

**FINANCIAL ASSISTANCE  
FUNDING OPPORTUNITY ANNOUNCEMENT**



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

***MINING INNOVATIONS FOR NEGATIVE EMISSIONS RESOURCE RECOVERY  
(MINER)***

Announcement Type: Initial Announcement  
Funding Opportunity No. DE-FOA-0002707  
CFDA Number 81.135

<b>Funding Opportunity Announcement (FOA) Issue Date:</b>	February 24, 2022
<b>First Deadline for Questions to <a href="mailto:ARPA-E-CO@hq.doe.gov">ARPA-E-CO@hq.doe.gov</a>:</b>	5 PM ET, April 5, 2022
<b>Submission Deadline for Concept Papers:</b>	9:30 AM ET, April 15, 2022
<b>Second Deadline for Questions to <a href="mailto:ARPA-E-CO@hq.doe.gov">ARPA-E-CO@hq.doe.gov</a>:</b>	5 PM ET, TBD
<b>Submission Deadline for Full Applications:</b>	9:30 AM ET, TBD
<b>Submission Deadline for Replies to Reviewer Comments:</b>	5 PM ET, TBD
<b>Expected Date for Selection Notifications:</b>	October 2022
<b>Total Amount to Be Awarded</b>	Approximately \$44 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002707 and DE-FOA-0002708.
<b>Anticipated Awards</b>	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between \$500,000 and \$5 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B 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.C.1 through III.C.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](mailto: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](mailto: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	<ul style="list-style-type: none"><li>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 the 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:<ul style="list-style-type: none"><li>Concept Summary</li><li>Innovation and Impact</li><li>Proposed Work</li><li>Team Organization and Capabilities</li><li>Appendix 1: TEA</li><li>Appendix 2-5: For each applicable category addressed.</li></ul></li></ul>	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

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

## **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.”<sup>1</sup> 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”)<sup>2</sup> 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. FOA SPECIFIC DEFINITIONS**

**CO<sub>2</sub>-reactive Minerals:** Minerals that react with CO<sub>2</sub> or CO<sub>2</sub>-derived chemistries to form stable carbonates and (or) the ability to sequester CO<sub>2</sub>. The term CO<sub>2</sub>-reactive minerals can encompass gangue, overburden, and tailings.

**Comminution:** The mineral grinding phase during mineral beneficiation.

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<sup>1</sup> OMB Circular A-11 ([https://www.whitehouse.gov/wp-content/uploads/2018/06/a11\\_web\\_toc.pdf](https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf)), Section 84, pg. 3.

<sup>2</sup> OMB Circular A-11 ([https://www.whitehouse.gov/wp-content/uploads/2018/06/a11\\_web\\_toc.pdf](https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf)), Section 84, pg. 3.

**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<sub>2</sub>-reactive mineralogy from the subsurface and reacting with CO<sub>2</sub> or CO<sub>2</sub>-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<sub>2</sub> or CO<sub>2</sub>-derived chemistries.

**Modified Ore:** Ore with intentionally carbonated mineralogy.

**Negative Emissions:** A technology that removes CO<sub>2</sub> 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<sub>2</sub>-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.

## **C. 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.% CO<sub>2</sub>e 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.F. Also provided within this FOA are performance targets for the technical categories of interest in Section I.G. Lastly, Sections I.H and I.I of the FOA provide information on technoeconomic analysis (TEA) and Life Cycle Assessment (LCA) requirements, respectively.

#### **D. PROGRAM OBJECTIVES**

The objective of the MINER program is to utilize the reactive potential of CO<sub>2</sub>-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 technoeconomic issues and performance metrics described in Sections I.G and I.H. 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<sub>2</sub>-reactive ore;
- Increase energy-relevant mineral yield by capturing energy-relevant minerals in CO<sub>2</sub>-reactive mineralogy;

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- Reprocessing existing CO<sub>2</sub> 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<sub>2</sub>-reactive ore;
- Develop surveying technologies to advance exploration vectors of CO<sub>2</sub>-reactive rock formations, quantify reservoir carbonation, and quantify energy-relevant minerals leached and re-mineralized during carbonation of the CO<sub>2</sub>-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.

## **E. BACKGROUND**

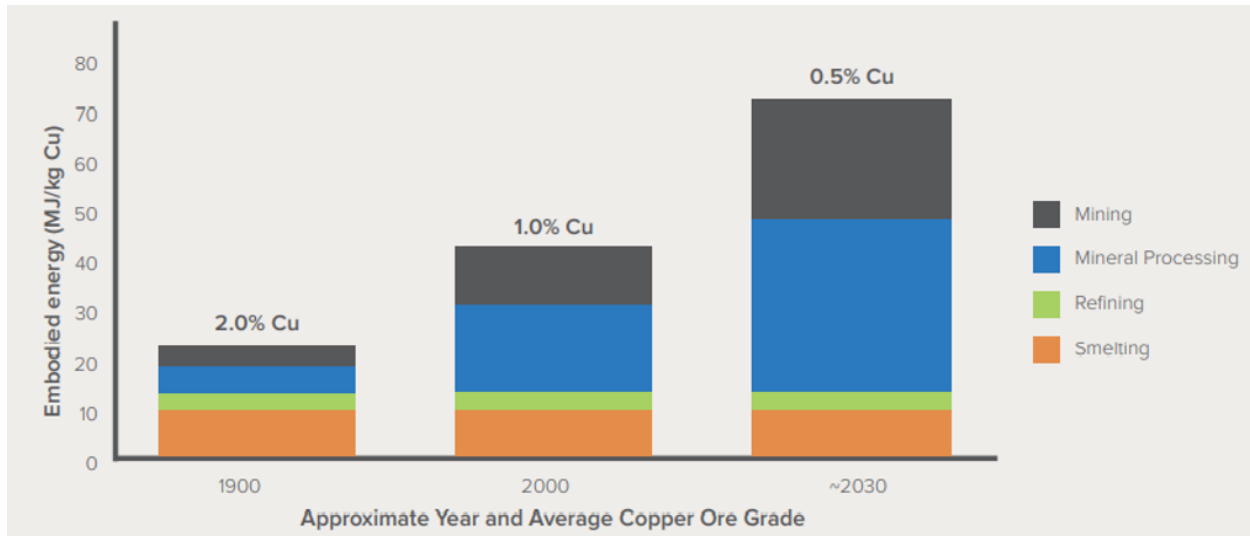
Since the creation of the United States' Critical Minerals Stockpiling Act (1939), the domestic supply of energy-relevant minerals has been a national security and economic concern. With the combination of rapid technological advancements<sup>3</sup> and geopolitical events<sup>4</sup>, the United States' 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<sup>5</sup>. Consequently, to meet the supply-demand, the United States may look towards unconventional minerals (i.e., CO<sub>2</sub>-reactive minerals) and carbon-negative mining methods.

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<sup>3</sup> Fortier et al. *US Geological Survey technical input document in response to Secretarial Order No. 3359*, **2018**, 2018-1021

<sup>4</sup> Ting & Seaman *Asian Studies Review*, **2013** 37 (2), 234-252

<sup>5</sup> Executive Order 14017, **2021**



**Figure 1: Embodied energy in mineral processing increases as ore grades decrease<sup>6</sup>.**

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%<sup>7</sup>. In quantifiable terms, copper ore grades of 0.20% require 10 MJ/kg of ore in comparison to 80 MJ/kg for 0.05% copper ore grades<sup>8</sup>. 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<sup>9</sup>. 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<sub>2</sub> 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<sub>2</sub> drawdown<sup>10</sup>. 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<sup>11</sup>. 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<sub>2</sub> within CO<sub>2</sub>-reactive mineral

<sup>6</sup> Low-Carbon\_Metals\_for\_a\_Low-Carbon\_World.pdf (rmi.org)

<sup>7</sup> Calvo et al. *Resources* 5 (4) **2016**, 36

<sup>8</sup> Koppelaar & Koppelaar *Biophysical Economics and Resource Quality* 1 (2), **2016**, 1-16

<sup>9</sup> Northey et al *Resources, Conservation and Recycling* 83, **2014**, 190-201

<sup>10</sup> Jagoutz et al. *Proceedings of the National Academy of Sciences* 113 (8), **2016**, 4935-4940

<sup>11</sup> Li et al., *Minerals* 8 (4), **2018**, 147

assemblages will be required for achieving an additional 50% carbon reduction for a true path towards net-zero, as shown in Figure 3<sup>12</sup>. Common mafic-ultramafic CO<sub>2</sub>-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<sub>2</sub>-reactive gangue mineralogy: (1) decreasing comminution by transforming CO<sub>2</sub>-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<sub>2</sub> drawdown operates within geologic time scales (>1 My)<sup>13</sup>. Anthropogenic *in situ* pilot-scale CO<sub>2</sub> injections into mafic-ultramafic rock demonstrate that 60-95% CO<sub>2</sub> mineralization occurs in approximately two years (e.g., the Carbfix pilot project in Iceland)<sup>14,15</sup>. 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<sup>16</sup> (e.g., thermal activation, chemical activation, and mechanical activation). Mechanistic insights into mafic-ultramafic carbonation further show carbonation kinetics can be accelerated by increasing ionic strength in CO<sub>2</sub> (aq) solution<sup>17,18</sup>, increasing temperature<sup>19</sup>, and increase P<sub>CO2</sub><sup>20</sup>.

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<sup>12</sup> Low-Carbon\_Metals\_for\_a\_Low-Carbon\_World.pdf (rmi.org)

<sup>13</sup> Frondini et al. *Geosciences* 9 (6), **2019**, 258

<sup>14</sup> White et al. *Environmental Science & Technology* 54 (22), **2020**, 14609-14616

<sup>15</sup> Stute et al. *Science* 352 (6291), **2016**, 1312-1314

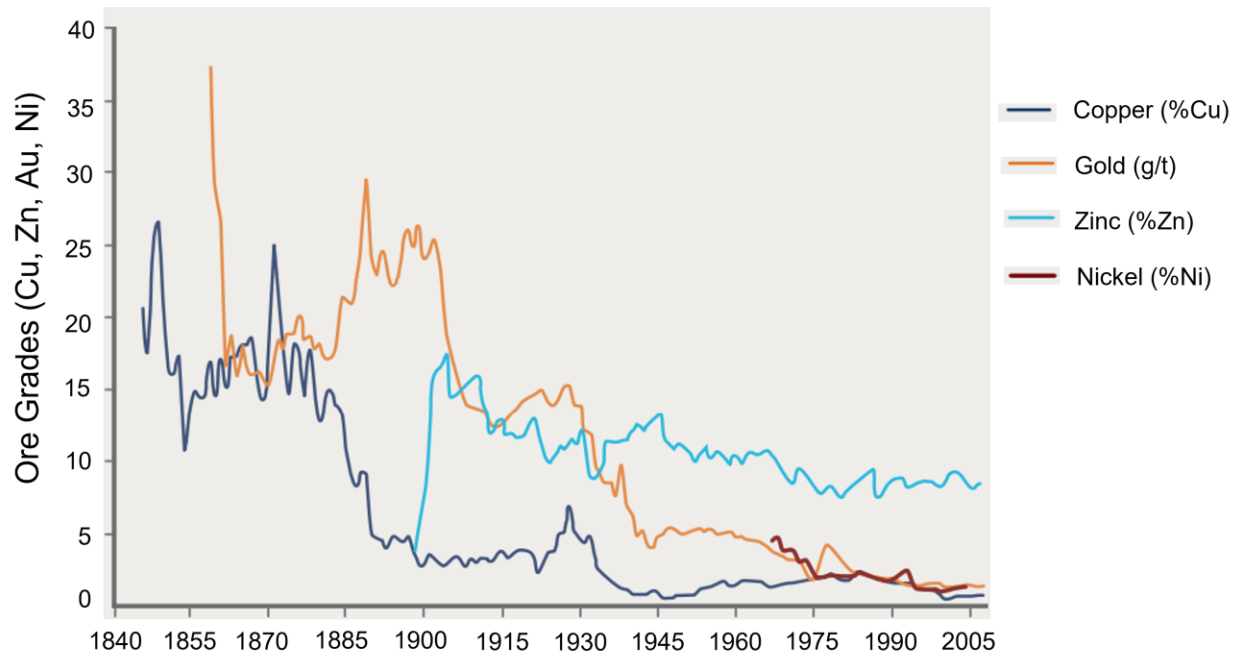
<sup>16</sup> Li et al. *Minerals* 8 (4) **2018**, 147

<sup>17</sup> Wang et al. *Minerals Engineering* 131, **2019**, 185-197

<sup>18</sup> Gadikota et al. *Physical Chemistry Chemical Physics* 16 (10), **2014**, 4679-4693

<sup>19</sup> Miller et al. *Environmental Science & Technology Letters* 6(8), **2019**, 431-442

<sup>20</sup> Kwon et al. *Journal of Environmental Sciences* 23 (8), **2011**, 1233-1239



**Figure 2: Grades of copper, gold, zinc, and nickel ore mined are decreasing over time<sup>21</sup>.**

Research shows that carbonated CO<sub>2</sub>-reactive mineralogy can increase the yield of energy-relevant minerals. CO<sub>2</sub>-reactive mineralogy is common and is a major constituent of mafic-ultramafic ore bodies. Typical CO<sub>2</sub>-reactive mineralogy (e.g., gangue minerals) includes olivine, serpentine, brucite, chrysotile, pyroxene, feldspar, and amphibole. The CO<sub>2</sub>-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<sup>22,23</sup>. Forsterite endmember olivine is a ubiquitous CO<sub>2</sub>-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<sup>24</sup>. 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<sup>25</sup>. Current research has shown approximately 80% of nickel within olivine can be leached and re-mineralized<sup>26</sup>. CO<sub>2</sub>-reactive minerals themselves are an untapped potential for energy-relevant minerals. For example, layered mafic intrusions can contain greater than 1700 Mt of ore<sup>27</sup>. Although energy-relevant mineral yield from CO<sub>2</sub>-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.

<sup>21</sup> Low-Carbon\_Metals\_for\_a\_Low-Carbon\_World.pdf (rmi.org)

<sup>22</sup> Santos et al. *Metals* 5 (3), **2015**, 1620-1644

<sup>23</sup> Wang et al. *Chemical Engineering Journal* 406, **2021**, 126761

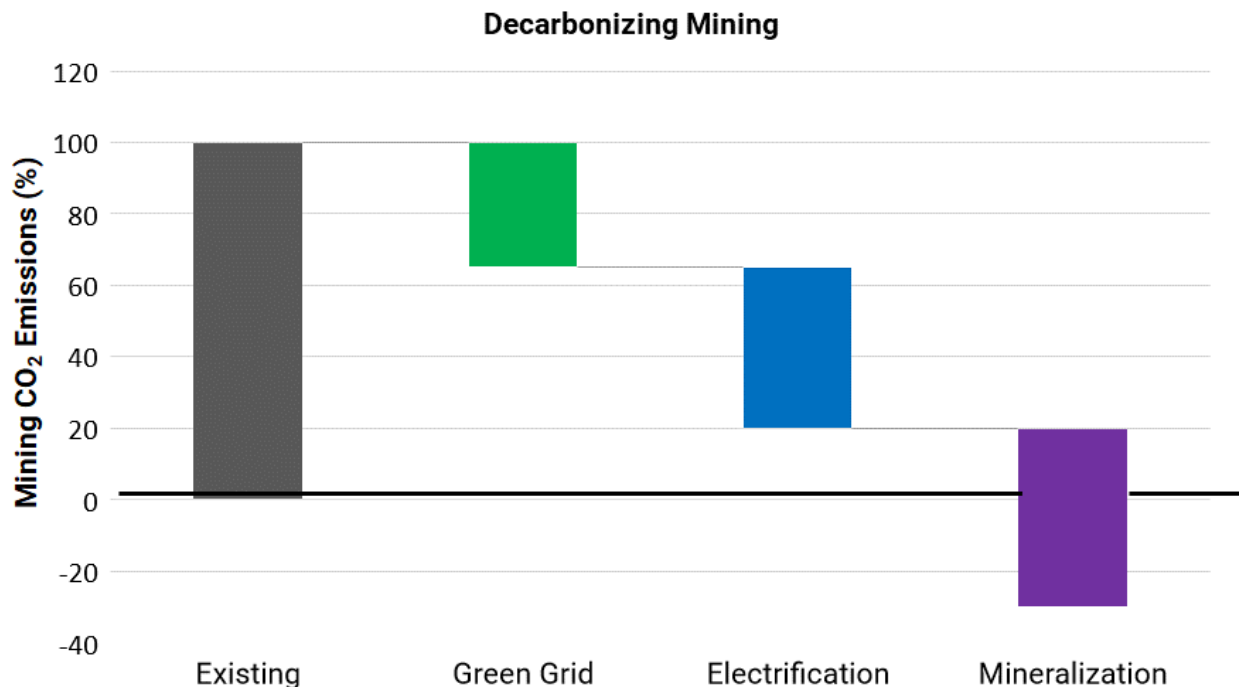
<sup>24</sup> Stopic et al. *Metals* 8, 2018, 993

<sup>25</sup> Siegel et al. *Lithos* 288, **2017**, 156-174

<sup>26</sup> Wang et al. *Chemical Engineering Journal* 406, **2021**, 126761

<sup>27</sup> Zientek et al. USGS scientific Investigations Report, **2014**

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<sup>28</sup>. *In situ* methods historically have been most considered for coal<sup>29</sup> and uranium<sup>30</sup> 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<sup>31</sup>. Uranium mining is the most common method to employ *in situ* mining methods. However, pilot tests have been conducted for copper<sup>32</sup> (e.g., San Manuel copper mine, Arizona USA) gold, vanadium, nickel, and rare earth elements<sup>33</sup>. Production at the San Manuel copper mine reached 11,000 t Cu/yr<sup>34</sup> showing promise for unconventional hard rock mining methods.



**Figure 3: Mineral carbonation can reduce CO<sub>2</sub> emissions by an estimated 50%<sup>35</sup>. Combined with electrification and the greening of electrical sources, it is expected that CO<sub>2</sub> mineralization can enable mining to become a net-negative industry.**

<sup>28</sup> Seredkin et al. *Ore Geology Reviews*, 79, **2016**, 500 - 514

<sup>29</sup> Xie et al. *Journal of China Coal Society*, 43 (5), **2018**, 1210 - 1219

<sup>30</sup> Mudd *Environmental Geology* 41 (3), **2001**, 390 - 403

<sup>31</sup> Liang et al. *Advances in Geo-Energy Research* 5 (1), **2021**, 1-4

<sup>32</sup> O'Gorman et al. Little Bear Laboratories, Inc, **2004**

<sup>33</sup> Seredkin et al. *Ore Geology Reviews*, 79, **2016**, 500 - 514

<sup>34</sup> Briggs Arizona Geological Survey Contributed Report, **2014**

<sup>35</sup> [https://rmi.org/wp-content/uploads/2018/08/RMI\\_Decarbonization\\_Pathways\\_for\\_Mines\\_2018.pdf](https://rmi.org/wp-content/uploads/2018/08/RMI_Decarbonization_Pathways_for_Mines_2018.pdf)

## **F. 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.F, I.G, and I.H 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<sub>2</sub>-reactive ore bodies;
- Physico-chemical changes and alteration mineralogy during rock carbonation;
- The ability to provide proper reservoir characterization to optimize rock carbonation and energy-relevant minerals capture from CO<sub>2</sub>-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<sub>2</sub>-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.G 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 CO<sub>2</sub>-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<sub>2</sub>-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<sub>2</sub>-reactive gangue mineralogy, overburden, and tailings during mineral beneficiation. Recapture of CO<sub>2</sub> 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.G 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<sub>2</sub>-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.G 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<sub>2</sub>-reactive ore bodies. Category 3 applicants may possess potential CO<sub>2</sub> 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<sub>2</sub>-reactive ore bodies. Even after mature carbon capture technology is available, locating dependable, safe, and long-term storage within CO<sub>2</sub>-reactive ore bodies will remain. Underground sensing and analysis of CO<sub>2</sub>-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<sub>2</sub>-reactive ore bodies. Traditionally mined CO<sub>2</sub>-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<sub>2</sub>-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.

## **G. 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 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 page 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<sup>36</sup> 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.F.

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.G evolve from current state-of-the-art levels. Section I.G details the necessary application questions/answers summary form and metrics. Section I.H outlines the TEA, and Section I.I 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

<sup>36</sup> LCAs will need to be done per ISO 14000 series and environmental impact determined using TRACI during the course of the program

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<sub>2</sub>-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<sub>2</sub>-reactive ore's mineral properties to decrease comminution energy for mineral beneficiation
- b. Modifying CO<sub>2</sub>-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<sup>37</sup>
- f. How CO<sub>2</sub> 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
<b>Q1.</b> What are the proposed feedstock(s), and from which specific deposit types? Do you expect restrictions of this proposed	

<sup>37</sup>"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.

technology to only specific mineral associations, i.e., ore type?	
<b>Q2.</b> 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.	
<b>Q3.</b> How will the proposed technology be utilized for preexisting mineral beneficiation processes? For example, <i>in situ</i> and (or) <i>ex situ</i> ? How will the process differ from conventional mineral beneficiation?	
<b>Q4.</b> Will this proposed technology decrease cradle-to-gate emissions? If CO <sub>2</sub> is released, how will CO <sub>2</sub> be recaptured?	
<b>Q5.</b> 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.	
<b>Q6.</b> 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 <sub>2</sub> -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 — CO<sub>2</sub>-REACTIVE MINERAL YIELD TECHNICAL TARGETS AND REPORTING

**Table 3: Category 2 — CO<sub>2</sub>-reactive Mineral Yield Technical Targets**

Description	Target
CO <sub>2</sub> -reactive mineral yield	80% recovery of energy-relevant minerals relative to bulk rock composition of energy-relevant minerals within the CO <sub>2</sub> -reactive mineral assemblage and (or) monomineralic assemblage (see background section for recovery amount review)

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

CO <sub>2</sub> -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 <sub>2</sub> -reactive mineral assemblage and (or) monomineralic assemblage
Increase CO <sub>2</sub> -reactive ore permeability	Demonstrate a percent increase in net permeability and porosity. If permeability is measured report in k (m <sup>2</sup> )

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<sub>2</sub>-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<sub>2</sub> if decarbonation of the ore occurs
- d. Efficiency and kinetics operate within a reasonable timeframe<sup>38</sup>
- e. Increase CO<sub>2</sub>-reactive ore rock permeability and porosity
- f. Employing the method *in situ* and (or) *ex situ*

**Table 4: Category 2 — CO<sub>2</sub>-reactive Mineral Yield Applicant Question and Answer Summary Form**

Question(s)	Applicant's Response
<b>Q1.</b> 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?	
<b>Q2.</b> Will this proposed technology decrease cradle-to-gate emissions? If CO <sub>2</sub> is released, how will CO <sub>2</sub> be recaptured?	

<sup>38</sup> "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.

<b>Q3.</b> 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, <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q4.</b> 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 <sub>2</sub> -reactive mineral assemblage and (or) monomineralic assemblage. Please respond in Kg and percent recovery relative to the bulk composition.	
<b>Q5.</b> 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.	
<b>Q6.</b> What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
<b>Q7.</b> 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 <sub>2</sub> e/metric ton of ore processed compared to existing state-of-the-art (Demonstrate based on 100 kg CO <sub>2</sub> e captured on a cradle-to-gate or ore-to-mineral basis)
Carbonation efficacy (rate)	<i>in situ</i> is constrained to months or less, and for <i>ex situ</i> is days or less

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

Increase CO <sub>2</sub> -reactive ore rock porosity and permeability	Demonstrate a percent increase in net permeability and porosity.
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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<sub>2</sub>-reactive minerals if Category 2 is pursued
- c. Efficiency and kinetics operate within a reasonable timeframe<sup>39</sup>
- d. Increase CO<sub>2</sub>-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
<b>Q1.</b> 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?	
<b>Q2.</b> Specify a method of carbonation measurement?	
<b>Q3.</b> Where will the technology be employed? For example, <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q4.</b> What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
<b>Q5.</b> What is the anticipated efficiency of the proposed technology compared to state-of-	

<sup>39</sup> "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.



the-art? Please report any quantities in wt.% CO <sub>2</sub> e/metric ton of ore, and by percent increase of carbon mineralization compared to the state-of-the-art.	
<b>Q6.</b> 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 <sub>2</sub> -reactive ore (Category 2)? Do you anticipate the proposed technology to 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 <sub>2</sub> -reactive rock formations	Develop exploratory vectors to locate CO <sub>2</sub> -reactive rock formations
Measuring and modeling CO <sub>2</sub> -rock interaction at subsurface depths	Characterize and model CO <sub>2</sub> -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 <sub>2</sub> -reactive minerals	
Predict comminution behavior prior to mineral beneficiation	
Estimate energy-relevant mineral ore grade that includes conventional minerals and CO <sub>2</sub> -reactive minerals	
Model CO <sub>2</sub> 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)

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geostatistical based technologies to perform sensing and analysis of carbonation potential and mineralization of CO<sub>2</sub>-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<sub>2</sub>-reactive rock formations
- b. Methods and technologies for measuring and modeling CO<sub>2</sub>-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<sub>2</sub>-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<sub>2</sub>-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<sub>2</sub> 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
<b>Q1.</b> Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
<b>Q2.</b> When will the technology be employed? For example, <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q3.</b> 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	

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Category 4 positively impact technologies to be developed from Categories 1 to 3?	
<b>Q4.</b> How will the proposed model(s) be validated?	
<b>Q5.</b> How can the proposed technology developed from Category 4 be integrated into existing mine operations?	
<b>Q6.</b> How can the proposed technology developed from Category 4 be integrated into exploration of CO <sub>2</sub> -reactive ore bodies?	
<b>Q7.</b> How will carbonation be estimated and (or) quantified after carbon mineralization?	
<b>Q8.</b> How will energy-relevant minerals leached and re-mineralized from carbonated CO <sub>2</sub> -reactive minerals be estimated and (or) quantified?	
<b>Q9.</b> How will comminution energy decrease or increase be estimated and (or) quantified <i>in situ</i> or <i>ex situ</i> when mineral properties are modified by processes such as Category 1?	
<b>Q10.</b> How will methods be developed to estimate energy-relevant mineral ore grade that includes conventional minerals and CO <sub>2</sub> -reactive minerals either <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q11.</b> 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?	
<b>Q12.</b> Will a method be developed to determine CO <sub>2</sub> reservoir leakage and storage capability?	
<b>Q13.</b> Other relevant accomplishments of the applicant's proposed technology?	

## H. 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

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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 <sub>2</sub> 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.

Individual awards may vary between \$500,000 and \$5 million in Federal share.

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be January 2023, or as negotiated.

ARPA-E encourages submissions stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists.

Submissions requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the period of performance. These submissions must contain an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration. Alternatively, submissions requiring proof-of-concept R&D can propose a project with the project end deliverable being an extremely creative, but partial solution. However, the Applicants are required to provide a convincing vision how these partial solutions can enable the realization of the program metrics with further development.

Applicants proposing projects for which some initial proof-of-concept demonstration already exists should submit concrete data that supports the probability of success of the proposed project.

ARPA-E will provide support at the highest funding level only for submissions with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

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

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

## **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 new award. Renewal funding is contingent on: (1) availability of funds appropriated by Congress for the purpose of this program; (2) substantial progress towards meeting the objectives of the approved application; (3) submittal of required reports; (4) compliance with the terms and conditions of the award; (5) ARPA-E approval of a renewal application; and (6) other factors identified by the Agency at the time it solicits a renewal application.

## **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."<sup>40</sup> Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.D below.

### **1. COOPERATIVE AGREEMENTS**

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.<sup>41</sup>

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.

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

### **2. FUNDING AGREEMENTS WITH FFRDCs/DOE LABS, GOGOs, AND FEDERAL INSTRUMENTALITIES**

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a

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<sup>40</sup> U.S. Congress, Conference Report to accompany the 21<sup>st</sup> Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

<sup>41</sup> The Prime Recipient is the signatory to the funding agreement with ARPA-E.

Project Team must provide the information requested in the “FFRDC Lab Authorization” and “Field Work Proposal” section of the Business Assurances & Disclosures Form, which is submitted with the Applicant’s Full Application.

When a FFRDC/DOE Lab (including the National Energy Technology Laboratory or NETL) is the *lead organization* for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the lead entity for the rest of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC/DOE Lab is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

When a FFRDC/DOE Lab is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC/DOE Lab and a single, separate Cooperative Agreement with the Prime Recipient, the lead entity for the rest of the Project Team. Notwithstanding the use of multiple agreements, the Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC/DOE Lab and the rest of the Project Team.

Funding agreements with DOE/NNSA FFRDCs take the form of Work Authorizations issued to DOE/NNSA FFRDCs through the DOE/NNSA Field Work Proposal system for work performed under Department of Energy Management & Operation Contracts. Funding agreements with non-DOE/NNSA FFRDCs, GOGOs (including NETL), and Federal instrumentalities (e.g., Tennessee Valley Authority) will be consistent with the sponsoring agreement between the U.S. Government and the Laboratory. Any funding agreement with an FFRDC or GOGO will have similar terms and conditions as ARPA-E’s Model Cooperative Agreement (<https://arpa-e.energy.gov/technologies/project-guidance/pre-award-guidance/funding-agreements>).

Non-DOE GOGOs and Federal agencies may be proposed to provide support to the Project Team members on an applicant’s project, through a Cooperative Research and Development Agreement (CRADA) or similar agreement.

### **3. OTHER TRANSACTIONS AUTHORITY**

ARPA-E may use its “other transactions” authority under the America COMPETES Reauthorization Act of 2010 to enter into an other transaction agreement with Prime Recipients, on a case-by-case basis.

ARPA-E may negotiate an other transaction agreement when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

In general, an other transaction agreement normally requires a minimum cost share of 50%. See Section III.B.2 of the FOA.



#### **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.
- 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<sup>42</sup> 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.

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<sup>42</sup> The term "nonprofit organization" or "nonprofit" is defined in Section IX.

### **III. ELIGIBILITY INFORMATION**

#### **A. ELIGIBLE APPLICANTS**

This FOA is open to U.S. universities, national laboratories, industry and individuals.

##### **1. INDIVIDUALS**

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,<sup>43</sup> as the lead for a Project Team,<sup>44</sup> or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

##### **2. DOMESTIC ENTITIES**

For-profit entities<sup>45</sup>, educational institutions<sup>46</sup>, and nonprofits<sup>47</sup> that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

FFRDCs/DOE Labs are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team that includes institutions of higher education, companies, research foundations, or trade and industry research collaborations, but not as a Standalone Applicant.

State, local, and tribal government entities are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

##### **3. FOREIGN ENTITIES**

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team.

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<sup>43</sup> A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

<sup>44</sup> A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

<sup>45</sup> For-Profit Organizations (Other than Small Businesses) (or *large businesses*): Means entities organized for-profit other than small businesses as defined elsewhere in this Glossary.

<sup>46</sup> Institutions of Higher Education (or educational institutions): Has the meaning set forth at 20 U.S.C. 1001.

<sup>47</sup> 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 Prime Recipient or Subrecipient.

Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. All work under the ARPA-E award must be performed in the United States. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at <https://arpa-e-foa.energy.gov/> (see “View Template Application Documents”). Refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

#### **4. CONSORTIUM ENTITIES**

Consortia, which may include domestic and foreign entities, must designate one member of the consortium as the consortium representative to the Project Team. The consortium representative must be incorporated in the United States. The eligibility of the consortium will be determined by reference to the eligibility of the consortium representative under Section III.A of the FOA. Each consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium entity must provide a written description of its internal governance structure and its internal rules to the Contracting Officer ([ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov)).

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This collaboration agreement binds the individual consortium members together and shall include the consortium's:

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

#### **B. COST SHARING<sup>48</sup>**

Applicants are bound by the cost share proposed in their Full Applications.

##### **1. BASE COST SHARE REQUIREMENT**

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime

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<sup>48</sup> Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

Recipient must provide at least 20% of the Total Project Cost<sup>49</sup> as cost share, except as provided in Sections III.B.2 or III.B.3 below.<sup>50</sup>

## 2. INCREASED COST SHARE REQUIREMENT

Large businesses<sup>51</sup> are strongly encouraged to provide more than 20% of the Total Project Cost as cost share. ARPA-E may consider the amount of cost share proposed when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under an “other transaction” agreement, the Prime Recipient is normally expected to provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this cost share requirement, as appropriate.

## 3. REDUCED COST SHARE REQUIREMENT

ARPA-E has reduced the base cost share requirement for the following types of projects:

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs/DOE Labs/Federal agencies and instrumentalities (other than DOE) are required to provide at least 5% of the Total Project Cost as cost share. Small businesses – or consortia of small businesses – may provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the “Cost Share Grace Period”).<sup>52</sup> If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.
- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.
- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other

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<sup>49</sup> 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 and FFRDCs.

<sup>50</sup> Energy Policy Act of 2005, Pub.L. 109-58, sec. 988(c)

<sup>51</sup> The term “For-Profit Organizations (Other than Small Businesses)” or “large business” is defined in Section IX.

<sup>52</sup> The term “small business” is defined in Section IX.

patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.

- Projects that do not meet any of the above criteria are subject to the base cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

#### **4. LEGAL RESPONSIBILITY**

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying, or ensuring payment of the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

The Prime Recipient is solely responsible for managing cost share contributions by the Project Team and enforcing cost share obligations assumed by Project Team members in subawards or related agreements.

#### **5. COST SHARE ALLOCATION**

Each Project Team is free to determine how much each Project Team member will contribute towards the cost share requirement. The amount contributed by individual Project Team members may vary, as long as the cost share requirement for the project as a whole is met.

#### **6. COST SHARE TYPES AND ALLOWABILITY**

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G of the FOA.

Project Teams may provide cost share in the form of cash or in-kind contributions. Cash contributions may be provided by the Prime Recipient or Subrecipients. Allowable in-kind contributions include but are not limited to personnel costs, indirect costs, facilities and administrative costs, rental value of buildings or equipment, and the value of a service, other resource, or third party in-kind contribution. Project Teams may use funding or property received from state or local governments to meet the cost share requirement, so long as the funding or property was not provided to the state or local government by the Federal Government.

The Prime Recipient may not use the following sources to meet its cost share obligations:

- Revenues or royalties from the prospective operation of an activity beyond the period of performance;
- Proceeds from the prospective sale of an asset of an activity;
- Appropriated Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds<sup>53</sup> to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under “other transaction” agreements.

Project Teams may not use the same cash or in-kind contributions to meet cost share requirements for more than one project or program.

Cost share contributions must be specified in the project budget, verifiable from the Prime Recipient’s records, and necessary and reasonable for proper and efficient accomplishment of the project. Every cost share contribution must be reviewed and approved in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.306 and 910.130, and 10 C.F.R. §§ 603.525-555.

## **7. COST SHARE CONTRIBUTIONS BY FFRDCs AND GOGOS**

Because FFRDCs are funded by the Federal Government, costs incurred by FFRDCs generally may not be used to meet the cost share requirement. FFRDCs may contribute cost share only if the contributions are paid directly from the contractor’s Management Fee or a non-Federal source.

Because GOGOs/Federal Agencies are funded by the Federal Government, GOGOs/Federal Agencies may not provide cost share for the proposed project. However, the GOGO/Agency costs would be included in Total Project Costs for purposes of calculating the cost-sharing requirements of the applicant.

## **8. COST SHARE VERIFICATION**

Upon selection for award negotiations, Applicants are required to provide information and documentation regarding their cost share contributions. Please refer to Section VI.B.3 of the FOA for guidance on the requisite cost share information and documentation.

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<sup>53</sup> As defined in Federal Acquisition Regulation SubSection 31.205-18.

## **C. OTHER ELIGIBILITY REQUIREMENTS**

### **1. COMPLIANT CRITERIA**

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III.A 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.A 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.



### **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.F 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.

## **IV. APPLICATION AND SUBMISSION INFORMATION**

### **A. APPLICATION PROCESS OVERVIEW**

#### **1. 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>).

#### **2. 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.C 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.

#### **3. 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.C 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.

#### **4. 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-EeXCHANGE. 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.C.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.

#### **5. 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.

#### **6. 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.C 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.G of the FOA for the appropriate Technology Category in Section I.F 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
<b>Q1.</b> 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?	
<b>Q2.</b> 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.	
<b>Q3.</b> How will the proposed technology be utilized for preexisting mineral beneficiation processes? For example, <i>in situ</i> and (or) <i>ex situ</i> ? How will the process differ from conventional mineral beneficiation?	

<b>Q4.</b> Will this proposed technology decrease cradle-to-gate emissions? If CO <sub>2</sub> is released, how will CO <sub>2</sub> be recaptured?	
<b>Q5.</b> 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.	
<b>Q6.</b> 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 <sub>2</sub> -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: CO<sub>2</sub>-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<sub>2</sub>-Reactive Mineral Yield Applicant Question and Answer Summary Form**

<b>Question(s)</b>	<b>Applicant's Response</b>
<b>Q1.</b> 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?	
<b>Q2.</b> Will this proposed technology decrease cradle-to-gate emissions? If CO <sub>2</sub> is released, how will CO <sub>2</sub> be recaptured?	
<b>Q3.</b> 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, <i>in situ</i> and (or) <i>ex situ</i> ?	

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).



<b>Q4.</b> 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 <sub>2</sub> -reactive mineral assemblage and (or) monomineralic assemblage. Please respond in Kg and percent recovery relative to the bulk composition.	
<b>Q5.</b> 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.	
<b>Q6.</b> What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
<b>Q7.</b> 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**

<b>Question(s)</b>	<b>Applicant's Response</b>
<b>Q1.</b> 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?	
<b>Q2.</b> Specify a method of carbonation measurement?	
<b>Q3.</b> Where will the technology be employed? For example, <i>in situ</i> and (or) <i>ex situ</i> ?	

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

<b>Q4.</b> What is the anticipated effect on rock permeability and porosity? Please report any anticipated increase or decrease in rock permeability by percent.	
<b>Q5.</b> What is the anticipated efficiency of the proposed technology compared to state-of-the-art? Please report any quantities in wt.% CO <sub>2</sub> e/metric ton of ore, and by percent increase of carbon mineralization compared to the state-of-the-art.	
<b>Q6.</b> 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 <sub>2</sub> -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)**

Responses required for Concept Papers that address Program Category 4.

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**

<b>Question(s)</b>	<b>Applicant's Response</b>
<b>Q1.</b> Do you expect restrictions of this proposed technology to only specific mineral associations, i.e., ore type?	
<b>Q2.</b> When will the technology be employed? For example, <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q3.</b> 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?	
<b>Q4.</b> How will the proposed model(s) be validated?	

<b>Q5.</b> How can the proposed technology developed from Category 4 be integrated into existing mine operations?	
<b>Q6.</b> How can the proposed technology developed from Category 4 be integrated into exploration of CO <sub>2</sub> -reactive ore bodies?	
<b>Q7.</b> How will carbonation be estimated and (or) quantified after carbon mineralization?	
<b>Q8.</b> How will energy-relevant minerals leached and re-mineralized from carbonated CO <sub>2</sub> -reactive minerals be estimated and (or) quantified?	
<b>Q9.</b> How will comminution energy decrease or increase be estimated and (or) quantified <i>in situ</i> or <i>ex situ</i> when mineral properties are modified by processes such as Category 1?	
<b>Q10.</b> How will methods be developed to estimate energy-relevant mineral ore grade that includes conventional minerals and CO <sub>2</sub> -reactive minerals either <i>in situ</i> and (or) <i>ex situ</i> ?	
<b>Q11.</b> 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?	
<b>Q12.</b> Will a method be developed to determine CO <sub>2</sub> reservoir leakage and storage capability?	
<b>Q13.</b> 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]

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](mailto:ARPA-E-CO@hq.doe.gov) (with FOA name and number in subject line); see FOA Sec. VII.A. Problems with ARPA-EeXCHANGE? Email [ExchangeHelp@hq.doe.gov](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

## 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.C.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.C 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.G of the FOA for the appropriate technology Category in Section I.F 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-Leveraging of Federal Funds.** Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.
- VI. **High Project Impact Relative to Project Cost.**
- VII. **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](mailto: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 contractors 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]

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](mailto: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](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

## **VII. AGENCY CONTACTS**

### **A. COMMUNICATIONSWITH 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](mailto: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](mailto: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](mailto: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](mailto: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: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to ten (10) years 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. 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

**For-Profit Organizations (Other than Small Businesses) (or large businesses):** Means entities organized for-profit other than small businesses as defined elsewhere in this Glossary.

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

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

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

**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.

**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>).

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

**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).