FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

MINING INNOVATIONS FOR NEGATIVE EMISSIONS RESOURCE RECOVERY SBIR/STTR (MINER SBIR/STTR)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002708
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Funding Opportunity Announcement (FOA) Issue Date:	February 24, 2022
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, April 5, 2022
Submission Deadline for Concept Papers:	9:30 AM ET, April 15, 2022
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	October 2022
Total Amount to Be Awarded	Approximately $44 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002707 and DE-FOA-0002708.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $275,766 and $3,952,638.

- For eligibility criteria, see Section III.A – III.D of the FOA.
- For cost share requirements under this FOA, see Section III.E of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- For detailed guidance on compliance and responsiveness criteria, see Sections III.F.1 through III.F.4 of the FOA.

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

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REQUIRED DOCUMENTS CHECKLIST

For an overview of the application process, see Section IV.A of the FOA.

For guidance regarding requisite application forms, see Section IV.B of the FOA.

For guidance regarding the content and form of Concept Papers, Full Applications, and Replies to Reviewer Comments, see Sections IV.C, IV.D, and IV.E of the FOA.

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length including graphics, figures, and/or tables. Each Concept Paper must also include Appendix 1 and responses to Questions in Appendices 2 through 5, for each individual category they address. Each Appendix is limited to 1 page. Each Concept Paper submission must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities ○ Appendix 1: TEA ○ Appendix 2-5: For each applicable category addressed.	Mandatory	IV.C	9:30 AM ET, April 15, 2022
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]	Optional	IV.E	5 PM ET, TBD

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) to:

"(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 Funding Opportunity Announcement (FOA) under its authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA 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 down 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. By 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 lower than that of the incumbent technology.

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. 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")[2] 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).

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

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

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.[3]

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).[4] ARPA-E provides SBIR/STTR funding in three phases (Phase I, Phase II, and Phase IIS).

C. FOA SPECIFIC DEFINITIONS

CO_2-reactive Minerals: Minerals that react with CO_2 or CO_2-derived chemistries to form stable carbonates and (or) the ability to sequester CO_2. The term CO_2-reactive minerals can encompass gangue, overburden, and tailings.

Comminution: The mineral grinding phase during mineral beneficiation.

Conventional Minerals: Energy-relevant minerals typically mined from sulfides and oxides within ore.

Energy-relevant Minerals: Low-abundance minerals that are relevant to energy storage and transmission, such as Ni, Co, V, Li, Au, Cu, rare earth elements (REEs), platinum group elements (PGEs), etc.

***Ex situ*:** A process of extracting CO_2-reactive mineralogy from the subsurface and reacting with CO_2 or CO_2-derived chemistries and (or) recover energy-relevant minerals

Gangue Minerals: The mineral matrix historically viewed as waste rock (e.g., olivine, brucite, and serpentine) that surround conventional minerals (e.g., sulfides and oxides).

***In situ*:** A mining process used to recover energy-relevant minerals by using ore-leaching reagents directly in a subsurface ore deposit and (or) react with CO_2 or CO_2-derived chemistries.

Modified Ore: Ore with intentionally carbonated mineralogy.

[3] 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.
[4] See 84 Fed. Reg. 12794 (Apr. 2, 2019).

Negative Emissions: A technology that removes CO_2 from the atmosphere on a timescale that has a positive impact on climate.

Ore: Mineral assemblage composite characterized by both conventional minerals (e.g., sulfides and oxides) and CO_2-reactive minerals

Overburden: Material removed around the ore body of interest to access conventional minerals. For this program, overburden may be considered if a) *in situ* carbonation of overburden occurs or b) energy-relevant minerals not previously mined can be recovered from overburden.

Unmodified Ore: Ore with intentionally uncarbonated mineralogy.

Tailings: In this FOA tailings are grinded minerals and process effluents that are generated during mineral beneficiation.

D. PROGRAM OVERVIEW

The Mining Innovations for Negative Emissions Resource Recovery (MINER) program's aim is to support the development of commercial-ready technologies that give the United States a net-zero or net negative emissions pathway toward increased domestic supplies of copper, nickel, lithium, cobalt, rare earth elements, and other critical elements required for the transition to clean energy. The lack of a secure domestic supply of these minerals poses a significant supply chain risk for the United States, especially with regard to batteries, renewable energy generation, and transmission. Meanwhile, the domestic mining industry faces the rapid depletion of high-profit deposits, increased cost of mining and processing, expensive management, and accumulation of tailings, resulting in an overall reduced return of investment by conventional mining methods. Consequently, the Advanced Research Projects Agency – Energy (ARPA–E) is issuing this Funding Opportunity Announcement (FOA) with objectives to support the development of technology and approaches to: (1) decrease comminution energy by 50% compared to state-of-the-art; (2) increase yield of energy-relevant minerals by reducing unrecovered energy-relevant minerals in the tailings by 50% compared to state-of-the-art; and (3) enabling the negative emissions production of key minerals by sequestering >10 wt.% CO2e per metric ton of ore processed.

Four categories have been identified as necessary to achieve these goals and are discussed in detail later:

I. Mineral comminution

II. Improvements to beneficiation and processing to increase mineral yield

III. Carbon negative reactions

IV. Sensing, analyzing and enabling carbonation potential and mineralization

This FOA supports the development of viable technologies to achieve these goals cost-effectively with the potential to reach commercial scalability. Identified within this FOA are technical categories of interest in Section I.G. Also provided within this FOA are performance targets for the technical categories of interest in Section I.H. Lastly, Sections I.I and I.J of the FOA provide information on technoeconomic analysis (TEA) and Life Cycle Assessment (LCA) requirements, respectively.

E. PROGRAM OBJECTIVES

The objective of the MINER program is to utilize the reactive potential of CO_2-reactive ore bodies to decrease comminution energy and increase the yield of energy-relevant minerals utilizing novel negative emission technologies. The purpose of the objective is to provide the United States with an increased domestic supply of copper, nickel, lithium, cobalt, rare earth elements, and other elements required for the transition to clean energy. To accomplish the objective, the MINER program seeks replicable cost-effective solutions that address the techno-economic issues and performance metrics described in Sections I.H and I.I. Successful MINER technologies will require diverse disciplines and may benefit from technologies developed for other applications. Specifically, ARPA-E seeks to support the development of technologies to:

- Decrease mineral comminution energy and reduce unrecovered energy-relevant minerals in the tailings by 50% during mineral beneficiation by modifying mineral properties of CO_2-reactive ore;
- Increase energy-relevant mineral yield by capturing energy-relevant minerals in CO_2-reactive mineralogy;
- Reprocessing existing CO_2 reactive overburden and tailings deposits for the purpose of recovering residual mineral value;
- Develop carbon-negative reactions cradle-to-gate (ore-to-metal) to carbonate CO_2-reactive ore;
- Develop surveying technologies to advance exploration vectors of CO_2-reactive rock formations, quantify reservoir carbonation, and quantify energy-relevant minerals leached and re-mineralized during carbonation of the CO_2-reactive minerals;
- Develop the technology to the extent of a demonstrable and justifiable path to full commercial scale-up from bench-scale demonstrations for either an *in situ* or *ex situ* approach.

ARPA-E will accept MINER submissions that cover one or more categories. Applicants must explain how their approach will meet the technical criteria and any integration issues into pre-existing upstream and downstream mining processes that are not part of their submission. Applicants will also provide technology integration and a technology-to-market plan. All

Applicants need to provide details for the Tech-to-Market scope and schedule, outlining intellectual property sale/licensing, partnering, and (or) other commercialization plans.

F. BACKGROUND

Since the creation of the United States' Critical Minerals Stockpiling Act (1939), the domestic supply of energy-relevant minerals has been a national security and economic concern. With the combination of rapid technological advancements[5] and geopolitical events[6], the United States' domestic conventional mineral supply is insufficient for the transition from fossil fuels to renewable and clean energy sources. Further exacerbating the issue is that the current global conventional mineral supply cannot even support the United States transition to 100% electrification[7]. Consequently, to meet the supply-demand, the United States may look towards unconventional minerals (i.e., CO_2-reactive minerals) and carbon-negative mining methods.

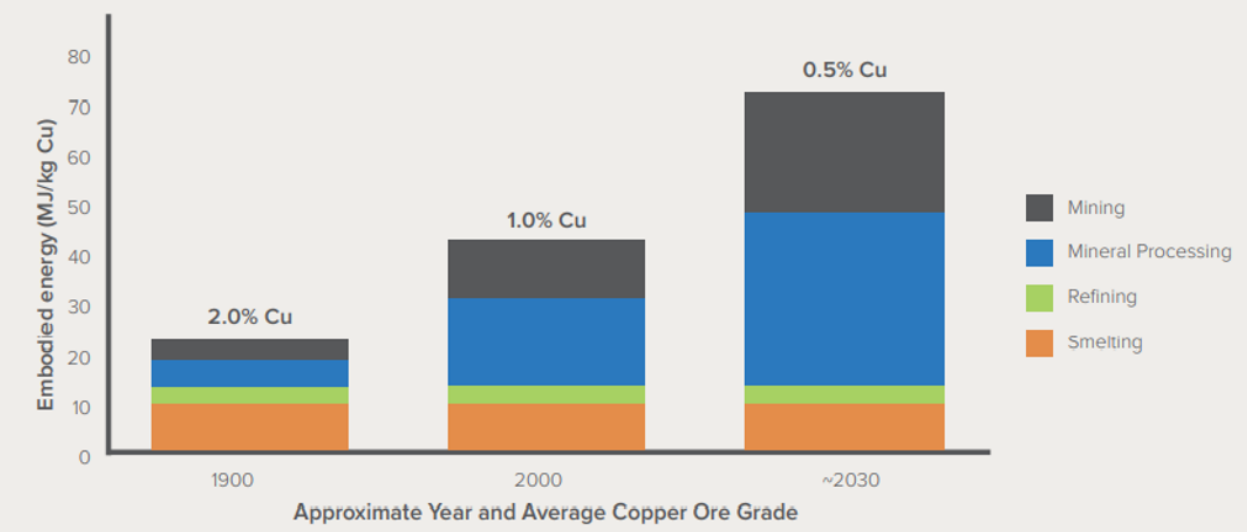

Figure 1: Embodied energy in mineral processing increases as ore grades decrease[8].

The mining industry's mineral beneficiation process of extracting and processing ore is one of the most energy-intensive industrial sectors. The primary energy-intensive portion of mineral beneficiation is comminution (i.e., mineral processing), as shown in Figure 1. Comminution energy possesses an inverse relationship with ore grade. For example, copper ore grades have decreased by 25% in the past decade and the energy required to process this ore has increased by 46%[9]. In quantifiable terms, copper ore grades of 0.20% require 10 MJ/kg of ore in

[5] Fortier et al. *US Geological Survey technical input document in response to Secretarial Order No. 3359,* ***2018****, 2018-1021*
[6] Ting & Seaman *Asian Studies Review*, **2013** 37 (2), 234-252
[7] Executive Order 14017, **2021**
[8] Low-Carbon_Metals_for_a_Low-Carbon_World.pdf (rmi.org)
[9] Calvo et al. *Resources* 5 (4) **2016**, 36

comparison to 80 MJ/kg for 0.05% copper ore grades[10]. Concomitant with this decrease in ore grade is also increased waste rock (i.e., gangue minerals and overburden) to achieve the same unit of produced metal[11]. With exploration requiring decades to discover and develop world-class deposits and decreasing ore grades over time (Fig. 2), mining companies have turned to remining tailings and mineral sludge. However, remining tailings and mineral sludge does not provide a long-term solution to decrease comminution energy and extract the energy-relevant minerals within the gigatons of gangue minerals and tailings produced during mining.

Carbon-negative reactions are a natural geochemical process in mafic-ultramafic rock. In nature, atmospheric CO_2 reacts with magnesium, calcium, and iron oxide-based silicates to form stable carbonates. Past research has reached a consensus that obducted mafic-ultramafic crust may have initiated the end of the Cretaceous Thermal Maximum by atmospheric CO_2 drawdown[12]. Integrating *in situ* and *ex situ* carbon-negative mineral reactions processes in the mining industry has begun to gain favor for its high potential for commercialization[13]. Pursuing net-zero pathways for mining, such as a green grid and (or) electrification alone, do not attain carbon neutrality. The implication is that mineralizing CO_2 within CO_2-reactive mineral assemblages will be required for achieving an additional 50% carbon reduction for a true path towards net-zero, as shown in Figure 3[14]. Common mafic-ultramafic CO_2-reactive deposit types include magmatic sulfide deposits (i.e., layered mafic intrusions), volcanogenic massive sulfide deposits, and komatiite-hosted sulfide deposits. The high potential for commercialization within these deposit types is due to four benefits of carbonating the CO_2-reactive gangue mineralogy: (1) decreasing comminution by transforming CO_2-reactive mineralogy into softer carbonates; (2) increasing energy-relevant metal yield; (3) extending mine life; and (4) increasing the number of potential deposits.

In natural systems, the carbonation of mafic-ultramafic rock by atmospheric CO_2 drawdown operates within geologic time scales (>1 My)[15]. Anthropogenic *in situ* pilot-scale CO_2 injections into mafic-ultramafic rock demonstrate that 60-95% CO_2 mineralization occurs in approximately two years (e.g., the Carbfix pilot project in Iceland)[16,17]. In these studies, cores were taken at the end of the study to observe reaction textures, but the reaction may have taken far less time to take place. However, research has also shown accelerating carbonation kinetics down to hours is possible. Pre-treatment mechanisms that increase carbonation kinetics aim to modify the crystal lattice of Ca/Mg-silicates or decrease the particle size to increase the reactive surface area[18] (e.g., thermal activation, chemical activation, and mechanical activation). Mechanistic insights into mafic-ultramafic carbonation further show carbonation kinetics can be accelerated

[10] Koppelaar & Koppelaar *Biophysical Economics and Resource Quality* 1 (2), **2016**, 1-16
[11] Northey et al *Resources, Conservation and Recycling* 83, **2014**, 190-201
[12] Jagoutz et al. *Proceedings of the National Academy of Sciences* 113 (8), **2016**, 4935-4940
[13] Li et al., *Minerals* 8 (4), **2018**, 147
[14] Low-Carbon_Metals_for_a_Low-Carbon_World.pdf (rmi.org)
[15] Frondini et al. *Geosciences* 9 (6), **2019**, 258
[16] White et al. *Environmental Science & Technology* 54 (22), **2020**, 14609-14616
[17] Stute et al. *Science* 352 (6291), **2016**, 1312-1314
[18] Li et al. *Minerals* 8 (4) **2018**, 147

by increasing ionic strength in $CO_{2\ (aq)}$ solution[19,20], increasing temperature[21], and increase P_{CO2}[22].

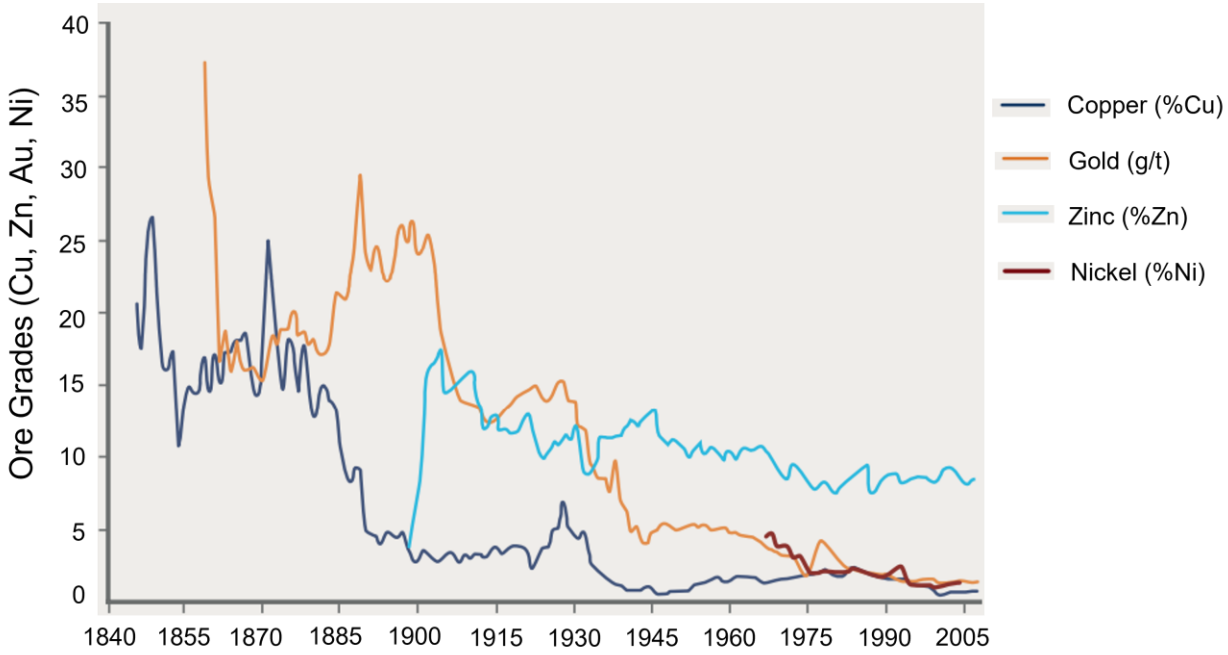

Figure 2: Grades of copper, gold, zinc, and nickel ore mined are decreasing over time[23].

Research shows that carbonated CO_2-reactive mineralogy can increase the yield of energy-relevant minerals. CO_2-reactive mineralogy is common and is a major constituent of mafic-ultramafic ore bodies. Typical CO_2-reactive mineralogy (e.g., gangue minerals) includes olivine, serpentine, brucite, chrysotile, pyroxene, feldspar, and amphibole. The CO_2-reactive mineralogy is of interest for its potential to concurrently leach energy-relevant minerals during carbonation, decrease comminution energy, and increase energy-relevant mineral yield[24,25]. Forsterite endmember olivine is a ubiquitous CO_2-reactive mineral, with published examples containing 23 kg of energy-relevant minerals per metric ton, of which nickel and cobalt comprise 7 kg and 0.6 kg, respectively[26]. Carbonation can also benefit possible REE-bearing minerals such as amphibole. Magmatic amphibole can contain up to 0.16 wt% of all REEs from REE-rich peralkaline intrusions[27]. Current research has shown approximately 80% of nickel within olivine can be leached and re-mineralized[28]. CO_2-reactive minerals themselves are an

[19] Wang et al. *Minerals Engineering* 131, **2019**, 185-197
[20] Gadikota et al. *Physical Chemistry Chemical Physics* 16 (10), **2014**, 4679-4693
[21] Miller et al. *Environmental Science & Technology Letters* 6(8,) **2019**, 431-442
[22] Kwon et al. *Journal of Environmental Sciences* 23 (8), **2011**, 1233-1239
[23] Low-Carbon_Metals_for_a_Low-Carbon_World.pdf (rmi.org)
[24] Santos et al. *Metals* 5 (3), **2015**, 1620-1644
[25] Wang et al. *Chemical Engineering Journal* 406, **2021**, 126761
[26] Stopic et al. *Metals* 8, 2018, 993
[27] Siegel et al. *Lithos* 288, **2017**, 156-174
[28] Wang et al. *Chemical Engineering Journal* 406, **2021**, 126761

untapped potential for energy-relevant minerals. For example, layered mafic intrusions can contain greater than 1700 Mt of ore[29]. Although energy-relevant mineral yield from CO_2-reactive minerals is less than that of conventional minerals, leaching energy-relevant minerals from the gigatons of feedstock available would result in substantial metal yield.

The transfer of the hydrometallurgical processing of minerals to the subsurface to directly obtain metal-bearing solutions may be an intrinsic evolution in hard rock mining. First employed in 1959 in the USA, unconventional *in situ* mining methods have gained favor for possibly decreasing the cost of production[30]. *In situ* methods historically have been most considered for coal[31] and uranium[32] mining. Typical *in situ* methods utilize production wells to recover ore-dissolving leaching solutions pumped into mineralized zones. Extreme complexities in *in situ* ore recovery from low-permeability and high pressure-temperatures hard rock reservoir conditions define the technical challenges for successful recovery of metal-bearing solutions[33]. Uranium mining is the most common method to employ *in situ* mining methods. However, pilot tests have been conducted for copper[34] (e.g., San Manuel copper mine, Arizona USA) gold, vanadium, nickel, and rare earth elements[35]. Production at the San Manuel copper mine reached 11,000 t Cu/yr[36] showing promise for unconventional hard rock mining methods.

[29] Zientek et al. USGS scientific Investigations Report, **2014**
[30] Seredkin et al. *Ore Geology Reviews*, 79, **2016**, 500 - 514
[31] Xie et al. *Journal of China Coal Society*, 43 (5), **2018**, 1210 - 1219
[32] Mudd *Environmental Geology* 41 (3), **2001**, 390 - 403
[33] Liang et al. *Advances in Geo-Energy Research* 5 (1), **2021**, 1-4
[34] O'Gorman et al. Little Bear Laboratories, Inc, **2004**
[35] Seredkin et al. *Ore Geology Reviews,* 79, **2016**, 500 - 514
[36] Briggs *Arizona Geological Survey Contributed Report*, **2014**

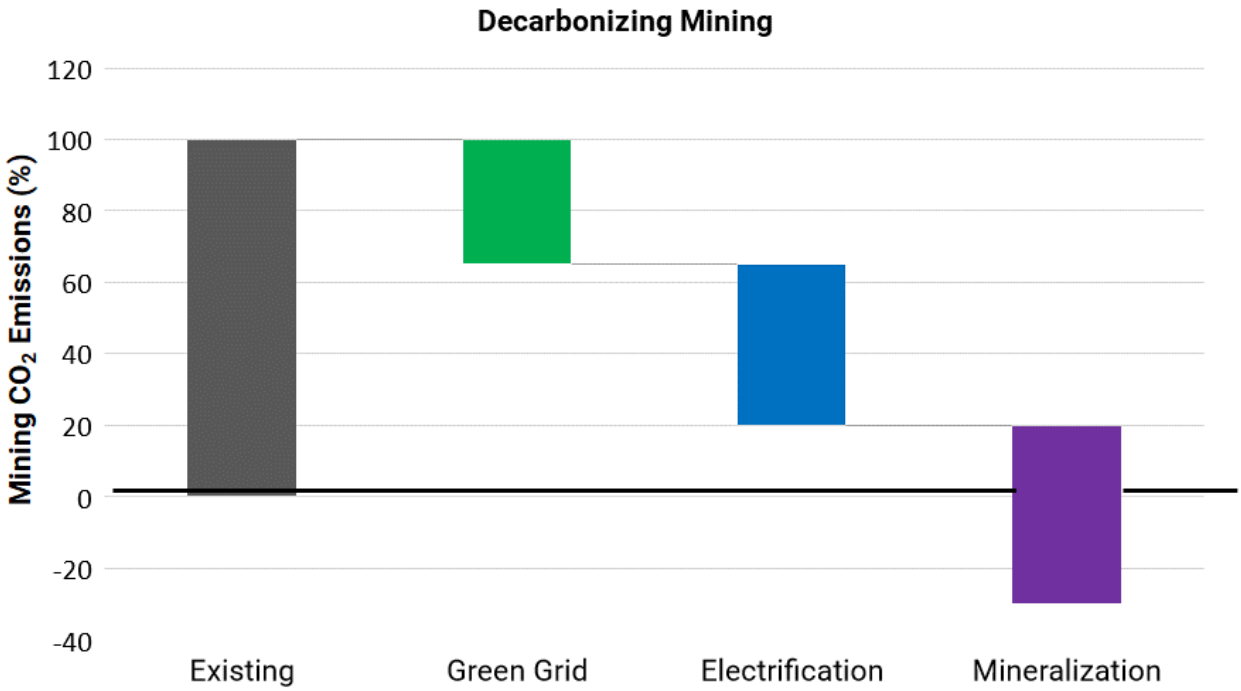

Figure 3: Mineral carbonation can reduce CO_2 emissions by an estimated 50%[37]. Combined with electrification and the greening of electrical sources, it is expected that CO_2 mineralization can enable mining to become a net-negative industry.

G. TECHNICAL CATEGORIES OF INTEREST / PROGRAM STRUCTURE

This FOA identifies four (4) MINER Program categories (1, 2, 3 and 4) to provide commercial-ready technologies that give the United States an increased domestic supply of copper, nickel, lithium, cobalt, rare earth elements, and other elements required for the energy transition. The MINER program anticipates the development of technologies for the following technical categories to conduct either an *in situ* and (or) *ex situ* real-world test. ARPA-E must emphasize that during development of the technologies from technical Categories 1 to 4, the defined requirements outlined in Sections I.G, I.H, and I.I remain (e.g., negative emissions, current comminution processes, etc.).

Given the technical challenges for a real-world test, MINER anticipates field characterization and planning by geophysicists, geologists, mine engineers, drilling engineers, and other relevant disciplines to characterize subsurface and surface geology. Consequently, successful MINER applicants may possess competencies for a real-world test in:

- Geochemical, mineralogical, structural, and petrological heterogeneity within CO_2-reactive ore bodies;
- Physico-chemical changes and alteration mineralogy during rock carbonation;

[37] https://rmi.org/wp-content/uploads/2018/08/RMI_Decarbonization_Pathways_for_Mines_2018.pdf

- The ability to provide proper reservoir characterization to optimize rock carbonation and energy-relevant minerals capture from CO_2-reactive minerals;
- Reservoir fluid dynamics to mitigate injection fluid loss and maximize recovery of possible production fluids;
- Operating and maintaining a drilling and injection site to perform successful rock carbonation and recovery of carbonated samples.

Submissions to MINER can address a single program category or combinations thereof. The program categories are as follows:

I. CATEGORY 1 — MINERAL COMMINUTION ENERGY REDUCTION

Comminution energy remains one of the most energy-intensive industrial sectors. The mining industry faces an increased cost of mineral beneficiation and reduced investment return by conventional mining methods. Developing novel technologies to minimize comminution energy can provide significant energy- and cost-reducing advantages to a mining operation. Cost-reducing advantages in addition to reduced energy during mineral comminution include reduced waste rock and reducing unrecovered energy-relevant minerals in the tailings compared to state-of-the-art during beneficiation. Alternative and more efficient extraction methods may also reduce the need to grind minerals to current state-of-the-art levels.

The objective of Category 1 is to develop cost-reducing technologies to significantly decrease comminution energy and reduce unrecovered energy-relevant minerals in the tailings from mineral beneficiation. The technology must accomplish this objective by changing the mineral properties of the CO_2-reactive ore to utilize preexisting mineral beneficiation processes. Methods may include modifying mineral properties by incorporating biology-based solutions, carbonation of ore, and (or) other methods. The methods may decrease comminution by decreasing hardness, particle size, and (or) producing crystallographic weaknesses. These methods may be employed before (*in situ*) and (or) concurrently to comminution (*ex situ*).

Applicants should be aware that Categories 2 and 3 may also focus on comminution-related technologies. Section I.H specifies the kinetics of the reaction must occur on a time-limited scale. The time-limited scale for *in situ* is constrained to months or less, and for *ex situ* is days or less. Such restricted time-limited scales allow for proper integration into upstream and downstream mining operations. Category 1 applicants may possess potential mineral beneficiation processes, carbonate chemistry, and carbonate mineralogy proficiencies.

II. CATEGORY 2 — IMPROVEMENTS IN ENERGY RELEVANT MINERAL YIELD FROM CO2-REACTIVE MINERALS

The mining industry faces a rapid decrease in ore grades and increased expenses managing the accumulation of waste rock. A solution to increase energy-relevant mineral yield and decrease

waste rock is to leach energy-relevant minerals within overburden, gangue mineralogy, and tailings.

The objective of Category 2 is to develop technologies to capture energy-relevant minerals from CO_2-reactive ore. The technology must accomplish this objective by not negatively impacting the yield from conventional minerals (e.g., oxides and sulfides). For example, carbonating gangue minerals must not negatively affect the mineralogically associated conventional minerals (e.g., oxides and sulfides). Other requirements are to avoid decarbonation of CO_2-reactive gangue mineralogy, overburden, and tailings during mineral beneficiation. Recapture of CO_2 is required if ore undergoes decarbonization. Methods proposed may include biology-based solutions, ore carbonation, and (or) other methods. The method may be employed before (*in situ*) or concurrently with mineral beneficiation (*ex situ*). Although MINER is open to *in situ* and *ex situ* approaches for Category 2, the MINER program seeks concurrent *in situ* energy-relevant mineral leaching and re-mineralization approaches.

Applicants should be aware that Categories 1 and 3 technologies may also focus on improving the yield of energy-relevant minerals. Section I.H specifies the kinetics of the reaction must occur on a time-limited scale. The time-limited scale for *in situ* is constrained to months or less, and for *ex situ* is days or less. Such restricted time-limited scales allow for proper integration into upstream and downstream mining operations. Category 2 applicants may possess potential metallurgy, mafic-ultramafic petrology, carbonate chemistry, carbonate mineralogy, and (or) catalysis proficiencies.

III. CATEGORY 3 — CARBON-NEGATIVE EMISSIONS REACTIONS

The MINER program aims to produce negative emissions mining technologies. Past investigations have identified potential carbon capture pathways in the mining industry. However, there remains a lack of knowledge and proofs-of-concept to achieve carbon-negative mining operations.

The objective of Category 3 is to develop technologies to achieve carbon-negative mining operations, and the technology must accomplish this objective by developing carbon-negative reactions within CO_2-reactive ore to produce carbon-negative mining processes on a cradle-to-gate (more-to-metal) basis. Any method, including biological means, may be used. Carbon negative reactions may be employed *in situ* within the subsurface, *ex situ* during excavation, and (or) *ex situ* post-excavation.

Applicants should be aware Categories 1 and 2 may also focus on carbon capture-related technologies. Section I.H specifies the kinetics of the reaction must occur on a time-limited scale. The time-limited scale for *in situ* is constrained to months or less, and for *ex situ* is days or less. Such restricted time-limited scales allow for proper integration into upstream and

downstream mining operations. Methods to increase kinetics may include pre-treatment mechanisms and modifying intensive and extensive variables.

MINER anticipates laboratory experiments, numerical modeling, and characterization of physico-chemical changes during carbonation, given the diverse composition of CO_2-reactive ore bodies. Category 3 applicants may possess potential CO_2 sequestration, mafic-ultramafic petrology, petrophysics, carbonate chemistry, and (or) catalysis proficiencies.

IV. CATEGORY 4 — SENSING, ANALYZING AND ENABLING CARBONATION POTENTIAL AND MINERALIZATION

Another challenge of this program is the ability to perform sensing and analysis of carbonation potential and mineralization of CO_2-reactive ore bodies. Even after mature carbon capture technology is available, locating dependable, safe, and long-term storage within CO_2-reactive ore bodies will remain. Underground sensing and analysis of CO_2-reactive ore bodies will play a future role in estimating storage capacities, approval of geologic sites, determining leakage risk, and (or) possibly awarding future carbon credits. The MINER program also aims to develop sensing and analyzing technologies for mining operations in CO_2-reactive ore bodies. Traditionally mined CO_2-reactive ore bodies also contain conventional minerals, such as sulfides and oxides. Therefore, MINER also seeks to integrate pre-existing and future data such as geochemical (e.g., whole-rock, mineral microanalyses), geophysical (e.g., seismic, resistivity), and geostatistical data to create models to improve current and future exploration, mine planning, and mine operation efficiency for mining in CO_2-reactive ore bodies.

The objective of Category 4 is to develop technology-specific methods for conducting geophysical, geochemical, and (or) geostatistical surveys for sensing and analyzing carbonation mineralization potential. The objective may be accomplished *in situ* within the subsurface *or ex situ* once the ore is excavated. MINER expects validation of any proposed models and methods. For example, validating a model could be done by comparison to core. Category 4 applicants may possess potential geophysical, geochemical, and geostatistical modeling of ore bodies proficiencies.

H. TECHNICAL PERFORMANCE TARGETS

Submissions to MINER can address a single program category or combinations thereof. If a submission applies to more than one category, only a single four-page technical narrative is required. However, applicants must complete a separate one-page question-and-answer table for each Category their submission applies to. The table(s) are provided for each category in this FOA below. For example, if an Applicant would like their submission to be considered for Categories 1, 2 and 3, a single four-page technical narrative would be required, along with information in response to three separate one-page question-and-answer tables. The information in response to the question-and-answer tables do not count towards the page limit

on the technical narrative, but any text beyond 4 pages for technical narrative or 1 page per table response will exceed the respective pages limits and be redacted in the review process.

Applicants proposing the development of technologies for Categories 1 to 3 offered under this funding opportunity must meet the following criteria:

a. Contribute to attaining net-zero or negative GHG emissions for the entire mining operation

b. Water and land use must be equivalent to or better than state-of-the-art

c. Pay for themselves through energy savings and (or) yield increases (with no application of carbon/emissions credits)

d. Demonstrate recycling, repurposing, and (or) proper long-term storage potential of waste material(s)

Applicants to all Categories (1 through 4) must provide an overview description of their proposed technology that includes details of:

a. Integrating the technology into preexisting mining operations

b. Maintaining upstream to downstream operational efficiency, i.e., the new technology cannot reduce mine operation and mineral beneficiation efficiency relative to the state-of-the-art

c. The current stage of development for the proposed technology, such as full-scale prototype production, technology availability, and scalability

d. The type(s) of feedstock(s) that will be processed, along with the availability and scalability

e. Include information to substantiate commercial readiness of selected technology

f. Overcoming current technical challenges for the proposed method(s)

g. Impact to current mining operations, future operations, and energy-relevant mineral supply

h. A comparison of the proposed technology's cost and performance to state-of-the-art

During the program, a demonstration of negative emissions carbon mining operations through LCA[38] on a cradle-to-gate (ore-to-metal) basis will be required. However, for this application phase, a discussion of only the expected technological contribution towards a path to net-zero mining operations is required. An estimation of economic viability through an initial system level technoeconomic analysis (TEA) for the proposed technology is also expected in the application. In addition to the requirements mentioned above, the FOA expects requirements for the proposed methods and technologies for each category previously discussed in Section I.G.

The chosen metrics for the MINER program meet the United States' need for net-zero commercial-ready technologies that provide energy-relevant minerals for economic and national security. The targets proposed in Section I.H evolve from current state-of-the-art levels. Section I.H details the necessary application questions/answers summary form and metrics. Section I.I outlines the TEA, and Section I.J outlines the LCA requirements.

I. CATEGORY 1— MINERAL COMMINUTION TECHNICAL TARGETS AND REPORTING

Table 1: Category 1— Mineral Comminution Technical Targets

Description	Target
Grinding energy decrease	50% reduction in comminution energy relative to an existing state-of-the art process
Grinding energy decrease efficacy (rate)	Demonstrate on a minimum of 100 kg processed @10+ kg/hr
Increase of energy-relevant mineral yield during comminution	50% decrease of unrecovered energy-relevant minerals yield in tailings from comminution relative to an existing state-of-the art process
Increase of energy-relevant mineral lost during comminution efficacy (rate)	Process ore @10+ kg/hr meeting 50% decrease of unrecovered energy-relevant minerals yield in tailings from comminution relative to an existing state-of-the art process

Table 1 shows the technical targets to guide Applicant's responses through Category 1. Applicants proposing breakthrough technologies to modify mineral properties of CO_2-reactive ore to decrease comminution energy and increase energy-relevant mineral yield should respond to the question-and-answer section in Table 2. The purpose of Table 2 is to guide Applicant's responses of how their innovation will accomplish the following:

a. Modifying CO_2-reactive ore's mineral properties to decrease comminution energy for mineral beneficiation

[38] LCAs will need to be done per ISO 14000 series and environmental impact determined using TRACI during the course of the program

b. Modifying CO_2-reactive ore's mineral properties to decrease unrecovered energy-relevant minerals yield in tailings compared to state-of-the-art

c. Incorporating this new technology to use preexisting beneficiation processes

d. Must not increase cradle-to-gate emissions

e. Efficiency and kinetics operate within a reasonable timeframe[39]

f. How CO_2 will be recaptured if decarbonization of the ore occurs

g. Possibly reduce the need to grind minerals to current state-of-the-art levels

h. Employing the method *in situ* and (or) *ex situ*

Table 2: Category 1 - Mineral Comminution Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. How will the mineral properties of the ore be modified to decrease grinding comminution energy and decrease unrecovered energy-relevant mineral yield in tailings? Please report any quantities in MJ/kg of ore, or by percent increase compared to state-of-the-art.	
Q3. How will the proposed technology be utilized for preexisting mineral beneficiation processes? For example, *in situ* and (or) *ex situ*? How will the process differ from conventional mineral beneficiation?	
Q4. Will this proposed technology decrease cradle-to-gate emissions? If CO_2 is released, how will CO_2 be recaptured?	

[39] "reasonable timeframe": For *in situ*, reactions should be in months or less to allow for smooth integration into mine operations. For *ex situ*, reactions should be in days or less to allow for smooth integration into mine operations.

Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in kg/hr of ore, or by percent decrease or increase compared to the state-of-the-art.	
Q6. If Applicant chooses to develop technologies for other Categories from 2, 3 and 4, will this proposed technology negatively or positively impact energy-relevant mineral yield from CO_2-reactive minerals (Category 2) and (or) ability to undergo carbonation reactions (Category 3)? Do you anticipate the proposed technology to operate concurrently with technologies developed from Categories 2, 3 and 4?	

II. CATEGORY 2 — CO2-REACTIVE MINERAL YIELD TECHNICAL TARGETS AND REPORTING

Table 3: Category 2 — CO_2-reactive Mineral Yield Technical Targets

Description	Target
CO_2-reactive mineral yield	80% recovery of energy-relevant minerals relative to bulk rock composition of energy-relevant minerals within the CO_2-reactive mineral assemblage and (or) monomineralic assemblage (see background section for recovery amount review)
CO_2-reactive mineral yield efficacy (rate)	@1+ kg/hr meeting 80 % recovery of energy-relevant minerals relative to bulk rock composition of energy-relevant within the CO_2-reactive mineral assemblage and (or) monomineralic assemblage
Increase CO_2-reactive ore permeability	Demonstrate a percent increase in net permeability and porosity. If permeability is measured report in k (m^2)

Table 3 shows the technical targets to guide Applicant's responses through Category 2. Applicants proposing breakthrough technologies that improve the yield of energy-relevant minerals from CO_2-reactive minerals should respond to the question-and-answer section in Table 4. The purpose of Table 4 is to guide Applicant's responses of how their innovation will accomplish the following:

a. Employing this technology will not negatively impact the yield of energy-relevant minerals from possible mineralogically associated conventional minerals (e.g., sulfides and oxides)

b. Employing this technology will not decarbonate the ore

c. Recapture of CO_2 if decarbonation of the ore occurs

d. Efficiency and kinetics operate within a reasonable timeframe[40]

e. Increase CO_2-reactive ore rock permeability and porosity

f. Employing the method *in situ* and (or) *ex situ*

Table 4: Category 2 — CO_2-reactive Mineral Yield Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. Will this proposed technology decrease cradle-to-gate emissions? If CO2 is released, how will CO_2 be recaptured?	
Q3. Can this proposed technology be utilized with existing mineral beneficiation processes? Will mineral beneficiation processes have to be changed to accommodate this technology? When will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q4. What proportion of energy-relevant minerals do you anticipate recovering? Please base your response on total energy-relevant minerals within a bulk rock composition of a specified CO_2-reactive mineral assemblage and (or) monomineralic assemblage. Please respond in Kg and percent recovery relative to the bulk composition.	

[40] "reasonable timeframe": For *in situ*, reactions should be in months or less to allow for smooth integration into mine operations. For *ex situ*, reactions should be in days or less to allow for smooth integration into mine operations.

Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in kg/hr of energy-relevant minerals, or by percent decrease or increase compared to the state-of-the-art.	
Q6. What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
Q7. If Applicant chooses to develop technologies from other Categories from 1, 3 and 4, will this proposed technology positively or negatively impact mineral beneficiation (Category 1) and (or) carbonation (Category 3)? Do you anticipate the proposed technology to operate concurrently with technologies to be developed from Categories 1, 2, and 4?	

III. CATEGORY 3 — CARBON NEGATIVE REACTIONS TECHNICAL TARGETS AND REPORTING

Table 5: Category 3 — Carbon Negative Reactions Technical Targets

Description	Target
Carbon negative reactions	Achieve -10 wt.% CO_2e/metric ton of ore processed compared to existing state-of-the-art (Demonstrate based on 100 kg CO_2e captured on a cradle-to-gate or ore-to-mineral basis)
Carbonation efficacy (rate)	*in situ* is constrained to months or less, and for *ex situ* is days or less
Increase CO_2-reactive ore rock porosity and permeability	Demonstrate a percent increase in net permeability and porosity.

Table 5 shows the technical targets to guide Applicant's responses through Category 3. Applicants proposing breakthrough for carbon-negative mining operations should respond to the question-and-answer section in Table 6. The purpose of Table 6 is to guide Applicant's responses of how their innovation will accomplish the following:

a. Technology will provide carbon-negative mining processes on a cradle-to-gate (ore-to-metal) basis

b. Employment of this technology will not adversely affect energy-relevant mineral yield from conventional minerals nor yield of energy-relevant minerals from CO_2-reactive minerals if Category 2 is pursued

c. Efficiency and kinetics operate within a reasonable timeframe[41]

d. Increase CO_2-reactive ore rock porosity and permeability

e. Employing the method *in situ* and (or) *ex situ*

Table 6: Category 3 — Carbon Negative Reactions Applicant Question And Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. Specify a method of carbonation measurement?	
Q3. Where will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q4. What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in wt.% CO_2e/metric ton of ore, and by percent increase of carbon mineralization compared to the state-of-the-art.	
Q6. If Applicant chooses to develop technologies for other Categories from 1, 2 and 4, will this proposed technology positively or negatively impact mineral beneficiation (Category 1) and (or) energy-relevant mineral yield from CO_2-reactive ore (Category 2)? Do you anticipate the proposed technology to	

[41] "reasonable timeframe": For *in situ*, reactions should be in months or less to allow for smooth integration into mine operations. For *ex situ*, reactions should be in days or less to allow for smooth integration into mine operations.

operate concurrently with technologies developed from Categories 1, 2, and 4?	

IV. CATEGORY 4 — SENSING AND ANALYZING CARBONATION POTENTIAL AND MINERALIZATION TARGETS AND REPORTING

Table 7: Category 4 — Sensing and Analyzing Carbonation Potential and Mineralization Technical Targets

Description	Target
Exploratory vectors of CO_2-reactive rock formations	Develop exploratory vectors to locate CO_2-reactive rock formations
Measuring and modeling CO_2-rock interaction at subsurface depths	Characterize and model CO_2-Rock interaction >900m with low uncertainty
Predict and quantify rock carbonation	±10% relative to a method to validate model (e.g, comparison to core)
Quantify energy-relevant minerals leached and re-mineralized from carbonated CO_2-reactive minerals	
Predict comminution behavior prior to mineral beneficiation	
Estimate energy-relevant mineral ore grade that includes conventional minerals and CO_2-reactive minerals	
Model CO_2 reservoir leakage and storage potential	
Utilize geochemical and petrophysical properties determined from core and (or) other data into modeling	Applicant to define and justify target

Table 7 shows the technical targets to guide Applicants' responses through Category 4 for their application. Applicants proposing breakthrough geophysical, geochemical, and (or) geostatistical based technologies to perform sensing and analysis of carbonation potential and mineralization of CO_2-reactive ore bodies should respond to the question-and-answer section in Table 8. Which questions are answered in Table 8 are at the discretion of the Applicant. The purpose of Table 8 is to guide Applicant's responses of how their innovation will accomplish a combination of some items selected from the following:

a. Methods to produce models that develop exploratory vectors of CO_2-reactive rock formations

b. Methods and technologies for measuring and modeling CO_2-rock interaction at subsurface depths (*in situ*)

c. Methods to predict and quantify rock carbonation

d. Methods and technologies to quantify energy-relevant minerals leached and re-mineralized from carbonated CO_2-reactive minerals

e. Methods to predict comminution behavior before mineral beneficiation when mineral properties are modified by Category 1

f. Methods to estimate energy-relevant mineral ore grade that includes conventional minerals and CO_2-reactive minerals

g. Methods to employ geochemical and petrophysical properties determined from core and (or) other field data into modeling

h. Employing the method *in situ* and (or) *ex situ*

i. Determining CO_2 leakage and storage potential of the reservoir

j. Other relevant accomplishments of the applicant's proposed technology

Table 8: Category 4 — Sensing and Analyzing Carbonation Potential and Mineralization Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. When will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q3. Do you anticipate the proposed technology to operate before and (or) concurrently with technologies to be developed from Categories 1 to 3? How will technologies developed from Category 4 positively impact technologies to be developed from Categories 1 to 3?	
Q4. How will the proposed model(s) be validated?	
Q5. How can the proposed technology developed from Category 4 be integrated into existing mine operations?	

Q6. How can the proposed technology developed from Category 4 be integrated into exploration of CO_2-reactive ore bodies?	
Q7. How will carbonation be estimated and (or) quantified after carbon mineralization?	
Q8. How will energy-relevant minerals leached and re-mineralized from carbonated CO_2-reactive minerals be estimated and (or) quantified?	
Q9. How will comminution energy decrease or increase be estimated and (or) quantified *in situ* or *ex situ* when mineral properties are modified by processes such as Category 1?	
Q10. How will methods be developed to estimate energy-relevant mineral ore grade that includes conventional minerals and CO_2-reactive minerals either *in situ* and (or) *ex situ*?	
Q11. Will these methods be able to employ preexisting petrological based data and (or) petrophysical data determined from, for example core, and (or) other methods into modeling? If so, please describe how pre-existing data can be used to create models for sensing and analyzing carbonation potential and mineralization?	
Q12. Will a method be developed to determine CO_2 reservoir leakage and storage capability?	
Q13. Other relevant accomplishments of the applicant's proposed technology?	

I. TECHNOECONOMIC ANALYSIS REQUIREMENTS

Submissions should include details such as process information and data to support the technology readiness level of the overall process, the unit operations within the process, and the original application. Proposed technical metrics and milestones should be based on preliminary data, where available, and represent a meaningful baseline and set of targets.

A preliminary technoeconomic analysis (TEA) should be provided and will be used to assess viability of the proposed technology. Submissions without the requested information may be excluded from review. Additionally, certain provided information or data about proposed technology may be used as a basis for review and discussion during an initial verification post award and may be used as the project's baseline. The analysis should be bracketed to consider

a base case, representing the current state-of-the-art, and a research case, representing the applicant's proposed research technology. A description and discussion of the analysis should detail the technology benefit of the proposed research case. Details that should be included in the TEA are outlined below. Additional details that are required to be used in the preliminary TEA are also detailed below. As expected in preliminary evaluations of this nature, there are significant uncertainties associated with the results obtained. Applicants should provide a brief description of no less than 3 major assumptions used in the preliminary TEA, along with the nature of the uncertainty.

Details to Include in Preliminary TEA:

Base case

- Simple diagram to which the proposed research is to be applied
- Brief description of the relevant current state and/or condition of the base case, detailing any known yields, compositions, assay, recovery, products, co-products, and (or) economic values

Research case

- Simple diagram demonstrating research applied to base case, highlighting the change or innovation from base case
- Brief description of the functional or material change from base case

Benefit Analysis and Discussion

Technoeconomic analysis with a brief description of the analysis and subsequent benefits of the research case when compared to the base case. Proposed benefits may be classified into one or more of the categories below (Table 9), and can be described accordingly:

Table 9: Technoeconomic Analysis Benefit Categories

Benefit Category (if applicable)	Response Prompts
Revenue	If the technology improves revenue: Identify and describe the method and subsequent improvement to energy-relevant mineral recovery/yield, e.g., changes in concentrate leading to increased metal revenue recognition
Operating Cost	If the technology reduces operating cost: Identify and describe the method and subsequent improvement in operating cost from base case, e.g., reduction in mechanical grinding energy use translated

Other	Combination of revenue improvement and (or) operating cost and/or other benefit for utilization of CO_2 mineralization for energy-relevant mineral recovery

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $44 million available for new awards under this FOA, to be shared between FOAs DE-FOA-0002707 and DE-FOA-0002708, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-15 total awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

ARPA-E will accept only new applications under this FOA. Applicants may not seek renewal or supplementation of their existing awards through this FOA.

ARPA-E plans to fully fund negotiated budgets at the time of award.

Applicants must apply for a Combined Phase I/II/IIS award. Combined Phase 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 $3,952,638. Funding amounts will be consistent with the Phase I and Phase II limits posted on the SBA's website.[42]

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 $275,766 and the maximum amount for a Phase I/II award is $2,114,202.

The period of performance for funding agreements may not exceed 36 months for a Combined Phase I/II/IIS Award. ARPA-E expects the start date for funding agreements to be January 2023, or as negotiated.

B. RENEWAL AWARDS

At ARPA-E's sole discretion, awards resulting from this FOA 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

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

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.

C. ARPA-E 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.

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."[43] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

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 Prime Recipients 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 Prime Recipients to review the Model Cooperative Agreement, which is available at https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements.

D. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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.

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

- 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 Prime 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 Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting 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 and 200.340.
- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits[44] to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment 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 deployment of ARPA-E-funded technologies.

[44] The term "nonprofit organization" or "nonprofit" is defined in Section IX.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. SBIR ELIGIBILITY

SBA rules and guidelines govern eligibility to apply to this FOA. 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/about.

A Small Business Concern[45] may apply as a Standalone Applicant[46] or as the lead organization for a Project Team.[47] 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.[48]

For information on eligibility as a Small Business Concern, please refer to SBA's website (https://www.sba.gov/content/am-i-small-business-concern).

2. STTR ELIGIBILITY

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

Only a Small Business Concern may apply as the lead organization for a Project Team. 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

[45] A Small Business Concern is a for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture. Small Business Concerns that are majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms are eligible to apply to this FOA.

[46] A "Standalone Applicant" is an Applicant that applies for funding on its own, not as part of a Project Team.

[47] The term "Project Team" is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

[48] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

Cost. Please refer to Section III.B.1 of the FOA for guidance on Research Institutions' participation in STTR projects.

For information on eligibility as a Small Business Concern, please refer to SBA's website (https://www.sba.gov/content/am-i-small-business-concern).

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;
- 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[49] 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, including Small Business Concerns

[49] 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.

- Nonprofits other than Research Institutions[50]
- Government-Owned, Government Operated laboratories (GOGOs)
- State, local, and tribal government entities
- Foreign entities[51]

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.

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.

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 Contracting 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 Contracting 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.

[50] 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.

[51] All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (see Section IV.G.6 of the FOA). However, the Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form submitted with the Full Application.

D. 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:

- 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[52] 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.**

[52] 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 Program Policy Directive" at https://www.sbir.gov/sites/default/files/SBIR-STTR_Policy_Directive_2019.pdf.

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 FOA for the following year. For example, if SBA determined on June 1, 2017 that a small business failed to meet the Phase II Transition Rate Benchmark requirement, that small business would not be eligible to apply to an ARPA-E SBIR/STTR FOA from June 1, 2017 to May 31, 2018.

E. COST SHARING

Cost sharing is not required for this FOA.

F. OTHER ELIGIBILITY REQUIREMENTS

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III of the FOA;
- The Concept Paper complies with the content and form requirements in Section IV.C of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Concept Papers found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Concept Papers, including Concept Papers submitted through other means, Concept Papers submitted after the applicable deadline, and incomplete Concept Papers. A Concept Paper is incomplete if it does not include required information. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Full Applications are deemed compliant if:

- The Applicant submitted a compliant and responsive Concept Paper;

- The Applicant meets the eligibility requirements in Section III of the FOA;
- The Full Application complies with the content and form requirements in Section IV.D of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

Full Applications found to be noncompliant may not be merit reviewed or considered for award. ARPA-E may not review or consider noncompliant Full Applications, including Full Applications submitted through other means, Full Applications submitted after the applicable deadline, and incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA; and
- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information due to server/connection congestion. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

2. RESPONSIVENESS CRITERIA

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 fail to include responses in at least one of the Tables provided above outlining target metrics in technical categories. Submissions should include information responding to the questions in the tables for all applicable Categories.
- Submissions that do not include a base case TEA.
- Category 4 submissions that do not show applicability to ongoing mining operations.
- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to currently issued ARPA-E FOAs.

- Submissions that are not scientifically distinct from applications submitted in response to currently issued ARPA-E FOAs.
- 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 FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. 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.A of the FOA.
- Submissions that do not propose a Combined Phase I/II or I/II/IIS Award, as described in Section II.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Technologies or processes that do not advance a net zero carbon process on an LCA cradle-to-gate (ore-to-metal) basis.
- Proposals of processes that release carbon or increase net emissions at some point in the mining process.
- Technologies that do not involve and consider a mining process for energy-relevant minerals.
- Submissions involving the recovery of metals from the recovery of metals from electronic waste.
- Submissions based on extraction of or from fossil hydrocarbons.
- Proposals that rely on the development or use of carbon offsets not directly linked to energy mineral production.

Applicants are encouraged to consult Section I.G of this FOA (Funding Opportunity Description) for additional guidance regarding of topics within scope of interest.

4. 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 FOA, provided that each application is scientifically distinct.

However, small businesses that qualify as a "Small Business Concern" may apply to only one of the two ARPA-E MINER FOAs: ARPA-E FOA DE-FOA-0002708 (SBIR/STTR), Mining Innovations For Negative Emissions Resource Recovery (MINER SBIR/STTR), or ARPA-E FOA DE-FOA-0002707, Mining Innovations For Negative Emissions Resource Recovery (MINER). Small businesses that qualify as "Small Business Concerns" are strongly encouraged to apply under the former (SBIR/STTR FOA). To determine eligibility as a "Small Business Concern" under DE-FOA-0002708, please review the eligibility requirements in Sections III.A – III.D above.

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN SBA COMPANY REGISTRY

Applicants must register with the U.S. Small Business Administration (SBA) Company Registry (http://sbir.gov/registration). Upon completing registration, Applicants will receive a unique small business Control ID and Registration Certificate in Adobe PDF format, which may be used at any participating SBIR and STTR agencies. Applicants that have previously registered in the SBA Company Registry need not register again.

Applicants that are sole proprietors and do not have an Employer Identification Number may use social security numbers for purposes of registering in the SBA Company Registry. Applicants that do not possess a Dun and Bradstreet Data Universal Numbering System (DUNS) number may also use their social security number in the SBA Company Registry.

Applicants must submit their Registration Certificate in ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov) as part of their Full Application (see Section IV.D.6 of the FOA).

2. REGISTRATION IN ARPA-E eXCHANGE

Applicants must register in ARPA-E eXCHANGE, ARPA-E's online application portal. For detailed guidance on using ARPA-E eXCHANGE, please refer to Section IV.H.1 of the FOA and the "ARPA-E eXCHANGE User Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

3. CONCEPT PAPERS

Applicants must submit a Concept Paper by the deadline stated in the FOA. Section IV.C of the FOA provides instructions on submitting a Concept Paper.

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.G of the FOA. Concept Papers 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 Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.1 of the FOA.

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. 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. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

4. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 45 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.G of the FOA. 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.A.2 and V.B.1 of the FOA.

5. 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. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the FOA. Section IV.E of the FOA provides instructions on submitting a Reply to Reviewer Comments.

ARPA-E performs a preliminary review of Replies to determine whether they are compliant, as described in Section III.G.1 of the FOA. ARPA-E will review and consider compliant Replies only. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be non-compliant.

6. 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 Contracting 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.

7. 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 and program policy factors in Sections V.A.2 and V.B.1 of the FOA. 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.

Applicants are promptly notified of ARPA-E's selection determination. ARPA-E may stagger its selection determinations. As a result, some Applicants may receive their notification letter in advance of other Applicants. Please refer to Section VI.A of the FOA for guidance on award notifications.

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

C. CONTENT AND FORM OF CONCEPT PAPERS

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 section 1-4 must not exceed 4 pages in length including graphics, figures, and/or tables. Appendix 1: Techno-economic assessment is required for each Concept Paper and shall not exceed one (1) page in length including graphics, figures, and/or tables. Concept Papers must submit the applicable Appendix for each Category they apply to, Appendix 2-5. Each Appendix is limited to 1 page. The information tables do not count towards the page limit on the technical narrative for Section 1-4, but any text beyond 4 pages for technical narrative or 1 page for each Appendix responses will be redacted.
- 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 Funding Requested (Federal and Cost Share), and Project Duration.

Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award (see Section III.G of the FOA).

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.

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 below. If Applicants exceed the maximum page length indicated above, ARPA-E will review only the authorized number of pages and disregard any additional pages.

1. CONCEPT PAPER

a. CONCEPT SUMMARY

- Describe the proposed concept with minimal jargon and explain how it addresses the Program Objectives of the FOA.

b. INNOVATION AND IMPACT

- Clearly identify the problem to be solved with the proposed technology concept.
- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the

Technical Performance Targets in Section I.H of the FOA for the appropriate Technology Category in Section I.G of the FOA.

c. Proposed Work

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.
- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.
- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.
- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?
- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.
- Estimated federal funds requested; total project cost including cost sharing.

d. Team Organization and Capabilities

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.
- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.
- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.
- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.

e. Appendix 1: Techno-economic assessment (1 Page Maximum)

Required for each Concept Paper.

- Applicants should supply the elements of a base case TEA.

f. Appendix 2: Category 1: Mineral Comminution (1 Page Maximum)

Responses required for Concept Papers that address Program Category 1.

Note: Submissions to MINER can address a single program category or combinations thereof.

Table 2: Category 1— Mineral Comminution Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. How will the mineral properties of the ore be modified to decrease grinding comminution energy and decrease unrecovered energy-relevant mineral yield in tailings? Please report any quantities in MJ/kg of ore, or by percent increase compared to state-of-the-art.	
Q3. How will the proposed technology be utilized for preexisting mineral beneficiation processes? For example, *in situ* and (or) *ex situ*? How will the process differ from conventional mineral beneficiation?	
Q4. Will this proposed technology decrease cradle-to-gate emissions? If CO_2 is released, how will CO_2 be recaptured?	
Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in kg/hr of ore, or by percent decrease or increase compared to the state-of-the-art.	
Q6. If Applicant chooses to develop technologies for other Categories from 2, 3 and 4, will this proposed technology negatively or positively impact energy-relevant mineral yield from CO_2-reactive minerals (Category 2) and (or) ability to undergo carbonation reactions (Category 3)? Do you anticipate the proposed technology to operate concurrently with technologies developed from Categories 2, 3 and 4?	

g. Appendix 3: Category 2: CO2-Reactive Mineral Yield (1 Page Maximum)

Responses required for Concept Papers that address Program Category 2.

Note: Submissions to MINER can address a single program category or combinations thereof.

Table 4: Category 2 — CO_2-Reactive Mineral Yield Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. Will this proposed technology decrease cradle-to-gate emissions? If CO2 is released, how will CO_2 be recaptured?	
Q3. Can this proposed technology be utilized with existing mineral beneficiation processes? Will mineral beneficiation processes have to be changed to accommodate this technology? When will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q4. What proportion of energy-relevant minerals do you anticipate recovering? Please base your response on total energy-relevant minerals within a bulk rock composition of a specified CO_2-reactive mineral assemblage and (or) monomineralic assemblage. Please respond in Kg and percent recovery relative to the bulk composition.	
Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in kg/hr of energy-relevant minerals, or by percent decrease or increase compared to the state-of-the-art.	
Q6. What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
Q7. If Applicant chooses to develop technologies from other Categories from 1, 3 and 4, will this proposed technology positively or negatively impact	

mineral beneficiation (Category 1) and (or) carbonation (Category 3)? Do you anticipate the proposed technology to operate concurrently with technologies to be developed from Categories 1, 2, and 4?	

h. APPENDIX 4: CATEGORY 3: CARBON NEGATIVE REACTIONS (1 PAGE MAXIMUM)

Responses required for Concept Papers that address Program Category 3.

Note: Submissions to MINER can address a single program category or combinations thereof.

Table 6: Category 3 — Carbon Negative Reactions Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. Specify a method of carbonation measurement?	
Q3. Where will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q4. What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
Q5. What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in wt.% CO_2e/metric ton of ore, and by percent increase of carbon mineralization compared to the state-of-the-art.	
Q6. If Applicant chooses to develop technologies for other Categories from 1, 2 and 4, will this proposed technology positively or negatively impact mineral beneficiation (Category 1) and (or) energy-relevant mineral yield from CO_2-reactive ore (Category 2)? Do you anticipate the proposed technology to	

operate concurrently with technologies developed from Categories 1, 2, and 4?	

i. Appendix 5: Category 4: Sensing and Analyzing Carbonation Potential and Mineralization (1 Page Maximum)

Required for Concept Papers that address Program Category 3.

Note: Submissions to MINER can address a single program category or combinations thereof.

Table 8: Category 4 — Sensing and Analyzing Carbonation Potential and Mineralization Applicant Question and Answer Summary Form

Question(s)	Applicant's Response
Q1. Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
Q2. When will the technology be employed? For example, *in situ* and (or) *ex situ*?	
Q3. Do you anticipate the proposed technology to operate before and (or) concurrently with technologies to be developed from Categories 1 to 3? How will technologies developed from Category 4 positively impact technologies to be developed from Categories 1 to 3?	
Q4. How will the proposed model(s) be validated?	
Q5. How can the proposed technology developed from Category 4 be integrated into existing mine operations?	
Q6. How can the proposed technology developed from Category 4 be integrated into exploration of CO_2-reactive ore bodies?	
Q7. How will carbonation be estimated and (or) quantified after carbon mineralization?	
Q8. How will energy-relevant minerals leached and re-mineralized from carbonated CO_2-reactive minerals be estimated and (or) quantified?	
Q9. How will comminution energy decrease or increase be estimated and (or) quantified *in situ* or *ex situ* when mineral properties are modified by processes such as Category 1?	

Q10. How will methods be developed to estimate energy-relevant mineral ore grade that includes conventional minerals and CO_2-reactive minerals either *in situ* and (or) *ex situ*?	
Q11. Will these methods be able to employ preexisting petrological based data and (or) petrophysical data determined from, for example core, and (or) other methods into modeling? If so, please describe how pre-existing data can be used to create models for sensing and analyzing carbonation potential and mineralization?	
Q12. Will a method be developed to determine CO_2 reservoir leakage and storage capability?	
Q13. Other relevant accomplishments of the applicant's proposed technology?	

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through

other means (e.g., fax, hand delivery, email, postal mail). 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 "My Submissions" link 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 FOA, 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.**

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications may be deemed noncompliant (see Section III.G.1 of the FOA). 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 IV of the FOA;
- 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 FOA;
- 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.

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

ARPA-E performs a preliminary review of Concept Papers and Full Applications to determine whether they are compliant and responsive (see Section III.G of the FOA). ARPA-E also performs a preliminary review of Replies to Reviewer Comments to determine whether they are compliant.

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 FOA 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.H of the FOA for the appropriate technology Category in Section I.G of the FOA;
- 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 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 risks 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

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

B. REVIEW AND SELECTION PROCESS

1. 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.

2. 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 Contracting 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.

3. ARPA-E SUPPORT CONTRACTOR

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.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the Contracting Officer and are not merit reviewed or considered for award. The Contracting Officer sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification letter 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. Please refer to Section IV.G of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN JUNE 2022]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

Upon the issuance of a FOA, only the Contracting Officer may communicate with Applicants. ARPA-E personnel and our support contractors are prohibited from communicating (in writing or otherwise) with Applicants regarding the FOA. This "quiet period" remains in effect until ARPA-E's public announcement of its project selections.

During the "quiet period," Applicants are required to submit all questions regarding this FOA to ARPA-E-CO@hq.doe.gov. Questions and Answers (Q&As) about ARPA-E and the FOA are available at http://arpa-e.energy.gov/faq. For questions that have not already been answered, please send an email with the FOA name and number in the subject line to ARPA-E-CO@hq.doe.gov. Due to the volume of questions received, ARPA-E will only answer pertinent questions that have not yet been answered and posted at the above link.

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted no later than three business days in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- Responses are published in a document specific to this FOA under "CURRENT FUNDING OPPORTUNITIES – FAQS" on ARPA-E's website (http://arpa-e.energy.gov/faq).

Applicants may submit questions regarding ARPA-E eXCHANGE, ARPA-E's online application portal, to ExchangeHelp@hq.doe.gov. ARPA-E will promptly respond to emails that raise legitimate, technical issues with ARPA-E eXCHANGE. ARPA-E will refer any questions regarding the FOA to ARPA-E-CO@hq.doe.gov.

ARPA-E will not accept or respond to communications received by other means (e.g., fax, telephone, mail, hand delivery). Emails sent to other email addresses will be disregarded.

During the "quiet period," only the Contracting Officer may authorize communications between ARPA-E personnel and Applicants. The Contracting Officer may communicate with Applicants as necessary and appropriate. As described in Section IV.A of the FOA, the Contracting Officer may arrange pre-selection meetings and/or site visits during the "quiet period."

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. ARPA-E provides Applicants with a notification encouraging or discouraging the submission of a Full Application based on ARPA-E's assessment of the Concept Paper. In addition, ARPA-E provides Applicants with reviewer comments on Full Applications before the submission deadline for Replies to Reviewer Comments.

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 FOA. 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 VI.B.8. of this FOA.
  - 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 FOA made to a Bayh-Dole entity (domestic small businesses and nonprofit organizations) shall include the U.S. Competitiveness Provision in accordance with Section VI.B.8 of this FOA. 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 Prime 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 Prime 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 Prime 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. FOAS AND FOA MODIFICATIONS

FOAs 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 FOA 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 FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

F. OBLIGATION OF PUBLIC FUNDS

The Contracting 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 Contracting Officer, either explicit or implied, is invalid.

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

G. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

Applicants are required to make a full and complete disclosure of the information requested in the Business Assurances & Disclosures Form. Disclosure of the requested information is mandatory. Any failure to make a full and complete disclosure of the requested information may result in:

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;
- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

H. RETENTION OF SUBMISSIONS

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.

I. 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.

J. ADDITIONAL NOTICES

- This FOA is intended for informational purposes and reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR or STTR funding agreement, the terms of the funding agreement are controlling.
- Before award of an SBIR or STTR funding agreement, ARPA-E may request the selectee to submit certain organizational, management, personnel, and financial information to assure responsibility of the Prime Recipient. In addition, selectees will be required to make certain legal commitments at the time of execution of funding agreements resulting from this FOA. ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement for SBIR/STTR Awards, which is available at https://arpa-e.energy.gov/?q=site-page/funding-agreements.
- ARPA-E will not pay a fee or profit on Cooperative Agreements resulting from this FOA to recipients or subrecipients.
- Actual or suspected fraud, waste, or abuse may be reported to the DOE Office of Inspector General (OIG) at 1-800-541-1625.

K. COMPLIANCE AUDIT REQUIREMENT

A prime recipient organized as a for-profit entity expending $750,000 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 is either a Prime Recipient or a Subrecipient, and has expended $750,000 or more of Federal funds 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.

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: is the Advanced Research Projects Agency – Energy, an agency of the U.S. Department of Energy.

Cost Sharing: Is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

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.

FOA: Funding Opportunity Announcement.

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

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

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

Nonprofit Organizations (or *nonprofits*): Has the meaning set forth at 2 C.F.R. § 200.70.

Prime Recipient: The signatory to the funding agreement with ARPA-E.

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

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).

Small Business Concern: A for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture. Such joint ventures must submit the VCOC/FJV Certification (the seventh component of the Full Application).

Standalone Applicant: An Applicant that applies for funding on its own, not as part of a Project Team.

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.

Total Project Cost: The sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

TT&O: Technology Transfer and Outreach. (See Section IV.G.8 of the FOA for more information).