply only as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern). In STTR projects, a single Research Institution must perform at least 30%, but no more than 60%, of the work under the award in Phase I, Phase II, and/or Phase IIS (as applicable), as measured by the Total Project Cost.

2. OTHER PROJECT TEAM MEMBERS

The following entities are eligible to apply for SBIR/STTR funding as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern):

- For-profit entities (which includes large businesses and small businesses)
- Nonprofits other than Research Institutions[87]
- Government-Owned, Government Operated laboratories (GOGOs)
- State, local, and tribal government entities
- Foreign entities[88]

In SBIR projects, Project Team members other than the lead organization, including but not limited to Research Institutions, may collectively perform no more than 33.3% of the work under the award in Phase I and no more than 50% of the work under the award in Phase II and/or Phase IIS. This includes efforts performed by Research Institutions.

[86] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[87] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Subrecipient.

[88] All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (see Section II.B.3 of the NOFO). However, the Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form submitted with the Full Application.

In STTR projects, Project Team members (other than the lead organization and the partnering Research Institution) may collectively perform no more than 30% of work under the award in Phase I, Phase II, and/or Phase IIS.

3. FOREIGN ENTITIES

If a Foreign Country of Concern[89] or individual citizen(s) of a Foreign Country of Concern has any ownership interest in any of the entities included in a proposal, then the Full Application must include a Foreign Entity Waiver request for each such entity in order for ARPA-E to consider the participation of such entities.[90]

C. ELIGIBLE PRINCIPAL INVESTIGATORS

1. SBIR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform more than 50% of his or her work for, the Prime Recipient. The Grants Officer may waive this requirement or approve the substitution of the PI after consultation with the ARPA-E SBIR/STTR Program Director.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

2. STTR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform more than 50% his or her work for, the Prime Recipient or the partnering Research Institution. The Grants Officer may waive this requirement or approve the substitution of the PI after consultation with the ARPA-E SBIR/STTR Program Director.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

[89] "Foreign Countries of Concern", as defined by the State Department, include (as of December 29, 2023) Burma, People's Republic of China, Cuba, Eritrea, Iran, the Democratic People's Republic of Korea, Nicaragua, Pakistan, Russia, Saudi Arabia, Tajikistan, and Turkmenistan.

[90] The contents of a Foreign Entity Waiver request can be found in the Business Assurances & Disclosures Form.

D. FOREIGN PARTICIPATION

1. FOREIGN NATIONAL PARTICIPATION FROM COUNTRIES OF CONCERN

All applicants selected for an award under this NOFO and project participants (including subrecipients and contractors) who anticipate involving foreign nationals from Foreign Countries of Concern[91] in the performance of an award may be required to provide ARPA-E with specific information about each foreign national to satisfy requirements for foreign national participation. A "foreign national" is defined as any person who is not a United States citizen by birth or naturalization. The volume and type of information collected may depend on various factors associated with the award. ARPA-E approval is required before a foreign national can participate in the performance of any work under an award.

ARPA-E may elect to deny a foreign national's participation in the award. Likewise, ARPA-E may elect to deny a foreign national's access to ARPA-E site, information, technologies, equipment, programs or personnel.

2. FOREIGN PARTICIPATION CONSIDERATIONS

Foreign participation[92] in a project requires a Foreign Entity Waiver (see Waiver Request – Foreign Entity Participation in the Business Assurances & Disclosure Form). Awardees have an ongoing obligation to report new foreign participation in a project and may be required to obtain a waiver before new foreign participation can occur. A Foreign Work Waiver may also be required (see Section I.I.6 and the Business Assurances & Disclosures Form).

E. ELIGIBILITY OF PRIOR SBIR AND STTR AWARDEES: SBA BENCHMARKS ON PROGRESS TOWARDS COMMERCIALIZATION

Applicants awarded multiple prior SBIR or STTR awards must meet DOE's benchmark requirements for progress towards commercialization before ARPA-E may issue a new Phase I award. For purposes of this requirement, Applicants are assessed using their prior Phase I and Phase II SBIR and STTR awards across all SBIR agencies. If an awardee fails to meet either of the benchmarks, that awardee is not eligible for an SBIR or STTR Phase I award and any Phase II award for a period of one year from the time of the determination.

ARPA-E applies two benchmark rates addressing an Applicant's progress towards commercialization: (1) the DOE Phase II Transition Rate Benchmark and (2) the SBA Commercialization Rate Benchmark:

[91] Please see footnote 89 for list of Foreign Countries of Concern.

[92] "Participation" includes any activities performed under an ARPA-E award, including, but not limited to, all work described in the milestone schedule of an award (commonly referred to as "Attachment 3" or the "Statement of Project Objectives (SOPO)") and any services that include testing, including services performed by vendors or consultants. Participation also includes activities that involve the procurement of foreign equipment or supplies.

- The DOE Phase II Transition Rate Benchmark sets the minimum required number of Phase II awards the Applicant must have received for a given number of Phase I awards received during the specified period. **This Transition Rate Benchmark applies only to Phase I Applicants that have received more than 20 Phase I awards during the last five (5) year period, excluding the most recently completed fiscal year**. DOE's Phase II Transition Rate Benchmark requires that 25% of all Phase I awards received over the past five years transition to Phase II awards.

  The SBIR/STTR Phase II transition rates and commercialization rates are calculated using the data in the SBA's TechNet database. For the purpose of these benchmark requirements, awardee firms are assessed once a year, on June 1st, using their prior SBIR and STTR awards across all agencies. SBA makes this tabulation of awardee transition rates and commercialization rates available to all federal agencies. ARPA-E uses this tabulation to determine which companies do not meet the DOE benchmark rates and are, therefore, ineligible to receive new Phase I awards.

- The Commercialization Rate Benchmark sets the minimum Phase III[93] commercialization results that an Applicant must have achieved from work it performed under prior Phase II awards (i.e., this measures an Applicant's progress from Phase II or Phase IIS to Phase III awards). **This benchmark requirement applies only to Applicants that have received more than 15 Phase II awards during the last 10 fiscal years, excluding the two most recently completed fiscal years.**

  The current Commercialization Benchmark requirement, agreed upon and established by all 11 SBIR agencies, is that the Applicants must have received, to date, an average of at least $100,000 of sales and/or investments per Phase II award received, or have received a number of patents resulting from the relevant SBIR/STTR work equal to or greater than 15% of the number of Phase II awards received during the period.

- On June 1 of each year, SBIR/STTR awardees registered on SBIR.gov are assessed to determine if they meet the Phase II Transition Rate Benchmark requirement. (At this time, SBA is not identifying companies that fail to meet the Commercialization Rate Benchmark requirement). Companies that fail to meet the Phase II Transition Rate Benchmark as of June 1 of a given year will not be eligible to apply to an SBIR/STTR NOFO for the following year.

[93] Phase III refers to work that derives from, extends or completes an effort made under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR Program. Phase III work is typically oriented towards commercialization of SBIR/STTR research or technology. For more information please refer to the Small Business Administration's "Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Policy Directive" at https://www.sbir.gov/sites/default/files/2024-07/SBA SBIR_STTR_POLICY_DIRECTIVE_May2023.pdf.

F. COMPLIANCE AND RESPONSIVENESS

Submissions that are noncompliant or nonresponsive to the NOFO as described in Sections IV.E and V.A are not eligible.

G. LIMITATION ON NUMBER OF SUBMISSIONS

ARPA-E is not limiting the number of submissions from Applicants. Applicants may submit more than one application to this NOFO, provided that each application is scientifically distinct.

Small business Applicants that qualify as a "Small Business Concern" may apply to only one of the two ARPA-E RECOVER NOFOs: DE-FOA-0003511 (RECOVER SBIR/STTR), or DE-FOA-0003510 (RECOVER). Small businesses that qualify as "Small Business Concerns" are strongly encouraged to apply under the former (SBIR/STTR NOFO). To determine eligibility as a "Small Business Concern" under DE-FOA-0003511 (SBIR/STTR), please review the eligibility requirements in Sections II.A – II.C above.

H. COST SHARING

Cost sharing is not required for this NOFO.

III. APPLICATION CONTENTS AND FORMAT

A. GENERAL APPLICATION CONTENT REQUIREMENTS

1. MARKING OF CONFIDENTIAL INFORMATION

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes.

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information should be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

The cover sheet of the Concept Paper, Full Application, Reply to Reviewer Comments, or other submission must be marked as follows and identify the specific pages containing confidential, proprietary, or privileged information:

Notice of Restriction on Disclosure and Use of Data:

Pages [___] of this document may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes or in accordance with a financial assistance or loan agreement between the submitter and the Government. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: “Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure.” In addition, every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

2. EXPORT CONTROL INFORMATION

Do not include information subject to export controls in any submissions, including Concept Papers, Full Applications, and Replies to Reviewer Comments – whether marked as subject to US export control laws/regulations or otherwise. Such information may not be accepted by ARPA-E and may result in a determination that the application is non-compliant, and therefore not eligible for selection. This prohibition includes any submission containing a general, non-determinative statement such as “The information on this page [or pages _ to__] may be

subject to US export control laws/regulations", or similar. Under the terms of their award, awardees shall be responsible for compliance with all export control laws/regulations.

B. CONCEPT PAPERS

1. FIRST COMPONENT: CONCEPT PAPER

The Concept Paper is mandatory (i.e., in order to submit a Full Application, a compliant and responsive Concept Paper must have been submitted) and must conform to the following formatting requirements:

- The Concept Paper must not exceed 5 pages in length including graphics, figures, and/or tables. Sections 1-4 in the Concept Paper template must not exceed 4 pages in length total, and Appendix 1: Short Answer Questions (see Section I.F) must not exceed 1 page in length.
- The Concept Paper must be submitted in Adobe PDF format.
- The Concept Paper must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11-inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.
- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, Proposed Federal Funding Requested, and Project Duration.

A fillable Concept Paper template is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov. Concept Papers must conform to the content requirements described in the template.

Each Concept Paper must be limited to a single concept or technology. Unrelated concepts and technologies must not be consolidated into a single Concept Paper.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section II.F of the NOFO).

2. SECOND COMPONENT: SUMMARY SLIDE

Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format. This slide will be used during ARPA-E's evaluation of Concept Papers. A summary slide template is available on ARPA-E eXCHANGE.

C. FULL APPLICATIONS

Full Applications must conform to the following formatting requirements:

- Each document must be submitted in the file format prescribed below and/or written in the document template at https://arpa-e-foa.energy.gov.
- The Full Application must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11-inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator's Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

Fillable Full Application template documents are available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Full Applications found in any component to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section II.F of the NOFO).

ARPA-E provides detailed guidance on the content and form of each component below.

1. FIRST COMPONENT: TECHNICAL VOLUME

The Technical Volume is the centerpiece of the Full Application. The Technical Volume must be submitted in Adobe PDF format. The Technical Volume must conform to the content and form requirements included within the template, including maximum page lengths. If Applicants exceed the maximum page lengths specified for each section, or add any additional sections not requested, ARPA-E may review only the authorized number of pages and disregard any additional pages or sections.

Applicants must provide sufficient citations and references to the primary research literature to justify the claims and approaches made in the Technical Volume. ARPA-E and reviewers may review primary research literature in order to evaluate applications. However, all relevant technical information should be included in the body of the Technical Volume.

2. SECOND COMPONENT: SF-424

The SF-424 must be submitted in Adobe PDF format using the available template. An instructional document is also available on ARPA-E eXCHANGE. Applicants must complete all required fields in accordance with the instructions. Applicants may identify and include in Block 14 the entities, their addresses, and corresponding census tract numbers for any project

activities that will occur within any designated Qualified Opportunity Zone (QOZ). To locate QOZ, go to: https://www.cdfifund.gov/opportunity-zones.

Recipients and Subrecipients are required to complete SF-LLL (Disclosure of Lobbying Activities), also available on ARPA-E eXCHANGE, if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any Federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with your application or funding agreement. The completed SF-LLL must be appended to the SF-424.

ARPA-E provides the following supplemental guidance on completing the SF-424:

- Each Project Team should submit only one SF-424 (i.e., a Subrecipient should not submit a separate SF-424).
- The list of certifications and assurances in Block 21 can be found at https://www.energy.gov/management/articles/certifications-and-assurances-use-sf-424.
- The dates and dollar amounts on the SF-424 are for the entire period of performance, not a portion thereof.
- Applicants are responsible for ensuring that the proposed costs listed in eXCHANGE match those listed on forms SF-424 and the Budget Justification Workbook/SF-424A. Inconsistent submissions may impact ARPA-E's final award determination.

3. THIRD COMPONENT: BUDGET JUSTIFICATION WORKBOOK/SF-424A

Applicants are required to complete the Budget Justification Workbook/SF-424A Excel spreadsheet using the available template. Recipients must complete each tab of the Budget Justification Workbook for the project as a whole, including all work to be performed by the Recipient and its Subrecipients and Contractors. The SF-424A form included with the Budget Justification Workbook will "auto-populate" as the Applicant enters information into the Workbook. Applicants should carefully read the "Instructions and Summary" tab provided within the Budget Justification Workbook, and all instructions at the top of each category tab. For more information, an ARPA-E Budget Justification Guidance document is also available on ARPA-E eXCHANGE.

Subrecipient information must be submitted as follows:

- Each Subrecipient incurring greater than or equal to 10% of the Total Project Cost must complete a separate Budget Justification workbook to justify its proposed budget. These worksheets must be inserted as additional sheets within the Recipient's Budget Justification.
- Subrecipients incurring less than 10% of the Total Project Cost are not required to complete a separate Budget Justification workbook. However, such Subrecipients are

required to provide supporting documentation to justify their proposed budgets. At a minimum, the supporting documentation must show which tasks/subtasks are being performed, the purpose/need for the effort, and a sufficient basis for the estimated costs.

4. FOURTH COMPONENT: SUMMARY FOR PUBLIC RELEASE

Applicants are required to provide a 250-word maximum Summary for Public Release following the instructions in the available template. The Summary for Public Release must be submitted in Adobe PDF format. For applications selected for award negotiations, the Summary may be used as the basis for a public announcement by ARPA-E; therefore, this summary should not include any confidential, proprietary, or privileged information. This summary may not include any graphics, figures, or tables. The summary should be written for a lay audience (e.g., general public, media, Congress) using plain English.

5. FIFTH COMPONENT: SUMMARY SLIDE

Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format. This slide will be used during ARPA-E's evaluation of Full Applications. Summary Slides must conform to the content requirements described in the template.

6. SIXTH COMPONENT: BUSINESS ASSURANCES & DISCLOSURES FORM

Applicants are required to provide the information requested in the Business Assurances & Disclosures Form. The information must be submitted in Adobe PDF format and digitally signed by all required parties. The fillable Business Assurances & Disclosures Form template on ARPA-E eXCHANGE includes instructions for items the Applicant is required to disclose, describe, or request a waiver for.

6. SEVENTH COMPONENT: SBIR.GOV COMPANY REGISTRATION

Applicants are required to provide a copy of the SBIR.gov Company Registration confirmation document generated from SBIR.gov (see Section IV.A of the NOFO) in Adobe PDF form. Applicants that have previously completed SBIR.gov Company Registration need not register again and may submit a copy their existing Registration.

7. EIGHTH COMPONENT: ADDITIONAL OWNERSHIP CERTIFICATIONS

Only those Applicants that are (a) majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms and/or (b) joint ventures minority-owned by a foreign entity are required to complete the Certification for Applicants Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, and Private Equity Funds and

Joint Venture Applicants Minority-Owned by Foreign Business Entities (VCOC/FJV Certification). The certification must be submitted in Adobe PDF format.

In the VCOC/FJV Certification, the Applicant is required to self-identify as an entity that falls into one of those categories, provide certain information, verify its ownership status, and verify that it has completed SBIR.gov Company Registration (see Section IV.A) as such an entity.

Applicants that are neither (a) majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms nor (b) joint ventures minority-owned by a foreign entity are not required to complete the VCOC/FJV Certification.

D. REPLIES TO REVIEWER COMMENTS

Written feedback on Full Applications is made available to Applicants before the submission deadline for Replies to Reviewer Comments. Applicants have a brief opportunity to prepare a short Reply to Reviewer Comments responding to one or more comments or supplementing their Full Application. A fillable Reply to Reviewer Comments template is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).

Replies to Reviewer Comments must conform to the following requirements:

- The Reply to Reviewer Comments must be submitted in Adobe PDF format.
- The Reply to Reviewer Comments must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11-inch paper with margins not less than one inch on every side. Use Times New Roman typeface, a black font color, and a font size of 12 points or larger (except in figures and tables).
- The Reply to Reviewer Comments must be a maximum of 3 pages – 2 pages maximum for text, and 1 page maximum for images (e.g., graphics, charts, or other data).
- The Control Number must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

IV. SUBMISSION REQUIREMENTS AND DEADLINES

All documents, templates, and instructions required to apply to this NOFO are either linked in this document or available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE. ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail).

ARPA-E expects to retain copies of all Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions. No submissions will be returned. By applying to ARPA-E for funding, Applicants consent to ARPA-E's retention of their submissions.

A. COMPLETION OF SBIR.GOV COMPANY REGISTRATION

The first step in applying to this NOFO is completing the SBIR.gov Company Registration (https://app.www.sbir.gov/company-registration/overview). Upon completing registration, Applicants will receive a unique Small Business Concern (SBC) Control ID and SBC Registration confirmation document in Adobe PDF format. Applicants that have previously completed SBIR.gov Company Registration need not register again.

Applicants must submit their Registration confirmation document with SBC Control ID as part of their Full Application (see Section III.C.6 of the NOFO).

B. UNIQUE ENTITY IDENTIFIER AND SAM REGISTRATION

Applicants must register with the System for Award Management (SAM) at www.sam.gov/SAM prior to submitting an application, at which time the system will assign (if newly registered) a Unique Entity Identifier (UEI). Applicants should commence this process as soon as possible. Registering with SAM and obtaining the UEI could take several weeks.

Recipients must:

- Maintain a current and active registration in SAM.gov at all times during which it has an active Federal award or an application or plan under consideration by a Federal awarding agency, including (if applicable) information on its immediate and highest-level owner and subsidiaries and on all predecessors that have been awarded a Federal contract or financial assistance award within the last three years.;
- Remain registered in SAM.gov after the initial registration;
- Update its information in SAM.gov as soon as it changes;
- Review its information in SAM.gov annually from the date of initial registration or subsequent updates to ensure it is current, accurate and complete;
- Include its UEI in each application it submits; and

- Not make a subaward to any entity unless the entity has provided its UEI.

Subrecipients are not required to complete a full registration in SAM.gov but must obtain a UEI.

ARPA-E may not execute a funding agreement with the Recipient until it has obtained a UEI and completed its SAM registration.

C. USE OF ARPA-E EXCHANGE

To apply to this NOFO, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE Applicant Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

Upon creating an application submission in ARPA-E eXCHANGE, Applicants will be assigned a Control Number. If the Applicant creates more than one application submission, a different Control Number will be assigned for each application.

Once logged in to ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx), Applicants may access their submissions by clicking the "Submissions" and then "My Submissions" links in the navigation on the left side of the page. Every application that the Applicant has submitted to ARPA-E and the corresponding Control Number is displayed on that page. If the Applicant submits more than one application to a particular NOFO, a different Control Number is shown for each application.

Applicants are responsible for meeting each submission deadline in ARPA-E eXCHANGE. **Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.** Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), Applicants should allow at least 1 hour to submit a Concept Paper or Full Application. In addition, Applicants should allow at least 15 minutes to submit a Reply to Reviewer Comments. Once the application is submitted in ARPA-E eXCHANGE, Applicants may revise or update their application until the expiration of the applicable deadline.

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to submit their applications. **ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.**

D. REQUIRED DOCUMENTS CHECKLIST AND DEADLINES

The following table outlines the required documents and their submission deadlines.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	NOFO SECTION	DEADLINES

Concept Paper	• Concept Paper (Adobe PDF format)
	  ○ Sections 1-4 (4 pages max.)
	  ○ Appendix 1: Short Answer Questions (1 page max.)
	  ○ Bibliographic References (no page limit)
	• Summary Slide (1 page limit, Microsoft PowerPoint format)
		Mandatory	III.B	9:30 AM ET December 31, 2024

Full Application	• Technical Volume (Adobe PDF format):
	  ○ Cover Page (1 page max.)
	  ○ Executive Summary (1 page max.)
	  ○ Sections 1-5 (20 pages max.)
	  ○ Bibliographic References (no page limit)
	  ○ Personal Qualification Summaries (each summary limited to 5 pages in length, no cumulative page limit)
	• Signed SF-424 (Adobe PDF format);
	• Budget Justification Workbook/SF-424A (Microsoft Excel format);
	• Summary for Public Release (250 words max., Adobe PDF format);
	• Summary Slide (1 slide limit, Microsoft PowerPoint format);
	• Signed Business Assurances & Disclosures Form(s) (no page limit, Adobe PDF format);
	• SBA Company Registration Certificate generated in the SBA Company Registry; (http://sbir.gov/registration) (Adobe PDF format); and
	• If applicable, Certification for Applicants that are (a) Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, or Private Equity Firms; and/or (b) joint ventures minority-owned by a foreign entity (Adobe PDF format).
		Mandatory	III.C	TBD

Reply to Reviewer Comments	• Reply to Reviewer Comments (3 page max., Adobe PDF format)	Optional	III.D	TBD

E. COMPLIANCE

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the NOFO. Such applications may be deemed noncompliant (see Section II.F of the NOFO). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section III of the NOFO;
- Failing to enter required information in ARPA-E eXCHANGE;
- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the NOFO;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

ARPA-E urges Applicants to carefully review their applications and to allow sufficient time for the submission of required information and documents.

F. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372 (Intergovernmental Review of Federal Programs).

V. APPLICATION REVIEW INFORMATION

A. RESPONSIVENESS

1. TECHNICAL RESPONSIVENESS REVIEW

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. The following types of submissions may be deemed nonresponsive and may not be reviewed or considered:

- Submissions that fall outside the technical parameters specified in this NOFO.
- Submissions that have been submitted in response to currently issued ARPA-E NOFOs.
- Submissions that are not scientifically distinct from applications submitted in response to currently issued ARPA-E NOFOs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the NOFO.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the NOFO. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by any other office within Department of Energy.
- Submissions that are not distinct in scientific approach or objective from activities currently supported by or actively under consideration for funding by other government agencies or the private sector.
- Submissions that do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.B of the NOFO.

2. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

Submissions that propose the following will be deemed nonresponsive and will not be merit reviewed or considered:

- Technologies/processes only focused on a single ion recovery;

- Chemical precipitation technologies such as struvite and calcium phosphate precipitation that rely on relatively stable chemical costs and are already mature;
- Technologies tuned for the removal of nitrate, or the conversion of nitrate to ammonia;
- Metals/materials deemed Not Critical by DOE 2023 Final Critical Materials List as part of the two required primary recovery constituents (non-critical materials are acceptable if recovered as tertiary product); and
- Research on waste streams that do not fall under the categories of municipal wastewater, animal feedlot wastewater, mining wastewater, or produced water.

B. REVIEW CRITERIA

ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application and whether to select a Full Application for award negotiations.

1. CRITERIA FOR CONCEPT PAPERS

(1) *Impact of the Proposed Technology Relative to NOFO Targets* (50%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement compared to existing or emerging technologies;
- Achievement of the technical performance targets defined in Section I.F of the NOFO for the appropriate technology Category in Section I.E of the NOFO;
- Identification of techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- Demonstration of awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

(2) *Overall Scientific and Technical Merit* (50%) - This criterion involves consideration of the following:

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- Clearly defined project outcomes and final deliverables; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among

team members supporting the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement.

2. CRITERIA FOR FULL APPLICATIONS

Full Applications are evaluated based on the following criteria:

(1) *Impact of the Proposed Technology* (30%) - This criterion involves consideration of the following:

- The potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;
- Thorough understanding of the current state-of-the-art and presentation of an innovative technical approach to significantly improve performance over the current state-of-the-art;
- Awareness of competing commercial and emerging technologies and identification of how the proposed concept/technology provides significant improvement over these other solutions; and
- A reasonable and effective strategy for transitioning the proposed technology from the laboratory to commercial deployment.

(2) *Overall Scientific and Technical Merit* (30%) - This criterion involves consideration of the following:

- Whether the proposed work is unique and innovative;
- Clearly defined project outcomes and final deliverables;
- Substantiation that the proposed project is likely to meet or exceed the technical performance targets identified in this NOFO;
- Feasibility of the proposed work based upon preliminary data or other background information and sound scientific and engineering practices and principles;
- A sound technical approach, including appropriately defined technical tasks, to accomplish the proposed R&D objectives; and
- Management of risk, to include identifying major technical R&D risks and feasible, effective mitigation strategies.

(3) *Qualifications, Experience, and Capabilities of the Proposed Project Team* (30%) - This criterion involves consideration of the following**:**

- The PI and Project Team have the skill and expertise needed to successfully execute the project plan, evidenced by prior experience that demonstrates an ability to perform R&D of similar risk and complexity; and

- Access to the equipment and facilities necessary to accomplish the proposed R&D effort and/or a clear plan to obtain access to necessary equipment and facilities.

(4) *Soundness of Management Plan* (10%) - This criterion involves consideration of the following:

- Plausibility of plan to manage people and resources;
- Allocation of appropriate levels of effort and resources to proposed tasks;
- Reasonableness of the proposed project schedule, including major milestones; and
- Reasonableness of the proposed budget to accomplish the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement.

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

ARPA-E has not established separate criteria to evaluate Replies to Reviewer Comments. Instead, Replies to Reviewer Comments are evaluated as an extension of the Full Application.

C. PROGRAM POLICY FACTORS

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining which Concept Papers to encourage to submit a Full Application and which Full Applications to select for award negotiations:

I. **ARPA-E Portfolio Balance**. Project balances ARPA-E portfolio in one or more of the following areas:
   a. Diversity of technical personnel in the proposed Project Team;
   b. Technological diversity;
   c. Organizational diversity;
   d. Geographic diversity;
   e. Technical or commercialization risk; or
   f. Stage of technology development.

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of U.S. dependence on foreign energy sources;
   b. Stimulation of U.S. manufacturing and/or software development
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

III. **Synergy of Public and Private Efforts**.
   a. Avoids duplication and overlap with other publicly or privately funded projects;
   b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
   c. Increases unique research collaborations.

IV. **Low likelihood of other sources of funding.** High technical and/or financial uncertainty that results in the non-availability of other public, private or internal funding or resources to support the project.

V. **High Project Impact Relative to Project Cost.**

VI. **Qualified Opportunity Zone (QOZ).** Whether the entity is located in an urban and economically distressed area including a Qualified Opportunity Zone (QOZ) or the proposed project will occur in a QOZ or otherwise advance the goals of QOZ. The goals include spurring economic development and job creation in distressed communities throughout the United States. For a list or map of QOZs go to: https://www.cdfifund.gov/opportunity-zones.

D. REVIEW AND SELECTION PROCESS

1. CONCEPT PAPERS

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.B.1 and V.C of the NOFO. ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to encourage the submission of a Full Application.

2. FULL APPLICATIONS

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive. Full Applications found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.B.2 and V.C of the NOFO.

3. REPLY TO REVIEWER COMMENTS

Once ARPA-E has completed its review of Full Applications, reviewer comments on compliant and responsive Full Applications are made available to Applicants via ARPA-E eXCHANGE. ARPA-

E may also provide more direct feedback at this time. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the NOFO.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.D of the NOFO. ARPA-E will review and consider compliant Replies only.

4. PRE-SELECTION CLARIFICATIONS AND "DOWN-SELECT" PROCESS

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Grants Officer's discretion, conduct a pre-selection clarification process and/or perform a "down-select" of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, written correspondence, or site visits that can be used to make a final selection determination. ARPA-E will not reimburse Applicants for travel and other expenses relating to pre-selection meetings or site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for award negotiations and make awards without pre-selection meetings and site visits. Participation in a pre-selection meeting or site visit with ARPA-E does not signify that Applicants have been selected for award negotiations.

5. SELECTION FOR AWARD NEGOTIATIONS

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria, risk reviews, and program policy factors in Sections V.B, V.G, and V.C of the NOFO. ARPA-E considers a mix of quantitative and qualitative criteria in determining whether to select an application for award negotiation.

The Selection Official may select all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

ARPA-E expects to announce selections for negotiations in approximately June 2025 and to execute funding agreements in approximately September 2025.

E. ARPA-E REVIEWERS

By submitting an application to ARPA-E, Applicants consent to ARPA-E's use of Federal employees, contractors, and experts from educational institutions, nonprofits, industry, and governmental and intergovernmental entities as reviewers. ARPA-E selects reviewers based on

their knowledge and understanding of the relevant field and application, their experience and skills, and their ability to provide constructive feedback on applications.

ARPA-E requires all reviewers to complete a Conflict-of-Interest Certification and Nondisclosure Agreement through which they disclose their knowledge of any actual or apparent conflicts and agree to safeguard confidential information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments. In addition, ARPA-E trains its reviewers in proper evaluation techniques and procedures.

Applicants are not permitted to nominate reviewers for their applications. Applicants may contact the Grants Officer by email (ARPA-E-CO@hq.doe.gov) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

F. ARPA-E SUPPORT CONTRACTORS

ARPA-E utilizes contractors to assist with the evaluation of applications and project management. To avoid actual and apparent conflicts of interest, ARPA-E prohibits its support contractors from submitting or participating in the preparation of applications to ARPA-E.

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

G. RISK REVIEW

If selected for award negotiations, ARPA-E may evaluate the risks posed by the Applicant using the criteria set forth at 2 CFR §200.206(b)(2). ARPA-E may require special award terms and conditions depending upon results of the risk analysis.

Further, as DOE invests in critical infrastructure and funds critical and emerging technology areas, DOE also considers possible vectors of undue foreign influence in evaluating risk. If high risks are identified and cannot be sufficiently mitigated, DOE may elect to not fund the applicant. As part of the research, technology, and economic security risk review, DOE may contact the applicant and/or proposed project team members for additional information to inform the review.

ARPA-E will not make an award if ARPA-E has determined that:

- The entity submitting the proposal or application:
    - has an owner or Covered Individual that is party to a malign foreign talent recruitment program of the People's Republic of China or another foreign country of concern;[27]

  - has a business entity, parent company, or subsidiary located in the People's Republic of China or another foreign country of concern; or
  - has an owner or Covered Individual that has a foreign affiliation with a research institution located in the People's Republic of China or another foreign country of concern; and
- The relationships and commitments described above:
  - interfere with the capacity for activities supported by the Federal agency to be carried out;
  - create duplication with activities supported by the Federal agency;
  - present concerns about conflicts of interest;
  - were not appropriately disclosed to the Federal agency;
  - violate Federal law or terms and conditions of the Federal agency; or
  - pose a risk to national security.

If high risks are identified and cannot be sufficiently mitigated, ARPA-E may elect to not fund the applicant.

VI. AWARD NOTICES AND AWARD TYPES

A. AWARD NOTICES

Recipients should register with FedConnect in order to receive notification that their funding agreement has been executed by the Grants Officer and to obtain a copy of the executed funding agreement. Please refer to https://www.fedconnect.net/FedConnect/ for registration instructions.

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Grants Officer and are not merit reviewed or considered for award. The Grants Officer sends a notification email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification states the basis upon which the Concept Paper or Full Application was rejected.

2. CONCEPT PAPER NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to encourage or discourage the submission of a Full Application. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. ARPA-E provides feedback in the notification letter in order to guide further development of the proposed technology.

Applicants may submit a Full Application even if they receive a notification discouraging them from doing so. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. The purpose of the Concept Paper phase is to save Applicants the considerable time and expense of preparing a Full Application that is unlikely to be selected for award negotiations.

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project.

3. FULL APPLICATION NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination to select, postpone a final decision until a later date, or not select a Full Application for award negotiation. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE.

Written feedback on Full Applications is only made available to Applicants in the Replies to Reviewer Comments process. ARPA-E does not offer or provide debriefings.

ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants.

a. SUCCESSFUL APPLICANTS

ARPA-E has discretion to select all or part of a proposed project for negotiation of an award. A notification letter selecting a Full Application for award negotiations does not authorize the Applicant to commence performance of the project. **ARPA-E selects Full Applications for award negotiations, not for award.** Applicants do not receive an award until award negotiations are complete and the Grants Officer executes the funding agreement. The notice of Federal award signed by the Grants Officer is the official document that obligates funds. ARPA-E may terminate award negotiations at any time for any reason.

The Grants Officer is the only individual who can make awards on behalf of ARPA-E or obligate ARPA-E to the expenditure of public funds. A commitment or obligation by any individual other than the Grants Officer, either explicit or implied, is invalid.

ARPA-E awards may not be transferred, assigned, or assumed without the prior written consent of a Grants Officer.

b. POSTPONED SELECTION DETERMINATIONS

A notification letter postponing a final selection determination until a later date does not authorize the Applicant to commence performance of the project. ARPA-E may ultimately determine to select or not select the Full Application for award negotiations.

c. UNSUCCESSFUL APPLICANTS

By not selecting a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. ARPA-E hopes that unsuccessful Applicants will submit innovative ideas and concepts for future NOFOs.

B. PRE-AWARD COSTS

ARPA-E will not reimburse any pre-award costs incurred by Applicants before they are selected for award negotiations. Please refer to Section VI.A of the NOFO for guidance on award notices.

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 2 C.F.R. Part 200, as modified by 2 C.F.R. Part 910, and other Federal laws and regulations. All submitted budgets are subject to change and are

typically reworked during award negotiations. ARPA-E is under no obligation to reimburse pre-award costs if, for any reason, the Applicant does not receive an award or the award is made for a lesser amount than the Applicant expected, or if the costs incurred are not allowable, allocable, or reasonable.

C. RENEWAL AWARDS

At ARPA-E's sole discretion, awards resulting from this NOFO may be renewed by adding one or more budget periods, extending the period of performance of the initial award, or issuing a new award. Renewal funding is contingent on: (1) availability of funds appropriated by Congress for the purpose of this program; (2) substantial progress towards meeting the objectives of the approved application; (3) submittal of required reports; (4) compliance with the terms and conditions of the award; (5) ARPA-E approval of a renewal application; and (6) other factors identified by the Agency at the time it solicits a renewal application.

D. FUNDING AGREEMENTS

Through cooperative agreements, other transactions, and similar agreements, ARPA-E provides financial and other support to projects that have the potential to realize ARPA-E's statutory mission. ARPA-E does not use such agreements to acquire property or services for the direct benefit or use of the U.S. Government.

Cooperative Agreements involve the provision of financial or other support to accomplish a public purpose of support or stimulation authorized by Federal statute. Under Cooperative Agreements, the Government and Recipient share responsibility for the direction of projects.

Phase I will be made as a fixed-amount award. Phase II and Phase IIS of Combined Phase I/II/IIS awards will be made on a cost-reimbursement basis.

ARPA-E encourages Recipients to review the Model Cooperative Agreement, which is available at https://arpa-e.energy.gov/technologies/project-guidance.

VII. POST-AWARD REQUIREMENTS AND ADMINISTRATION

The Recipient is the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including but not limited to disputes and claims arising out of any agreement between the Recipient and a FFRDC contractor. Recipients are required to flow down these requirements to their Subrecipients through subawards or related agreements.

A. NATIONAL POLICY REQUIREMENTS

The following national policy requirements apply to Recipients.

- If an award is made to a DOE/NNSA National Laboratory, all Disputes and Claims will be resolved in accordance with the terms and conditions of the DOE/NNSA National Laboratory's management and operating (M&O) contract, as applicable, in consultation between DOE and the Recipient.
- If an award is made to another Federal agency or its FFRDC contractor, all Disputes and Claims will be resolved in accordance with the terms and conditions of the interagency agreement in consultation between DOE and the Recipient.

1. NATIONAL POLICY ASSURANCES

Project Teams, including Recipients and Subrecipients, are required to comply with the National Policy Assurances in effect on the date of award located at https://www.nsf.gov/awards/managing/rtc.jsp in accordance with 2 C.F.R. § 200.300.

2. ENVIRONMENTAL IMPACT QUESTIONNAIRE

By law, ARPA-E is required to evaluate the potential environmental impact of projects that it is considering for funding. In particular, ARPA-E must determine before funding a project whether the project qualifies for a categorical exclusion under 10 C.F.R. § 1021.410 or whether it requires further environmental review (i.e., an environmental assessment or an environmental impact statement).

To facilitate and expedite ARPA-E's environmental review, Recipients are required to complete an Environmental Impact Questionnaire during award negotiations. This form is available at https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/required-forms-and-templates. Each Recipient must wait to complete the Environmental Impact Questionnaire (EIQ) until after ARPA-E has notified them that Attachment 3 Statement of Program Objectives is in final form. The completed EIQ is then due back to ARPA-E within 14 calendar days.

B. ADMINISTRATIVE REQUIREMENTS

1. INTELLECTUAL PROPERTY AND DATA MANAGEMENT PLANS

ARPA-E requires every Project Team to negotiate and establish an Intellectual Property Management Plan for the management and disposition of intellectual property arising from the project. The Recipient must submit a completed and signed Intellectual Property Management plan to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement. All Intellectual Property Management Plans are subject to the terms and conditions of the ARPA-E funding agreement and its intellectual property provisions, and applicable Federal laws, regulations, and policies, all of which take precedence over the terms of Intellectual Property Management Plans.

ARPA-E has developed a template for Intellectual Property Management Plans (https://arpa-e.energy.gov/technologies/project-guidance/post-award-guidance/project-management-reporting-requirements) to facilitate and expedite negotiations between Project Team members. ARPA-E does not mandate the use of this template. ARPA-E and DOE do not make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the template. ARPA-E and DOE strongly encourage Project Teams to consult independent legal counsel before using the template.

Awardees are also required, post-award, to submit a Data Management Plan (DMP) that addresses how data generated in the course of the work performed under an ARPA-E award will be preserved and, as appropriate, shared publicly. The Recipient must submit a completed and signed DMP - as part of the Team's Intellectual Property Management Plan - to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement.

2. U.S. COMPETITIVENESS

A primary objective of DOE's multi-billion-dollar research, development and demonstration investments – including ARPA-E awards - is advancement of new energy technologies, manufacturing capabilities, and supply chains for and by U.S. industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant must agree to the following U.S. Competitiveness Provision as part of an award under this NOFO.

U.S. Competitiveness

> The Contractor (Recipient in ARPA-E awards) agrees that any products embodying any subject invention or produced through the use of any subject invention will be manufactured substantially in the United States unless the Contractor can show to the satisfaction of DOE that it is not commercially feasible. In the event DOE agrees to foreign manufacture, there will be a requirement that the Government's support of the technology be recognized in some appropriate manner, e.g., alternative binding

commitments to provide an overall net benefit to the U.S. economy. The Contractor agrees that it will not license, assign or otherwise transfer any subject invention to any entity, at any tier, unless that entity agrees to these same requirements. Should the Contractor or other such entity receiving rights in the invention(s): (1) undergo a change in ownership amounting to a controlling interest, or (2) sell, assign, or otherwise transfer title or exclusive rights in the invention(s), then the assignment, license, or other transfer of rights in the subject invention(s) is/are suspended until approved in writing by DOE. The Contractor and any successor assignee will convey to DOE, upon written request from DOE, title to any subject invention, upon a breach of this paragraph. The Contractor will include this paragraph in all subawards/contracts, regardless of tier, for experimental, developmental or research work.

A subject invention is any invention of the contractor conceived or first actually reduced to practice in the performance of work under an award. An invention is any invention or discovery which is or may be patentable. The contractor includes any awardee, recipient, sub-awardee, or sub-recipient.

As noted in the U.S. Competitiveness Provision, at any time in which an entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or U.S. manufacturing plan. The statement or plan would contain specific and enforceable commitments that would be beneficial to the U.S. economy and competitiveness. Commitments could include manufacturing specific products in the U.S., making a specific investment in a new or existing U.S. manufacturing facility, keeping certain activities based in the U.S. or supporting a certain number of jobs in the U.S. related to the technology. If DOE, in its sole discretion, determines that the proposed modification or waiver promotes commercialization and provides substantial U.S. economic benefits, DOE may grant the request and, if granted, modify the award terms and conditions for the requesting entity accordingly.

The U.S. Competitiveness Provision is implemented by DOE pursuant to a Determination of Exceptional Circumstances (DEC) under the Bayh-Dole Act and DOE Patent Waivers. See Section VIII.A, “Title to Subject Inventions”, of this NOFO for more information on the DEC and DOE Patent Waiver.

3. NONDISCLOSURE AND CONFIDENTIALITY AGREEMENTS REPRESENTATIONS

In submitting an application in response to this NOFO the Applicant represents that:

(1) **It does not and will not** require its employees or contractors to sign internal nondisclosure or confidentiality agreements or statements prohibiting or otherwise restricting its employees or contractors from lawfully reporting waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

(2) **It does not and will not** use any Federal funds to implement or enforce any nondisclosure and/or confidentiality policy, form, or agreement it uses unless it contains the following provisions:

a. *"These provisions are consistent with and do not supersede, conflict with, or otherwise alter the employee obligations, rights, or liabilities created by existing statute or Executive order relating to (1) classified information, (2) communications to Congress, (3) the reporting to an Inspector General of a violation of any law, rule, or regulation, or mismanagement, a gross waste of funds, an abuse of authority, or a substantial and specific danger to public health or safety, or (4) any other whistleblower protection. The definitions, requirements, obligations, rights, sanctions, and liabilities created by controlling Executive orders and statutory provisions are incorporated into this agreement and are controlling."*

b. The limitation above shall not contravene requirements applicable to Standard Form 312, Form 4414, or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

c. Notwithstanding the provision listed in paragraph (a), a nondisclosure confidentiality policy form or agreement that is to be executed by a person connected with the conduct of an intelligence or intelligence-related activity, other than an employee or officer of the United States Government, may contain provisions appropriate to the particular activity for which such document is to be used. Such form or agreement shall, at a minimum, require that the person will not disclose any classified information received in the course of such activity unless specifically authorized to do so by the United States Government. Such nondisclosure or confidentiality forms shall also make it clear that they do not bar disclosure to congress, or to an authorized official of an executive agency or the Department of Justice, that are essential to reporting a substantial violation of law.

4. INTERIM CONFLICT OF INTEREST POLICY FOR FINANCIAL ASSISTANCE

The DOE interim Conflict of Interest Policy for Financial Assistance (COI Policy) can be found at https://www.energy.gov/management/financial-assistance-letter-no-fal-2022-02. This policy is applicable to all non-Federal entities applying for, or that receive, DOE funding by means of a financial assistance award (e.g., a grant, cooperative agreement, or technology investment agreement or similar other transaction agreement) and, through the implementation of this policy by the entity, to each Investigator who is planning to participate in, or is participating in, the project funded wholly or in part under the DOE financial assistance award. DOE's interim COI Policy establishes standards that provide a reasonable expectation that the design, conduct, and reporting of projects funded wholly or in part under DOE financial assistance awards will be free from bias resulting from financial conflicts of interest or organizational conflicts of interest. The applicant is subject to the requirements of the interim COI Policy and within each application for financial assistance, the applicant must certify that it is, or will be by the time of receiving any financial assistance award, compliant with all requirements in the interim COI Policy. For applicants to any ARPA-E NOFO, this certification, disclosure of any managed or unmanaged conflicts of interest, and a copy of (or link to) the applicant's own conflict of interest policy must be included with the information provided in the Business Assurances & Disclosures Form. The applicant must also flow down the requirements of the interim COI Policy to any subrecipient non-Federal entities.

5. COMPLIANCE AUDIT REQUIREMENT

A recipient organized as a for-profit entity expending $1,000,000 or more of DOE funds in the entity's fiscal year (including funds expended as a Subrecipient) must have an annual compliance audit performed at the completion of its fiscal year. For additional information, refer to Subpart F of: (i) 2 C.F.R. Part 200, and (ii) 2 C.F.R. Part 910.

If an educational institution, non-profit organization, or state/local government has expended $1,000,000 or more of Federal funds (including funds expended as a Subrecipient) in the entity's fiscal year, the entity must have an annual compliance audit performed at the completion of its fiscal year. For additional information refer to Subpart F of 2 C.F.R. Part 200.

6. RESEARCH SECURITY TRAINING REQUIREMENT

Covered individuals listed on applications under this NOFO are required to certify that they have taken research security training consistent with Section 10634 of the CHIPS and Science Act of 2022. In addition, applicants who receive an award must maintain sufficient records (records must be retained for the time period noted in 2 CFR 200.334 and made available to DOE upon request) of their compliance with this requirement for covered individuals at the Recipient organization and they must extend this requirement to any and all Subrecipients. To fulfill this requirement, an applicant may utilize the four one-hour training modules developed by the National Science Foundation at https://new.nsf.gov/research-security/training or

develop and implement their own research security training program aligned with the requirements in Section 10634(b) of the CHIPS and Science Act of 2022. The submission of an application to this NOFO constitutes the applicant's acceptance of this requirement.

C. REPORTING

Recipients are required to submit periodic, detailed reports on technical, financial, and other aspects of the project, as described in Attachment 4 to ARPA-E's Model Cooperative Agreement (https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements).

1. FRAUD, WASTE, AND ABUSE

An applicant, recipient, or subrecipient must promptly disclose whenever in connection with the federal award (including any activities or subawards thereunder), it has credible evidence of the commission of a violation of Federal criminal law involving fraud, conflict of interest, bribery, or gratuity violations found in Title 18 of the United States Code or a violation of the civil False Claims Act (31 U.S.C. 3729-3733). The disclosure must be made in writing to the Federal agency, the agency's Office of Inspector General, and pass-through entity (if applicable.) Recipients and subrecipients are also required to report matters related to recipient integrity and performance in accordance with Appendix XII of this part. Failure to make required disclosures can result in any of the remedies described in 2 C.F.R. §200.339. (See also 2 C.F.R. part 180, 31 U.S.C. 3321, and 41 U.S.C. 2313.)

For guidance on reporting such violations and information to the DOE Office of Inspector General (OIG), please visit https://www.energy.gov/ig/ig-hotline.

You may report fraud, waste, mismanagement, or misconduct involving SBA programs or employees either online (https://www.sbir.gov/fraud-waste-abuse) or by calling the OIG Hotline toll-free at (800) 767-0385.

2. COMMERCIALIZATION PLAN AND SOFTWARE REPORTING

If your project is selected and it targets the development of software, you may be required to prepare a Commercialization Plan for the targeted software and agree to special provisions that require the reporting of the targeted software and its utilization. This special approach to projects that target software mirrors the requirements for reporting that attach to new inventions made in performance of an award.

VIII. OTHER INFORMATION

A. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below:

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions;
- All other parties: The federal Non-Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the government obtains title to new subject inventions unless a waiver is granted (see below):
  - Class Patent Waiver for Domestic Large Businesses: DOE has issued a class patent waiver that applies to this NOFO. Under this class patent waiver, domestic large businesses may elect title to their subject inventions similar to the right provided to the domestic small businesses, educational institutions, and nonprofits by law. In order to avail itself of the class patent waiver, a domestic large business must agree to the U.S. Competitiveness Provision in accordance with Section VII.B.2 of this NOFO.
  - Advance and Identified Waivers: For applicants that do not fall under the class patent waiver or the Bayh-Dole Act, those applicants may request a patent waiver that will cover subject inventions that may be made under the award, in advance of or within 30 days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver for identified inventions, i.e., individual subject inventions that are disclosed to DOE within the time frames set forth in the award's intellectual property terms and conditions. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784.
- DEC: On June 07, 2021, DOE approved a DETERMINATION OF EXCEPTIONAL CIRCUMSTANCES (DEC) UNDER THE BAYH-DOLE ACT TO FURTHER PROMOTE DOMESTIC MANUFACTURE OF DOE SCIENCE AND ENERGY TECHNOLOGIES. In accordance with this DEC, all awards, including sub-awards, under this NOFO made to a Bayh-Dole entity (domestic small businesses and nonprofit organizations) shall include the U.S. Competitiveness Provision in accordance with Section VII.B.2 of this NOFO. A copy of the DEC may be found on the DoE website. Pursuant to 37 CFR § 401.4, any Bayh-Dole entity affected by this DEC has the right to appeal it by providing written notice to DOE within 30 working days from the time it receives a copy of the determination.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

Where Recipients and Subrecipients retain title to subject inventions, the U.S. Government retains certain rights.

1. GOVERNMENT USE LICENSE

The U.S. Government retains a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world. This license extends to contractors doing work on behalf of the Government.

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Recipient or Subrecipient who has elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

The U.S. Government may exercise its march-in rights if it determines that such action is necessary under any of the four following conditions:

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

C. RIGHTS IN TECHNICAL DATA

Data rights differ based on whether data is first produced under an award or instead was developed at private expense outside the award.

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: Pursuant to special statutory authority for SBIR/STTR awards, data generated under ARPA-E SBIR/STTR awards may be protected from public disclosure

for twenty years from the date of award in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

D. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g., weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;
- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;
- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

E. TECHNOLOGY PROTECTION PLAN

The Recipient must submit a Technology Protection Plan within 60 days of award setting out the Recipient's policies and procedures for identifying, accessing, handling, controlling, and releasing the following under this Award: (1) Recipient's proprietary information, including non-public technical information, trade secrets and other confidential business information, including but not limited to information, know-how, methods or processes that give the Recipient a competitive advantage in the marketplace; (2) information that is subject to U.S. export control laws or regulations; (3) information that has been designated as classified or

controlled unclassified information (CUI) by DOE/ARPA-E; (4) any other information designated by DOE/ARPA-E as sensitive throughout the period of performance. The Recipient must meet the stated objectives set forth in its Technology Protection Plan. The Recipient must notify ARPA-E of any revisions to the Technology Protection Plan or the proposed security approach. A report on the Recipient's progress toward meeting the objectives and milestones set forth in the Technology Protection Plan must be included in any continuation application. The Technology Protection Plan and any revisions to the plan and all related deliverables must be emailed securely to the point of contact designated by ARPA-E.

Any review comments or feedback provided to the Recipient by ARPA-E does not constitute an endorsement or approval of any specific elements within the Technology Protection Plan or the proposed security approach. Therefore, such feedback should not be referenced or used in marketing or promotional materials.

F. MATERIAL SUPPLY PLAN

The Recipient must submit a Material Supply Plan to ARPA-E within 60 days of award setting out the Recipient's strategy and approach for materials supply, including a new supply chain for North American and European suppliers, in form and substance satisfactory to ARPA-E. The Recipient must meet the stated objectives set forth in its Material Supply Plan. The Recipient must notify ARPA-E of any revisions to the Material Supply Plan. A report on the Recipient's progress towards meeting the objectives and milestones set forth in the Material Supply Plan must be included in any continuation application. The Material Supply Plan and any revisions to the plan and all related deliverables must be emailed securely to the point of contact designated by ARPA-E.

IX. GLOSSARY

Applicant: The entity that submits the application to ARPA-E. In the case of a Project Team, the Applicant is the lead organization listed on the application.

Application: The entire submission received by ARPA-E, including the Preliminary Application, Full Application, Reply to Reviewer Comments, and Small Business Grant Application (if applicable).

ARPA-E: The Advanced Research Projects Agency – Energy, an agency of the U.S. Department of Energy.

Covered Individual: an individual who contributes in a substantive, meaningful way to the scientific development or execution of an R&D project proposed to be carried out with an award from ARPA-E. This includes, but is not limited to, the PI, Co-PI, Key Personnel, and technical staff (e.g., postdoctoral fellows/researchers and graduate students). ARPA-E may further designate covered individuals during award negotiations or the award period of performance.

Deliverable: A deliverable is the quantifiable goods or services that will be provided upon the successful completion of a project task or sub-task.

DOE: U.S. Department of Energy

DOE/NNSA: U.S. Department of Energy/National Nuclear Security Administration.

FFRDCs: Federally Funded Research and Development Centers

Foreign Affiliation: A funded or unfunded academic, professional, or institutional appointment or position with a foreign government or government-owned entity, whether full-time, part-time, or voluntary (including adjunct, visiting, or honorary).

For-Profit Organizations (or For-Profit Entities): Entities organized for-profit that are Large Businesses or Small Businesses as those terms are defined elsewhere in this Glossary.

GOCOs: U.S. Government Owned, Contractor Operated laboratories.

GOGOs: U.S. Government Owned, Government Operated laboratories.

Institutions of Higher Education (or *educational institutions*): Has the meaning set forth at 20 U.S.C. 1001.

Large Business: Large businesses are entities organized for-profit other than small businesses as defined elsewhere in this Glossary.

Malign Foreign Talent Recruitment Program: The meaning given such term in section 10638 of the Research and Development, Competition, and Innovation Act (division B of Public Law 117–167) or 42 USC 19237, as of October 20, 2022.

Milestone: A milestone is the tangible, observable measurement that will be provided upon the successful completion of a project task or sub-task.

PI: Principal Investigator.

SBA: U.S. Small Business Administration.

SBIR: Small Business Innovation Research Program.

Small Business: Small businesses are domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards).

STTR: Small Business Technology Transfer Program.

Subject Invention: Any invention conceived or first actually reduced to practice under an ARPA-E funding agreement.

Task: A task is an operation or segment of the work plan that requires both effort and resources. Each task (or sub-task) is connected to the overall objective of the project, via the achievement of a milestone or a deliverable.

TT&O: Technology Transfer and Outreach. (See Section I.I.8 of the NOFO for more information).